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Dental implant maintenance and home hygiene – information pathways, clinical practice and patient realities in Australia

Monique Charlene Cheung

BDSc (Hons) (Melb), FRACDS

orcid.org/0000-0001-5326-3048

Doctor of Philosophy

December 2019

Melbourne Dental School

Faculty of Medicine, Dentistry and Health Sciences

The University of Melbourne

Submitted in total fulfilment of the requirements for

the degree of Doctor of Philosophy

Abstract

Dental implants have widened treatment paradigms in dentistry since the 1980s and are placed in the millions annually around the world, but plaque-induced peri-implant diseases which can reduce treatment success are not completely understood. The real-life practices of patients and dental practitioners in minimising peri-implant disease risks have not been widely documented. The information sources from which dental practitioners learn peri-implant maintenance are highly variable and also rarely documented. This thesis investigated the flow of information in implant maintenance and hygiene in Australia: from research, to educators, dental practitioners and patients; the limitations present and areas of further development.

A series of cross-sectional surveys was conducted to investigate: the hygiene habits of patients with implants in the community, patient-reported outcomes, implant success and peri-implant outcomes; the implant dentistry training attended and provision of implant services by dental practitioners in Australia; dental practitioners' preferences in implant hygiene instruction, diagnostics and maintenance, including the role of oral health practitioners; and the teaching of implant maintenance topics within implant dentistry education in Australia.

A survey of 51 patients in private general dental practice found 7.8% had peri-implantitis and 33.3% had peri-implant mucositis (7.7% and 24.4% of 78 implants respectively). At the implant level, peri-implant disease prevalence was significantly higher where implants were cleaned only with toothbrushing ($p<0.001$) or had plaque/calculus present ($p<0.001$). Implant success was significantly reduced if any local factors affecting hygiene accessibility were present ($p<0.001$). Patients recalled mixed provision of implant hygiene instructions from their treating dentists and reported 7.7% of implants as aesthetically unsatisfactory and 9.0% as having symptoms.

A survey of 303 general dentists found continuing professional development was the most common highest level of implant training attended, graduation decade affected the types of implant training attended, and dentists are providing implant treatments increasingly earlier in their careers. Highest attended training level was significantly correlated to greater complexity of implant treatment and maintenance services provided, and a more preventative approach in implant hygiene instruction. Conversely, dentists with little implant training and/or who do not provide implant treatments may not be providing optimum maintenance and preventative information. Compared with the dentists, 154 oral health practitioners surveyed reported more

preventative and evidence-based attitudes to implant hygiene instruction, diagnostics and maintenance, and they provided the bulk of preventative services in their workplaces.

Implant dentistry education convenors were surveyed (24 respondents outlining 43 programs) and implant maintenance teaching was found to generally reflect the available literature, which is established for diagnostics but limited for patient-performed hygiene, professional maintenance and review. Some respondents acknowledged the need to update their inclusion of implant maintenance topics.

As the peri-implant disease, hygiene and maintenance literature develops, current challenges include multi-disciplinary communication and the continuing development of implant dentistry education. By documenting current trends and identifying areas for clinical improvement and further research, it is hoped that this thesis, through the lens of implant hygiene and maintenance, provides possible future pathways for implant dentistry in Australia, to ultimately optimise treatment success and positive patient outcomes.

Declaration

This is to certify that the thesis comprises only my original work toward the PhD except where indicated in the preface; due acknowledgement has been made in the text to all other material used; the thesis is less than 100,000 words in length, exclusive of tables, figures, bibliographies and appendices.

Dr Monique Cheung

Preface

This thesis is based on the following publications/manuscripts:

1. Cheung, M. C., Hopcraft, M. S., & Darby, I. B. (2019). Implant education patterns and clinical practice of general dentists in Australia. Australian Dental Journal, 64(3), 273-281. doi:10.1111/adj.12708

2. Cheung, M. C., Hopcraft, M. S., & Darby, I. B. Patient-reported oral hygiene and implant outcomes in general dental practice. Clinical Oral Implants Research (submitted).

3. Cheung, M. C., Hopcraft, M. S., & Darby, I. B. Dentists' implant maintenance preferences. Part I: home hygiene and oral hygiene instruction. Journal of Oral Implantology (submitted).

4. Cheung, M. C., Hopcraft, M. S., & Darby, I. B. Dentists' implant maintenance preferences. Part II: diagnosis and treatment. Journal of Oral Implantology (submitted).

5. Cheung, M. C., Hopcraft, M. S., & Darby, I. B. Dental implant hygiene and maintenance – a survey of oral health practitioners in Australia. Journal of Dental Hygiene (submitted).

6. Cheung, M. C., Hopcraft, M. S., & Darby, I. B. Dental implant maintenance teaching in Australia – a survey of education providers. European Journal of Dental Education (submitted).

Several chapters of the thesis have been submitted for publication, as indicated above, and make up Chapters 2-7 of the thesis. For all of these publications/manuscripts, the author contributions are as follows: M.C. conceived the ideas with supervision and guidance from I.D.; M.C. developed the survey instruments and collected the data; M.C. analysed the data with guidance from I.D. and M.H.; M.C. led the writing. Additional discussion, links between the different parts of the thesis and possible directions of future research are presented in Chapter 8.

The formatting of the manuscripts vary according to the requirements of the journals to which they were submitted. There are inherently some repetitions in Chapters 3-5, as they refer to the same conducted survey but were designed to be published individually according to their different focuses, while Chapter 6 refers to a very similar survey with a different participant group. References are provided at the end of each chapter due to the structure of the thesis.

Poster presentations:

- Cheung et al., “Patient-reported implant hygiene and outcomes in general dental practice”. Presented at the 4th Meeting of the International Association for Dental Research (IADR) Asia Pacific Region 2019, November 2019, Brisbane, Australia
- Cheung et al., “Implant hygiene – practitioner preferences and patient-reported habits”. Presented at the 4th Meeting of IADR Asia Pacific Region 2019, November 2019, Brisbane, Australia
- Supported by the Student Travel Award, Melbourne Dental School, The University of Melbourne, and funding from Melbourne Dental School Colgate Travel Award competition, IADR

Funding:

- Melbourne Dental School, The University of Melbourne Postgraduate Research Funds 2016
- Australian Government Research Training Program Scholarship

Acknowledgements

This project has only been possible with the guidance, knowledge and support of my supervisors, Professor Ivan Darby and Associate Professor Matthew Hopcraft, whose calm experience I have always felt able to rely upon, even from a distance. I am very grateful to them for their time and advice in shaping my questions and observations into deployable investigations and encouraging me to pursue this project to its full extent.

My colleagues and principals at Clear Dental and Teachers Dental Surry Hills have always been completely supportive of my extra-clinical endeavours, especially Dr Mehri Eshraghi and Dr Johnson Huang who allowed me to conduct clinical research under their auspices, with thanks to the patients who kindly agreed to participate in this study. I must also acknowledge the much-appreciated help of the various organisations who assisted in the distribution of surveys and information to their members: the Australian Dental Association state branches, the Australian Society of Periodontology, the Royal Australasian College of Dental Surgeons, the Dental Hygienists Association of Australia and the Australian Dental and Oral Health Therapists' Association. Thank you to Mr Cameron Patrick of the Statistical Consulting Centre at The University of Melbourne for his assistance and advice.

Immeasurable thanks to my parents and sister for their unwavering belief in me and unconditional support of my endeavours, for always encouraging learning and curiosity and the satisfaction of doing one's best. Thank you also to my friends in Sydney and Melbourne and my coaches/teammates at SJJA for their years of generous friendship and providing balance in my life. I look forward to the next adventure and what the coming years will bring.

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Abbreviations

BOP – bleeding on probing

CPD – continuing professional development

GDP – general dental practitioner

KM – keratinised mucosa

OHI – oral hygiene instructions

OHP – oral health practitioner

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Introduction

This thesis was borne out of the observation in clinical practice that patients with dental implants seldom knew that additional oral hygiene measures might be needed to look after and maintain their implants. To investigate the reasons why, however, required understanding of the way that information is developed and flows in the evidence-based practice of implant dentistry. This encompasses the scientific literature, formal education programs and information sharing between educators and dental practitioners, dental practitioners teaching their patients, to the endpoint of whether patients are performing home hygiene techniques. At each stage there is the potential for miscommunication or lack of complete information transfer between the involved parties. The difficulty of understanding this information flow is increased by the fact that implant dentistry is a relatively new discipline, with the basic system of a transmucosal fixture to crown prosthesis in common use and mass production since the 1980s. However, the understanding of long-term management is still in its infancy.

Peri-implant diseases are plaque-induced infections of the mucosal tissues that support dental implants. They are reported to affect up to 50% of implants placed in patients (Zitzmann & Berglundh 2008), and can lead to inflammation and infection of the surrounding tissues, loss of bony support around the implant and eventual loss of the implant. Implant treatment is becoming increasingly popular as a method of tooth replacement, with high survival rates of over 95% reported (Jung et al., 2012). As the world's population ages, the number of people with implants into their elderly years will increase as well (Zitzmann et al., 2007) with age-related changes affecting implant outcomes (Bartold et al., 2016). Consequently, it could be expected that if the incidence of peri-implant disease (peri-implant mucositis and peri-implantitis) remains the same as previously found in the literature, that the number of these cases will increase overall, with associated morbidity and increased need for costly treatment.

It is well established in the literature that the prevention and management of peri-implant diseases involve both oral hygiene practices at home as well as professional treatment (Chen & Darby 2003; Lindhe & Meyle 2008; Renvert et al., 2008; Romanos & Weitz 2012; Serino & Ström 2009). There has been significant recent and continuing research into methods of professional treatment of peri-implant mucositis and peri-implantitis, based on the analogous treatment of gingivitis and periodontitis, including the development of the Cumulative Interceptive Supportive Therapy (CIST) maintenance protocol based on disease severity (Lang et al., 2000), comparison of mechanical, antimicrobial, surgical materials and techniques, and investigation

of risk factors which reduce the likelihood of treatment success. However, apart from didactic recommendations in the literature, the most recent significant research addressing implant hygiene practices dates to the early 1990s, and there has been little research conducted regarding specific different methods of home implant hygiene, their long-term efficacy in preventing or treating implant-related diseases, or their use in the community. A systematic review published in 2014 found a lack of evidence for any self-performed oral hygiene methods around dental implants, apart from a few studies comparing the efficacy of different toothbrushes (Louropoulou et al., 2014). The authors strongly recommended research into this area to delineate possible differences from current recommendations based on the cleaning of natural teeth. A consensus statement from the 8th European Workshop on Periodontology indicated "the lack of a standard preventative measure with demonstrated efficacy to preserve peri-implant health" (Sanz & Chapple 2012).

Additionally, there are many different sources, levels and types of implant education programs available to dentists, and it is unclear how implant maintenance is addressed in these programs. Furthermore, there is no literature available on what dentists are then recommending to their patients as a result of their education and training. The multidisciplinary nature of implant treatment and inherent communication challenges may also contribute to the lack of oversight in managing a patient's implant maintenance and oral hygiene instruction.

As a result of rapid development in the field of implant dentistry, there appear to be gaps between published research and the needs of clinical practice, particularly in the "simple" area of home oral hygiene and the unglamorous reality of long-term maintenance. Greater understanding of its role in minimising the problems associated with peri-implant diseases is particularly important given the increasing popularity of implant treatment as well as the aging of the population, the projected increase in assisted living and the need for provision of oral hygiene services by carers (Hopcraft et al., 2012).

The overarching aim of this thesis was therefore to evaluate information flow in the field of implant dentistry and specifically implant maintenance, in Australia, through the initial standpoint of implant oral hygiene, and to lay the groundwork for future improvement and research. This required a multi-pronged approach:

1. Establishing baseline data for each group's current attitudes and practices relating to implant oral hygiene and maintenance
2. Comparing each group's knowledge with the available literature to assess suitability, and comparing between groups to understand information flow and points of communication challenge particular to implant dentistry

3. Outlining possible improvements in communication such that information transfer between and within groups can be as effective as possible, when clearer evidence is established

Concurrently, other related insights into implant dentistry in Australia were also sought:

1. The current demographics and trends in implant training and practice at the practitioner level;
2. The provision of professional implant maintenance;
3. The role of oral health practitioners and the relative contribution of practitioner types in providing implant-related preventative services;
4. Outcomes reported by patients with implants;
5. Patient-performed hygiene habits compared to their clinical outcomes, in particular to increase the evidence base for clinical practice and further research.

Structure of the thesis and summary of methods

A literature review in Chapter 1 outlines the current state and historical focuses of previous research conducted into implant outcomes, peri-implant disease risk factors, implant maintenance, implant education systems, service provision by practitioners, patient expectations and patient-reported outcomes. Where appropriate, the relevant literature from the field of periodontology has also been included. The specific objectives of the thesis are outlined.

This thesis gathered data on the perspectives of the following groups:

Patients are the ultimate target endpoint for information as dental treatment is performed for their benefit and quality of life. The maintenance of implants that they have is part of maximising their outcomes and their investment. Fifty-one patients in the private practice setting were surveyed on their dental implant history, recollections of information imparted to them by clinicians and their home hygiene habits, and underwent an examination to assess their implant status. Correlations between hygiene habits and clinical outcomes, and patient-reported outcomes are presented in Chapter 2.

Dentists can provide both implant treatments and maintenance, and are often a primary source of information for patients together with the media and increasingly, the internet (Berge 2000; Pommer et al., 2011; Rustemeyer & Bremerich 2007; Tomruk et al., 2014; Zimmer et al., 1992). They were surveyed on their implant training after graduation, implant experience, preferred

implant hygiene instructions, implant review and maintenance services provided. Data from 303 general dental practitioners (GDPs) were collected and analysed in the focus areas of demographics, implant-related training, implant home hygiene and professional implant maintenance preferences, and are presented in Chapters 3-5.

Oral health practitioners (OHPs – dental hygienists, dental therapists and oral health therapists) are the other group of dental practitioners in Australia with significant involvement in implant maintenance, and prevention in dentistry in general. They were surveyed on their implant-related training and scope of practice, working arrangements, preferred implant hygiene instructions, implant review and maintenance services provided. Patterns of preventative service provision, implant home hygiene and professional implant maintenance attitudes and preferences from 154 OHPs are presented in Chapter 6.

Educators facilitate the formal training that dental practitioners undergo, in university degree programs and the several available forms of continuing professional development. The implant maintenance-related content included in 43 programs was collected via a web-based survey of educators and program convenors, and presented in Chapter 7.

Information flow between the above groups is evaluated in the thesis discussion in Chapter 8, as well as additional explication of GDPs' implant prosthesis preferences and differences between genders, not included elsewhere. Future areas of research relating to the body of evidence for implant maintenance, the teaching of and practice of implant dentistry in Australia and proposals for tools which could facilitate clinical practice are also considered.

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Chapter 1: Literature review

1.1 Implant prevalence and survival/success rates

The increasing popularity and the high reported success and survival rates of implant treatment are important to establish when surveying current knowledge levels, treatment trends and clinical preferences of dentists and patients in a particular population i.e. Australia, in order to compare with global statistics and the existing literature.

1.1.1 Prevalence of implants

Few studies have surveyed the popularity of dental implants as a treatment modality, with most conducted in Europe. The available recent results from surveys are presented here, indicating overall low frequency although global variation is present.

In the most recent Australian National Survey of Adult Oral Health (2017-18), 5.6% of a nationally representative sample of 15,731 subjects reported having dental implants (Do & Luzzi 2019), an increase from approximately 1% in the 2004-06 national survey (Slade et al., 2007). Internationally, the 2009 Adult Dental Health Survey in the UK (excluding Scotland) found implants in 1% of the population overall, <0.5% of people aged 25-34 years and 2% of people aged ≥65 years (White et al., 2012). In the 2005 Fourth German Oral Health Study, 1.4% of 35-44 year olds and 2.6% of 65-74 year olds had implant restorations (Micheelis & Schiffner 2006). A 2010 representative survey of 1000 Austrian adults found that 5% had undergone implant treatment (Pommer et al., 2011b). In Greece, a 2005 national oral health survey found implants in 0.8% of 35-44 year olds and 0.3% of 65-74 year olds (Mamai-Homata et al., 2012). The 2002 Swiss National Survey found that 4.4% of the adult population had implants (Zitzmann et al., 2007). In a cohort of approximately 1000 serially-surveyed 20-80 year olds in Jönköping, Sweden, 3.1% had implants in 2003 (Hugoson et al., 2005).

Even though these seem to be very low levels, in real numbers almost 2.3 million implants were estimated to have been placed in private practice in the USA in the year 2005-06 (American Dental Association 2007), although the prevalence is not known for this population. Whether implant popularity is increasing with time is also not reported in the scientific literature with serial survey results not currently available, but annual reports from implant companies such as

Straumann® report the continued growth of the dental implant market in the "mid-single digit percentage range" annually (Institut Straumann AG 2019).

1.1.2 Success vs survival

Implant treatment survival or success rates have been used in research to describe longitudinal outcomes in a patient sample, but the terms "success" and "survival" have often been conflated or inconsistently defined (Moraschini et al., 2015). Survival is one of the success criteria most commonly reported on and is the continued presence of the implant in the mouth, the opposite of "failure", where an implant has been lost or requires removal (Misch et al., 2008).

1.1.2.1 Survival rates

The survival rates of loaded implants after 5 years have been reported in many studies but only a few have over 10 years of follow-up (Jung et al., 2012; Moraschini et al., 2015). A large prospective multi-centre study of 2359 implants followed up to 8 years found a cumulative survival rate of 96.7% and an actual survival rate of 98.2% after 5 years for 488 implants (Buser et al., 1997). Systematic reviews have shown cumulative survival rate to be 97.2% after 5 years and 95.2% after 10 years in implants supporting single crowns (Jung et al., 2012), 95.6% after 5 years and 93.1% after 10 years in implants supporting fixed partial dentures (Pjetursson et al., 2012b), and 98.9% after 5 years in implants supporting cantilevered fixed prostheses (Romeo & Storelli 2012). In each of these prosthetic groups, the survival rate of the prostheses was slightly lower than that of the implants at each time point.

For implants supporting removable overdentures, a systematic review showed mandibular implants had a pooled survival rate of 95.7% at 5 years (Bryant et al., 2007), with 95.5% survival reported after 20 years of two-implant overdenture loading (Vercruyssen et al., 2010). The pooled implant survival rate is lower for maxillary overdentures, calculated to be 76.6% at 5 years (Bryant et al., 2007), although high implant survival rates of over 99% after 5 years have recently been reported (Slot et al., 2016). Maxillary overdentures also have a higher frequency of prosthetic complications (Andreiotelli et al., 2010). In implants supporting mandibular removable partial dentures with distal extension, survival rates have been reported from 95-100% after 1-8 years (de Freitas et al., 2012), while there appear to be no published reports of survival rates of implants supporting maxillary removable partial dentures.

Study designs, sample sizes, surgical protocols, implant designs, sizes and systems and loading times vary substantially across the studies reporting survival rates, but they primarily investigated non-representative "convenience samples" based in university or specialist clinics (Derks et al., 2016a). The few studies assessing a wider cross-section of the community have

found implant survival rates of 97.8% after 3-5 years (Da Silva et al., 2014) and 97% after 9 years (Derks et al., 2015b).

1.1.2.2 Success criteria – history and new developments

High implant survival rates do not preclude the presence of co-existing peri-implant pathology, whereas implant success specifies survival without pathology and also prosthetic success i.e. ideal clinical conditions. Historically, these overlaps in definition have been confused further by the multiple clinical parameters used to measure implant health or pathology, and various combinations thereof that constitute suggested success criteria (such as Albrektsson et al. 1986; Albrektsson & Zarb 1998; Buser et al. 1990; Karoussis et al. 2004; Misch et al. 2008), subsequently used in other studies. "The most traditional and accepted criteria at present" (Moraschini et al., 2015) has been that by Albrektsson et al. (1986), for which prosthesis-supporting implants show:

1. Lack of implant mobility;
2. Lack of peri-implant radiolucency;
3. Vertical bone loss <0.2mm annually after the first year of service;
4. Absence of persistent and/or irreversible signs and symptoms such as pain, infection, paraesthesia, neuropathies, nerve canal violation;
5. The above criteria and functional service of 85% of cases after 5 years and 80% of cases after 10 years, for a particular treatment modality to be considered successful.

However, these criteria did not include any clinical parameters measured via periodontal probing, which can quickly and easily reveal the condition of the soft tissue, the presence of bleeding and/or exudate and thus the presence of inflammation/pathology.

The International Congress of Oral Implantologists (ICOI) Pisa Implant Quality of Health Scale developed by consensus (Misch et al., 2008) additionally considered crestal bone loss within the first year and history of exudate, describing four clinical categories into which individual implants can be allocated to define their current success, qualified survival or failure status and therefore their prognosis. While this concept is useful in clinical management, deep probing depths up to 7mm could still be considered successful or satisfactory under these criteria, when it has been established that deeper pockets harbour more pathogenic bacteria (Papaioannou et al., 1995). Clinical signs of pathology (suppuration, soft tissue recession, pocket probing depth ≥6mm) are significantly associated with progressive bone loss (Fransson et al., 2008). Probing depth ≤5mm and no bleeding on probing (BOP) at a probing depth of 5mm have been included as success parameters by Karoussis et al. (2004), whose criteria have been subsequently used widely.

Clinically, parameters for success should also include assessment of prosthetic and aesthetic success and patient-reported outcomes (Papaspyridakos et al., 2012).

Nevertheless, to date there has been no international standardisation of success criteria, and studies continue to use different criteria or suggest their own (Moraschini et al., 2015), or judge implant success primarily by their survival and function (Iqbal & Kim 2007), making comparison between studies difficult.

The 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions established a new classification for peri-implant diseases (Renvert et al., 2018), taking into account soft tissue condition, bone level, and the possible absence of baseline records, but with no criteria suggested for implant success itself. It is hoped that a clearer picture of peri-implant success and pathology, in future research and in retrospective analysis of previous research, can emerge.

1.1.2.3 Success rates

In an analysis of studies of at least 10 years using the Albrektsson et al. (1986) success criteria, a cumulative mean success rate of 89.7% with an average 14.6-year follow-up period was found (Moraschini et al., 2015). When including various success criteria, success rates ranged from 34.9% (Degidi et al., 2012) to 100% (Ma et al., 2010; Mertens et al., 2012); the data published (Moraschini et al., 2015) shows a cumulative mean success rate of 82.8% with an average follow-up period of 13.4 years. However, there was great heterogeneity in the study designs and prostheses included. In the prospective multi-centre study of 2359 implants, the cumulative success rate was 93.3% after 8 years and actual success rate was 97.3% after 5 years for 488 implants; success was higher in screw-type (compared with hollow cylinder) and mandibular (compared with maxillary) implants (Buser et al., 1997).

In patients with implants supporting fixed partial dentures, a cumulative success rate of 66.4% after 5 years was found in a systematic review (Pjetursson et al., 2012b) with only 6 of 32 studies reporting the number of patients without complications. The authors recommended that future papers report survival rates together with the incidence of complications rather than non-comparable success rates. Alternatively, some studies analysed and presented results with multiple success thresholds to better allow comparison with other studies (Karoussis et al., 2004; Karoussis et al., 2003).

Again, most studies have used convenience samples based in university or specialist single clinic settings. Only very few studies have assessed a wider cross-section of the community, with a

large multi-centre study of a network of general dental practices reporting an implant success rate of 81.3% after a mean of 4.2 years (Da Silva et al., 2014).

1.1.3 Prevalence of peri-implant diseases

Implant complications reduce success rates and can be biological or technical (i.e. involving prosthetic components). The prevalence of peri-implant inflammatory diseases and their associated risk factors are important for clinicians and patients to understand in order to minimise preventable complications and maximise long-term success and survival.

As will be discussed further in the section on guidelines for diagnostic criteria of peri-implant mucositis and implantitis, lack of consensus is again an issue which makes comparison and aggregation of study results difficult (Tomasi & Derks 2012). Nevertheless, peri-implant mucositis has been shown by recent meta-analyses to have a weighted mean prevalence at the patient level of 43-63.4% (Atieh et al., 2013; Derks & Tomasi 2015; Lee et al., 2017) ranging in the literature from 19% at 1-5 years (Casado et al., 2013) to 77% after 9-14 years (Roos-Jansåker et al., 2006b). At the implant level, mucositis has a weighted mean prevalence of 30% (Atieh et al., 2013; Lee et al., 2017), ranging in the literature from 9% after 5-11 years (Kaemmerer et al., 2011) to 48% after 9-14 years (Roos-Jansåker et al., 2006b). Peri-implantitis has been shown to have a weighted mean prevalence at a patient level of 18.8-22% (Atieh et al., 2013; Derks & Tomasi 2015; Lee et al., 2017), ranging in the literature from 0.4% after 5 years (Zetterqvist et al., 2010) to 47% at 1-16 years (Koldsland et al., 2010). At the implant level, peri-implantitis has a weighted mean prevalence of 9.25-9.6% (Atieh et al., 2013; Derks & Tomasi 2015; Lee et al., 2017), ranging in the literature from 2% after 5-11 years (Kaemmerer et al., 2011) to 37% at 1-16 years (Koldsland et al., 2010). The extent of peri-implantitis (the proportion of implants affected in affected patients) has been reported at 41.8% (Fransson et al., 2009), 37% in patients with ≥4 implants (Mir-Mari et al., 2012) and 40.1% in patients with moderate/severe peri-implantitis (Derks et al., 2016a).

As in the success and survival rate reports, most studies used convenience samples. In a recent study of a “true cohort” of randomly selected Swedish implant patients treated by a wide range of practitioners, healthy peri-implant tissues were found in 23% of patients and 39.9% of implants after 9 years (Derks et al., 2016a); otherwise, the rate of peri-implant health has rarely been reported on and could not be estimated in a systematic review (Derks & Tomasi 2015). This study also reported a 32% prevalence of mucositis and 45% prevalence of peri-implantitis

(including 14.5% moderate/severe) at a patient level, 35% and 25% (8% moderate/severe) respectively at an implant level (Derks et al., 2016a).

The high rates of peri-implant disease reported may therefore more accurately reflect the true success rate, which appears to be lower than those reported in systematic reviews, whether this is due to the variability in success criteria or the non-representative nature of most research subject samples. Success criteria may be more useful when comparing treatment modalities within controlled trials with calibrated examiners, rather than in meta-analysis of studies where even the same criteria may be applied differently.

Additionally, the prevalence of peri-implantitis has been shown to be positively correlated to time in function (Derks & Tomasi 2015; Marrone et al., 2013) and the true prevalence is likely underestimated with the lack of many long-term studies. Time in function has varied greatly in studies reporting survival rates, with implant failure noted to occur and increase only after several years in function (Fransson et al., 2010; Karoussis et al., 2003; Roccuzzo et al., 2012), with more prospective longitudinal studies needed. Similarly, peri-implant bone loss triggered by residual cement has also been noted to have a possible delayed onset of several years (Wilson 2009).

The rate of peri-implant bone loss also appears to be non-linear, accelerating over time (Derks et al., 2016b; Fransson et al., 2010). Cross-sectional findings dominate the literature and the usefulness of calculated annual bone loss data has thus been questioned (Derks et al., 2016b; Fransson et al., 2010). The onset of progressive bone loss appears to be mostly within the first 3 years, which is early compared with the periodontal equivalent of severe periodontitis onset at generally over 20 years of age, from the little literature available (Derks et al., 2016b). The understanding of the natural history of peri-implant disease is still limited, and several hypothetical models for peri-implant bone loss have been proposed (Fransson et al., 2010; Schwartz-Arad et al., 2005), mirroring different forms of periodontitis progression.

A proposal was made recently that peri-implantitis is not a specific disease entity and has been over- or improperly diagnosed, and that marginal bone loss should be considered an immunological reaction to a foreign body exacerbated by complicating factors (Albrektsson et al., 2016). This appears to be an alternate approach in description only with no impact on the current understanding of risk factors, lesion progression and clinical management.

1.2 Peri-implant disease risk factors

Dental implants provide a transmucosal surface on which oral bacteria can form a plaque biofilm. Plaque is the primary aetiological factor in peri-implant disease, as it can induce a reversible inflammatory reaction in the soft tissue (peri-implant mucositis) (Zitzmann & Berglundh 2008) in a cause-and-effect relationship that mirrors the development of gingivitis (Pontoriero et al., 1994). In susceptible patients, progressive loss of peri-implant bone support can also occur (peri-implantitis), which may culminate in loss of the implant. Non-microbial factors such as prosthetic breakdown or residual cement may also induce a secondary bacterial infection, and categorisation of the primary triggering factor as surgical, prosthetic or plaque-related has been proposed (Canullo et al., 2016b).

Given the complexity of implant treatment and significant economic investment undertaken by patients, the high prevalence of peri-implant disease and possible sequelae of implant failure underline the need to understand how peri-implant health can be affected by general and local dental factors, systemic health, prosthetic or iatrogenic factors. These factors may predispose the patient to or modify their risk of developing plaque-induced peri-implant disease. Practitioner training and subsequent understanding of these factors influence their case selection, treatment planning and peri-implant disease management preferences, all of which are surveyed in this thesis. The evidence for the impact of each risk factor in the development of peri-implant disease varies considerably in quality and quantity.

1.2.1 General dental factors

1.2.1.1 History of periodontal disease

Pockets around teeth and implants are quickly colonised by similar bacteria profiles, including pathogenic species associated with periodontitis in shallow (Pontoriero et al., 1994) and deep pockets (Quirynen et al., 2006). Compared with periodontally healthy patients, patients with previously treated chronic periodontitis (Karoussis et al., 2003; Roccuzzo et al., 2010; Simonis et al., 2010) or previous periodontal bone loss (Hardt et al., 2002; Roos-Jansåker et al., 2006c) have lower implant survival and higher incidence of peri-implantitis. However, the periodontal status at time of examination, treatment history and maintenance regimes were rarely reported (Schou 2008). A more specific effect of current periodontal disease activity has been shown more recently, with significantly greater peri-implantitis prevalence in patients who at the time of assessment have active or current periodontitis compared with those with stabilised chronic

periodontitis (Canullo et al., 2016a; Costa et al., 2012; Derks et al., 2016a; Ferreira et al., 2006; Marrone et al., 2013), and in those with residual periodontal pockets compared with those without (Cho-Yan Lee et al., 2012; Pjetursson et al., 2012a). Alternatively, a strict maintenance program or adherence to supportive periodontal therapy appears to minimise the detrimental effects of a history of periodontitis on peri-implantitis occurrence (De Boever et al., 2009; Rinke et al., 2011; Roccuzzo et al., 2010; Zangrando et al., 2015).

The condition previously designated as generalised aggressive periodontitis (GAgP) is more clearly associated with a much greater risk of implant failure, peri-implant mucositis and even up to 14 times greater risk of peri-implantitis after 5-16 years compared with periodontally healthy patients (Swierkot et al., 2012). Other factors such as smoking and impaired general health cause significantly poorer outcomes again in GAgP patients (De Boever et al., 2009). Nevertheless, implants can still be a successful rehabilitation option for patients with GAgP, with reports of 100% survival with guided bone regeneration after 3 years (Mengel & Flores-de-Jacoby 2005), and 83% survival after 10 years (Mengel et al., 2007).

1.2.1.2 Maintenance and supportive periodontal therapy

The importance of maintenance and adherence to supportive periodontal therapy (SPT) has only been investigated as an individual factor relatively recently. In general, irregular or complete lack of attendance at maintenance appointments after 5-10 years is associated with significantly increased inflammation parameters and peri-implant bone loss (Costa et al., 2012; Hardt et al., 2002; Roccuzzo et al., 2010), implant loss (Roccuzzo et al., 2012; Roccuzzo et al., 2010), and increased risk of peri-implantitis (Costa et al., 2012) by up to 11 times (Rinke et al., 2011). However, there is significant variance in the definition of incomplete SPT adherence, from complete lack of attendance (Costa et al., 2012), to “deviation of more than 100%” from the recommended intervals (Rinke et al., 2011), lack of complete adherence to the recommended program (Roccuzzo et al., 2010) or graded compliance depending on number of visits per year (Frisch et al., 2014; Monje et al., 2017b). It has been recommended that “even irregular maintenance is better than none” (Rinke et al., 2011), but further research is needed to determine the effect of confounding factors such as smoking and oral hygiene (de Araujo Nobre et al., 2014), thin gingival biotype (Aguirre-Zorzano et al., 2013) and variables such as maintenance procedures and recall periods, for which no comparative evidence is available (Romanos et al., 2015; Wilson et al., 2014).

1.2.1.3 Oral hygiene

As plaque is the primary aetiological factor in the development of peri-implant mucositis, the level of oral hygiene performed by patients strongly impacts upon peri-implant outcomes. Three

weeks of refraining from oral hygiene significantly increases peri-implant inflammation parameters (plaque, gingival and bleeding indices, probing depths, mucosal margin swelling) and causes mucositis (Pontoriero et al., 1994). Poor overall plaque control by the patient has been strongly associated with increased peri-implant mucositis (Ferreira et al., 2006), peri-implant bone loss (only becoming significantly apparent after 3 years) (Lindquist et al., 1997), and peri-implantitis (Costa et al., 2012; Ferreira et al., 2006). Implant failure has been associated with higher pre-operative plaque levels (van Steenberghe et al., 1993). Plaque presence at the implant site has been associated with significantly greater prevalence of mucositis (Roos-Jansåker et al., 2006b) and peri-implantitis (Canullo et al., 2016a). Lack of accessibility for patient capability for oral hygiene around implants had a significant positive predictive value (65%) for peri-implantitis, while good accessibility had a high (82%) negative predictive value (Serino & Ström 2009). Oral hygiene accessibility around implants was found to be 78% in the Swedish community cross-section study (Derks et al., 2016a) but does not appear to have been reported elsewhere, nor in relation to hygiene methods or peri-implant disease incidence.

1.2.2 Local dental factors

1.2.2.1 Keratinised mucosa

The necessity of keratinised mucosa (KM) in maintaining periodontal health around teeth has been widely discussed, and the importance of keratinised mucosa and the dimensions needed for maintenance of peri-implant health is an ongoing question, with mixed findings regarding clinical thresholds and peri-implant disease. A threshold of 2mm or more has been most commonly used to designate an adequate width of KM, although thresholds of 1mm (Zigdon & Machtei 2008) and absolute absence or presence (Roccuzzo et al., 2016b) have also been used. Sites with <2mm KM have been shown to have significantly higher plaque scores (Adibrad et al., 2009; Bouri et al., 2008; Boynuegri et al., 2013; Chung et al., 2006; Roccuzzo et al., 2016b; Schrott et al., 2009), gingival inflammation (Adibrad et al., 2009; Bouri et al., 2008; Boynuegri et al., 2013; Chung et al., 2006), BOP (Adibrad et al., 2009; Schrott et al., 2009; Zigdon & Machtei 2008), mucosal recession (Adibrad et al., 2009; Kim et al., 2009; Roccuzzo et al., 2016b; Schrott et al., 2009; Zigdon & Machtei 2008), marginal bone loss (Bouri et al., 2008; Kim et al., 2009), or peri-implantitis (Canullo et al., 2016a). However, some studies found oral hygiene (Kim et al., 2009), BOP (Frisch et al., 2015; Roccuzzo et al., 2016b), or bone loss (Chung et al., 2006) were not affected by <2mm KM, and pocket probing depths were only found to be significantly worse where the threshold of 1mm was used (Zigdon & Machtei 2008). One study with long-term follow-up found >2mm KM was associated with greater incidence of peri-implant mucositis

(Roos-Jansåker et al., 2006c). The follow-up period of these studies varied considerably from 1 to over 10 years.

At the same time, peri-implant health can be maintained well with strict oral hygiene and maintenance program where no KM exists (Roccuzzo et al., 2016b), with some studies showing no additional benefit of adequate KM with at least annual SPT attendance (Frisch et al., 2015) or individualised oral hygiene and maintenance programs (Mericske-Stern et al., 1994).

Very little evidence exists to recommend thresholds at which KM should be increased to improve implant prognosis (Esposito et al., 2012b). A connective tissue graft (Frisch et al., 2015) or free gingival graft (Frisch et al., 2015; Roccuzzo et al., 2016b) can significantly increase KM width; where oral hygiene procedures in the absence of KM cause discomfort, a free gingival graft can facilitate the performance of oral hygiene, reducing plaque indices to the same level found in sites with pre-existing KM, at least in the posterior mandibular area (Roccuzzo et al., 2016b). The confounding factors of oral hygiene methods, SPT frequency and prosthetic design or accessibility for oral hygiene have rarely been reported or controlled and further research is needed before conclusions about any benefits of sufficient KM can be made. In general, KM width may not correlate directly to soft tissue health but rather plaque control (Renvert & Polyzois 2015; Wennström & Derks 2012) with a recent review concluding the evidence for it as a peri-implantitis risk factor to be limited (Schwarz et al., 2018).

Width of keratinised tissue may also be associated with tissue biotype (De Rouck et al., 2009), for which a widely used classification and assessment standard around teeth has not yet been developed (Fu et al., 2011). The impact of biotype on peri-implant disease has not been substantially investigated; thin biotype has been associated with increased incidence of peri-implant mucositis and peri-implantitis after 1 year (Aguirre-Zorzano et al., 2013) but was not a prognostic factor for peri-implantitis after 5 years in another study (Canullo et al., 2016a). The lack of consensus on biotype determination and classification precludes any clinically relevant recommendations at this time.

1.2.2.2 Occlusal overloading

Mechanical overloading was considered one of the main factors in late implant failure in the 1990s (Duyck & Vandamme 2014) with considerable research conducted into the impact of mechanical loading on osseointegration. However, the clinical evidence on the impact of occlusal schemes in clinical outcomes (Lewis & Klineberg 2011) and the role of post-osseointegration occlusal load on peri-implant disease and marginal bone loss (Naert et al., 2012) is scarce to non-existent, and most recently a literature review concluded there to be no

evidence that occlusal overload is a risk factor for peri-implantitis (Schwarz et al., 2018). The "main shortcoming in the literature" (Duyck & Vandamme 2014) is the lack of quantified and defined methods or indices for measuring overloading at the bone-implant interface, with overloading commonly presumed present based on unilateral posterior contact, increased crown to implant ratios, prosthetic damage or patient reports of bruxism. In one of the first studies to report marginal bone loss associated with occlusal overloading in the Brånemark® system (Quirynen et al., 1992), no relationship to soft tissue inflammation or peri-implant disease was established, nor has it been in any published studies since. Whether true overloading could ever be ethically tested in human studies has also been questioned. One study assessed dynamic occlusion using the T-Scan Occlusal Analysis System III (Tekscan Inc., Boston, MA, USA), where overload was defined as "when an implant was closest to the point of highest occlusal loading" and had a significantly increased odds ratio (18.7) of peri-implantitis (Canullo et al., 2016b). The clinical relevance and ability of practitioners to detect and manage this occlusal situation to improve outcomes is unknown.

In animal studies, dog models have suggested that supra-occlusal contacts may increase peri-implant bone loss in the presence of ligature-induced plaque accumulation (Kozlovsky et al., 2007) but in a well maintained environment do not cause bone loss (Heitz-Mayfield et al., 2004) and may even increase the bone-implant contact area (Kozlovsky et al., 2007), especially with lateral loading (Gotfredsen et al., 2001). However, testing of occlusal overloading with laterally directed forces in monkey models found that where oral hygiene was maintained, bone loss may not occur (Miyata et al., 1998) until a force threshold is reached (Miyata et al., 2000), and the loss of osseointegration may also occur (Isidor 1996).

There is a clear need for more research in this area given the lack of clinical applicability of previous studies and the confounding role of plaque, which is an important risk factor in its own right. Ligature-induced plaque accumulation is a controversial model, and spontaneous progression i.e. continued peri-implant bone loss following ligature removal is now considered to be a more valid representation of naturally occurring peri-implantitis (Renvert et al., 2011b). Occlusal load also changes over time as teeth move, as evidenced by studies showing changes in interproximal contacts between teeth and implants (Byun et al., 2015; Koori et al., 2010; Wang et al., 2016a; Wong et al., 2015). However, as the restorative dentist has the most control over occlusal loading compared with other factors, reducing the occlusal stress to the prosthesis with long-term monitoring and adjustment may be warranted given the lack of evidence (Duyck & Vandamme 2014).

1.2.3 Systemic factors

1.2.3.1 Smoking

Tobacco smoking is strongly established as a risk factor for periodontitis (Tonetti et al., 2015) and also affects implant outcomes. Mechanisms by which smoking affects wound healing include local vasoconstriction, impaired fibroblast function and reduced collagen production, compromised polymorphonucleocyte and lymphocyte function (Palmer et al., 2005).

Higher rates of late implant failures in smokers were first reported by Bain and Moy (1993) and have since been strongly corroborated (Anner et al., 2010; DeLuca et al., 2006; Vervaeke et al., 2012; Wilson & Nunn 1999), with poorer results in heavy smokers (Sanchez-Perez et al., 2007). In some studies, failure was only significantly greater in turned-surface rather than rough surface implants (Balshe et al., 2008; Sayardoust et al., 2013). Meta-analysis has not shown any increase in failure rate with increased follow-up time, possibly due to early or intermediate failure times (<4 or 4-24 months after placement) rather than long-term late failure (Moraschini & Barboza 2015); future long-term peri-implantitis studies may prove differently.

Significantly greater marginal bone loss occurs in smokers (DeLuca & Zarb 2006; Fransson et al., 2008; Roos-Jansåker et al., 2006c), particularly in the maxilla (Nitzan et al., 2005; Vandeweghe & De Bruyn 2011; Vervaeke et al., 2012), correlated to the amount of cigarette consumption (Lindquist et al., 1997; Nitzan et al., 2005) (although consumption stratification in studies varies widely), exacerbating the effect of poor oral hygiene (Lindquist et al., 1997) and IL-1 positive genotype (Gruica et al., 2004).

Relatively fewer studies have assessed peri-implant disease outcomes, but smoking is significantly associated with mucositis (Roos-Jansåker et al., 2006c) especially in patients with a history of periodontal disease (Rinke et al 2011), and is the strongest risk factor for peri-implantitis (Haas et al., 1996; Roos-Jansåker et al., 2006c) with an odds ratio of 31.6 reported (Rinke et al., 2011). However, the current evidence for smoking as a direct risk factor for peri-implantitis may be weak at a patient-level analysis (Sgolastra et al., 2015) and after multivariate analysis, perhaps due to confounding variables or inconsistent categorisation of smoking status (Schwarz et al., 2018). The success of peri-implantitis treatment is also reduced in smokers (Leonhardt et al., 2003).

Implant failure and peri-implant disease risk in smokers may be lowered by compliance with SPT (Karoussis et al., 2003; Rinke et al., 2011; Swierkot et al., 2012). It has been recommended that smoker patients give informed consent prior to implant therapy of their greater risks of failure and complications (Rinke et al., 2011; Sanchez-Perez et al., 2007). The effects of smoking on

early implant failure were shown to be negated by smoking cessation protocol around the time of surgery (Bain 1996). With some evidence available of reduced periodontitis progression with smoking cessation (Fiorini et al., 2014), similar investigations into the effects of smoking cessation on peri-implant disease are needed (DeLuca & Zarb 2006; Haas et al., 1996).

1.2.3.2 Interleukin-1 genotype

IL-1 genetic polymorphisms affect the host inflammatory response and severity of periodontitis (Kornman et al., 1997) and have been investigated as a peri-implant disease risk factor. A positive IL-1 genotype alone has not been associated with higher implant failure or peri-implantitis (Jansson et al., 2005; Lachmann et al., 2007; Wilson & Nunn 1999) except in one study which found that peri-implantitis after 2 years in function was significantly associated with the IL-1RN allele 2 carrier state (Laine et al., 2006). It appears to have a synergistic effect with smoking in increasing early implant failure (Jansson et al., 2005), biological complications (Gruica et al., 2004) and marginal bone loss (Feloutzis et al., 2003). Clinically, IL-1 genotype cannot be determined and testing may be more useful in predicting future risk and appropriate maintenance, as in periodontal disease (McGuire & Nunn 1999), although this has not been demonstrated in implants and little has been published on the topic in the last decade.

1.2.3.3 Diabetes mellitus, cardiovascular disease, metabolic syndrome

Diabetes mellitus is a systemic disease characterised by hyperglycaemia which can cause microvascular complications contributing to delayed wound healing and increased risk of infection, and it has a two-way relationship with periodontal disease (Grossi & Genco 1998; Preshaw et al., 2012). Implant failure rates do not appear to be increased in patients with diabetes type 2 (Accursi 2000; Anner et al., 2010; Tawil et al., 2008). Diabetes mellitus has seldom been assessed as a risk factor for peri-implantitis, showing a significant association in some studies (Ferreira et al., 2006; Tawil et al., 2008) but not others (Costa et al., 2012; Renvert et al., 2014). Generally, the level of diabetes control has been poorly reported in the implant literature; specific assessment shows that higher HbA1c values are significantly associated with BOP (Gomez-Moreno et al., 2015) and peri-implantitis (Tawil et al., 2008). A recent meta-analysis found that diabetes mellitus/hyperglycaemia is associated with a 3.39-fold greater risk of peri-implantitis in non-smokers, but no increased risk was found for mucositis (Monje et al., 2017a).

Cardiovascular disease has not been widely investigated as a risk factor in peri-implant disease, but it is highly prevalent in the community and there is an association between periodontal disease and systemic inflammation related to atherosclerotic cardiovascular disease (Scannapieco et al., 2003; Tonetti & Van Dyke 2013) although no causative relationship in either

direction has been established (Lockhart et al., 2012). Few studies have assessed it as an independent risk factor, finding no increased risk of implant failure (Moy et al., 2005) but increased marginal bone loss (Krennmair et al., 2016) and a significant odds ratio of 8.7 of having peri-implantitis and a history of cardiovascular disease, after adjusting for age, gender and smoking (Renvert et al., 2014). Further research is clearly indicated given this strong association.

Metabolic syndrome is characterised by abdominal obesity as well as dyslipidaemia, hypertension and/or impaired glucose intolerance and is related to increased diabetes mellitus and cardiovascular disease risk. It has been associated with severe periodontitis (D'Aiuto et al., 2008; Morita et al., 2009; Shimazaki et al., 2007) but research into any link between metabolic syndrome and peri-implantitis has only recently been suggested with animal models as a starting point (Schwarz et al., 2015c). Childhood obesity and diabetes have been described as an epidemic (Rocchini 2002; Zimmet et al., 2001) and related oral health impacts including periodontal and peri-implant disease may be substantial in the future.

1.2.3.4 Osteoporosis, hormone replacement therapy, bisphosphonates

The loss of bone mineral density in osteoporosis may affect bone quality at potential implant sites, and both osteoporosis and dental implants have higher prevalences in older age groups. More recent research has investigated osteoporosis and associated medications as risk factors in implant failure and peri-implant disease. Although variable osteoporosis inclusion criteria have been used e.g. self-reported osteoporosis, hip/spine scan diagnosis, mandibular bone density assessment, and with particularly variable or unreported use of hormone replacement therapy (HRT), there have been no significant associations reported with implant failure, bone loss or peri-implantitis rates (Corcuera-Flores et al., 2016; Dvorak et al., 2011; Temmerman et al., 2016). When assessed as a separate risk factor, HRT may not affect or improve implant survival in postmenopausal women except in combination with smoking, which increased implant failures (Minsk & Polson 1998). Using HRT has also been associated with higher implant failure rates compared with a wider general population (Moy et al., 2005).

Bisphosphonates are used to treat osteoporosis as well as malignant bone diseases by reducing osteoclastic activity to increase bone density, and have been associated with bisphosphonate-related osteonecrosis of the jaw (BRONJ) (Marx 2003) following dentoalveolar procedures or even spontaneously (Marx et al., 2005), particularly with intravenous forms but also with oral bisphosphonates. While implants have previously been placed without particular precautions in patients taking bisphosphonates, the notion of possible poorer osseointegration and therefore higher implant failure in these patients has been investigated. Oral bisphosphonates have not shown any significant impact on early implant failure (Memon et al., 2012), implant survival (Bell

& Bell 2008; Fugazzotto et al., 2007; Goss et al., 2010; Grant et al., 2008; Jeffcoat 2006) or development of BRONJ in cohort studies (Fugazzotto et al., 2007; Jeffcoat 2006). Nevertheless, individual cases of BRONJ associated with implant treatment have been reported (Lazarovici et al., 2010; Lopez-Cedrun et al., 2013; Wang et al., 2007), and long-term results, the effect of confounding factors and the impact on marginal bone loss are not known (Chrcanovic et al., 2016a).

Although elective implant treatment is generally contraindicated in patients taking intravenous bisphosphonates for cancer (Madrid & Sanz 2009), greater implant failure rates or related incidence of BRONJ have not been demonstrated with IV bisphosphonates in general (Goss et al., 2010). Nonetheless, it must be noted that the evidence is extremely limited.

Bisphosphonate-related peri-implant disease incidence is unknown. Taking bisphosphonates was associated with greater patient-reported implant success (aesthetic and functional satisfaction, absence of pain and mobility) at the implant level, in a questionnaire-only study of 415 patients (Al-Sabbagh et al., 2015). In the periodontal literature, periodontal disease may be a significant risk factor for intravenous bisphosphonate-related ONJ development (Tsao et al., 2013) yet the outcomes of non-surgical periodontal therapy may be improved with adjunctive use of oral bisphosphonates (Lane et al., 2005) including in postmenopausal women (Rocha et al., 2004).

1.2.3.5 Oral cancer treatment

Radiotherapy for the treatment of oral cancers may affect bony integrity and healing with possible later development of osteoradionecrosis; although high implant success rates and stability have been shown in patients treated with surgery and radiotherapy (Heberer et al., 2011; Linsen et al., 2012), failure rates may be higher in irradiated bone (Barrowman et al., 2011; Cuesta-Gil et al., 2009; Fenlon et al., 2012; Yerit et al., 2006), maxillary location or with radiation dose >50Gy (Buddula et al., 2012; Visch et al., 2002). Previous radiation therapy was significantly associated with mucositis in a cross-sectional study of 100 patients (Karbach et al., 2009). Adjunctive hyperbaric oxygen treatment has been used in some cases although the benefits have been unclear (Chrcanovic et al., 2016b; Mericske-Stern et al., 1999).

High-level evidence for the impact of chemotherapy on implant therapy is not yet available (Chrcanovic et al., 2016c). The effects of oral cancer treatment on peri-implant disease incidence are not known and other confounding factors have rarely been considered in the assessment of implant failure rates (Javed et al., 2010).

1.2.3.6 Age

The age of the patient may be a contributing factor in the development of peri-implantitis due to systemic conditions being more common in older individuals (Renvert et al., 2014). Aging affects wound healing, general health, oral hygiene and sociological issues such as access to services which are likely to impact implant outcomes (Bartold et al., 2016). A cross-sectional study of 415 patients treated at the University of Kentucky found that patient-reported implant success (satisfaction, absence of pain and mobility) decreased by 15% for every additional 5 years in age, when controlling for other variables (Al-Sabbagh et al., 2015). However, increased age has not been demonstrated to be a significant risk factor for implant failure (Becker et al., 2016; Roos-Jansåker et al., 2006a; Wilson & Nunn 1999) or peri-implant disease (Costa et al., 2012; Marrone et al., 2013; Meijer et al., 2001; Roos-Jansåker et al., 2006c) in several other studies, although confounding factors such as greater prevalence of periodontitis with age (Renvert et al., 2013), poor implant hygiene in the elderly (Isaksson et al., 2009), longer implant time in function (Marrone et al., 2013) can increase peri-implant disease incidence and generally have not been taken into account.

1.2.3.7 Other systemic factors

Limited individual studies have reported the association of other systemic factors with peri-implant marginal bone loss, including >10g daily alcohol intake (Galindo-Moreno et al., 2005) and rheumatic diseases (Krennmair et al., 2016). Selective serotonin re-uptake inhibitor (Chrcanovic et al., 2017b; Wu et al., 2014) and proton-pump inhibitor (Chrcanovic et al., 2017a; Wu et al., 2017) medications have been associated with higher implant failure rates (Chappuis et al., 2018).

1.2.4 Iatrogenic factors

1.2.4.1 Practitioner type

The type of practitioner placing and/or restoring the implant may affect the development of peri-implantitis. Very few studies have assessed this risk factor, with the Swedish community-based study finding that while the rate of implant failure was not affected, patients with implants restored by general practitioners had a significantly increased odds ratio of 4.27 of developing moderate/severe peri-implantitis compared with those with implants restored specialists (Derks et al., 2016b). The reasons for this difference are not known. Although other global or Australian statistics are not available, when considering that American general practitioners provided an estimated 2.03 million implant crowns in the 2005-6 year, compared

with 260,000 provided by prosthodontists (American Dental Association 2007), the scale of the potential problem becomes immense.

1.2.4.2 Cement- vs Screw-Retention

Ideally-performed cement- or screw-retention of implant crowns appear to show similarly excellent success outcomes and neither method has intrinsic disadvantages (Kotsakis et al., 2016; Vigolo et al., 2004; Vigolo et al., 2012), although cemented suprastructures harboured higher total cultivable cell counts and a more mature plaque with fewer coccoid cells than screw-retained suprastructures (Keller et al., 1998). However, the effect of non-ideal treatment is important to describe, with excess cement identified as a specific problem. In indirect overall comparisons, cement-retained implant prostheses may have higher rates of biological complications such as marginal bone loss >2mm, mucosal recession, implant failure in multi-unit constructions (Jung et al., 2012; Sailer et al., 2012) or suppuration/fistula (Wittneben et al., 2014), compared to screw-retained prostheses where soft-tissue inflammation can be associated with loose abutment screws (Andersen et al., 2001). Screw-retention is generally recommended where possible as technical repairs and retrieval can be performed more easily, and biological complications minimised (Sailer et al., 2012; Wittneben et al., 2014).

In terms of current usage of these retention methods in clinical practice, it appears that the use of screw-retention is increasing, with the proportion of single crowns retained by screws increasing from 12% to 30% from 2008 to 2012 in serial meta-analyses (Jung et al., 2008; Jung et al., 2012). A large majority (77%) of prosthodontists in Australia preferred screw-retention in 2009 (Sambrook et al., 2012), compared with 49% of general dentists surveyed in Victoria in 2008 (Cheung et al., 2016). Half a decade later, another Australia-wide survey in 2014 found over 86% of implant-providing general practitioners and over 96% of prosthodontists preferred screw-retention for ideal single implant crowns or multiple implant-supported non-full arch bridges (Guo 2015). In private practice in Victoria, specialists used screw-retention in 82% and cement in 3% of single implant crown cases, compared with general practitioners in 48% and 35% of cases respectively; lateral screw-retention or cross-pinning was used in about 16% of cases by both practitioner groups (Wang et al., 2016b). The reasons for this apparent disparity between ideal preference and clinical usage for general practitioners are not yet known, but may include training needs, lower cost and familiarity with cementation of indirect tooth-borne restorations.

1.2.4.3 Foreign Bodies

The presence of excess cement appears to be an important factor in the development of peri-implant inflammation and disease, with delayed onset a reported feature, and removal leading

to resolution. The type of cement, cement margin location relative to the soft tissues, abutment design all appear to affect cement retention and associated peri-implant complications. Cement loading technique may also affect the marginal position of the prosthesis and subsequent peri-implant inflammation.

1.2.4.3.1 Excess cement

Excess cement remnants have been highly associated with peri-implant mucositis (Korsch et al., 2014a) and peri-implantitis (Wilson 2009), with a greater impact in patients with a history of periodontitis compared with those without (Linkevicius et al., 2013a). The removal of cement remnants results in disease resolution after one month (Linkevicius et al., 2013a; Wilson 2009).

The time of onset of peri-implant inflammation and disease in the presence of residual cement may only occur after years in function and varies considerably, from a few weeks to 4 years after cementation (Linkevicius et al., 2013a; Pauletto et al., 1999; Wilson 2009). In one retrospective study, mean time of onset was about 2 years in patients with a history of periodontitis, compared with 3.5 years for those without, while some patients had cement remnants for over 2 years with no signs of disease (Linkevicius et al., 2013a).

1.2.4.3.2 Cement and prosthetic margin

With each millimetre that the prosthetic margin between the crown and abutment is positioned submucosally, significantly more cement remnants are left even after cleaning at the time of cementation (Kappel et al., 2015; Linkevicius et al., 2013b). The shape of the abutment also affects the ability to remove cement: standard abutments used with recommended margin depths are “usually too narrow to support the entire restoration without leaving undercuts” and thus have reduced cleaning accessibility (Linkevicius et al., 2013a). Elsewhere, individualised zirconia abutments retained more undetected excess cement than standard lithium disilicate abutments, possibly due to greater abutment surface area and mucosal pressure, or non-standard abutment shoulder-to-implant angles affecting cleaning accessibility (Kappel et al., 2015). The influence of abutment shape or size on residual cement is not established. The cementation of implant crowns with submucosal prosthetic margins requires reconsideration (Kappel et al., 2015; Linkevicius et al., 2013a; Linkevicius et al., 2013b), and pre-treatment planning of implant fixture type and position plays a major role in facilitating this.

Incomplete seating of the cemented implant crown is associated with cement remnants and inflammation (Pauletto et al., 1999) and increased marginal bone loss (Chen et al., 2013); if excessive cement application prevents adequate crown seating, the relative influence of the cement itself and/or the marginal gap in inducing bone loss is not known. Three main cement-

filling patterns for implant crowns (gross internal filling, brushed onto inner surfaces, application at the inner margin only) are apparently used by US dentists but lack consensus, uniformity and precision; research into cement properties and methods to more accurately deliver it in variable volumetric situations is needed (Wadhwani et al., 2012).

1.2.4.3.3 Type of cement

The peri-implant effect of the type of cement used has begun to be researched both *in vitro* and clinically. Different types of cements show significantly different abilities to inhibit planktonic and biofilm growth of periodontal pathogens *in vitro* (Raval et al., 2015), with excess methacrylate cement apparently promoting bacterial colonisation *in vivo* (Korsch et al., 2014a), and preferentially colonised in artificial saliva while zinc oxide eugenol cement (ZOE) showed a generally inhibiting effect (Korsch et al., 2014b).

Clinically, a methacrylate cement recommended for use with implant crowns increased peri-implant BOP and suppuration, and excess methacrylate exacerbated these findings; recementation using ZOE resulted in 71-88% reduction in these clinical parameters (Korsch & Walther 2015). Peri-implant bone loss and attachment loss were significantly worse in the presence of excess methacrylate cement compared with no excess or use of ZOE (Korsch & Walther 2015).

The lower viscosity (Korsch et al., 2014a) and poor radio-opacity (Wadhwani et al., 2010) of methacrylate cement compared with ZOE are likely to reduce the detection and removal of excess during cementation. Radiographs are also inadequate in detecting glass ionomer (Kappel et al., 2015; Wadhwani et al., 2010) or resin-modified glass ionomer cement (Linkevicius et al., 2013b; Wadhwani et al., 2010). In a simulated subgingival model, resin cement was the most difficult to remove from abutment surfaces (Agar et al., 1997). Despite these disadvantages, commercially-available implant cements tend to be resin-based, and resin-modified glass ionomer cement was the most popular cement taught in American dental schools, followed by resin, glass ionomer and zinc phosphate cements (Tarica et al., 2010).

On the other hand, ZOE may have anti-bacterial properties and excess is presumably still retained but may subsequently dissolve in sulcular fluid (Korsch & Walther 2015); zinc phosphate and zinc oxide non-eugenol cements have been used successfully with no impact on peri-implant disease occurrence compared to screw-retained crowns (Kotsakis et al., 2016). The differences between the properties required in cemented tooth-borne and implant-borne restorations should be more closely considered in the choice of implant cement.

1.2.4.3.4 Titanium granules

Recent pilot studies on human peri-implantitis biopsies taken at the time of flap surgery (Wilson et al., 2015) or explantation (Fretwurst et al., 2015) have revealed another category of foreign body associated with chronic inflammation: titanium debris. Possible mechanisms for titanium deposition have been proposed, including friction during implant placement (although particles were not generated *in vitro* [Sridhar et al. 2016]), micro-movement at the implant-abutment interface, surface wear during maintenance debridement and corrosion of the implant surface (Wilson et al., 2015). Continued research is indicated in this area.

1.2.4.4 Prosthetic and implant design

As has been previously described, accessibility for oral hygiene via prosthesis design is an important factor in plaque control (Derks et al., 2016a; Heitz-Mayfield & Salvi 2018; Serino & Ström 2009). It seems likely that plaque accumulation is affected by prosthesis design at a macro level e.g. where external connection junction gaps of a significant size or non-ideal embrasure contours may be present, rather than at the level of tight internal junction microgaps. The 2017 World Workshop on the Classification of Periodontal and Peri-implant Diseases and Conditions recommended the provision of oral hygiene-accessible prostheses and adjustment or replacement where biofilm removal cannot be performed (Heitz-Mayfield & Salvi 2018), in agreement with expert recommendations in a previous systematic review (Renvert & Polyzois 2015). However, there does not appear to be any literature on the ideal emergence profile/prosthesis shape for best peri-implant maintenance.

1.2.4.4.1 Splinted crowns

Very little research has directly compared long-term peri-implant health outcomes in adjacent single or splinted implant crowns. It appears that splinted implants are the standard with which alternatives such as separate crowns are compared in the literature, particularly in terms of loading, since concerns with marginal bone loss were reported with apparent occlusal overloading in the early 1990s (Quirynen et al., 1992), or where crown to implant ratios are high (Blanes et al., 2007). A 2008 review article published in the Australian Dental Journal described the splinting of adjacent implants as “current practice”, with posterior “unconnected adjacent implants…still controversial” (Gross 2008). However, in more recent years no significant changes in crestal bone loss were found in either group after 5-10 years in university and/or prosthodontic settings (Blanes et al., 2007; Naert et al., 2002; Vigolo & Zaccaria 2010). The concern of oral hygiene accessibility outlined in review articles (Goldberg et al., 2001; Grossmann et al., 2005; Weigl 2003) remains and a prospective split-mouth clinical study reported that patients preferred the hygiene accessibility of non-splinted over splinted

restorations (the former group also exhibited more frequent screw-loosening) (Clelland et al., 2016). The subsequent impact on soft tissue and peri-implant condition is yet to be assessed in clinical research, particularly where accessibility is not ideal, or outside of a university or specialist clinic environment. To date no evidence is available for any particular design form or emergence profile around single crowns or prostheses on splinted implants, although "easy access to interproximal surfaces with adequate gingival embrasures" has been recommended (Grossmann et al., 2005).

1.2.4.4.2 Prosthetic margin, abutment-implant interface and crestal bone position

Prosthetic margin location depends on the implant system and abutment type used and the three-dimensional position of the fixture. A distance of ≤1.5mm between the prosthetic margin and crestal bone level was significantly associated with moderate/severe peri-implantitis in the Swedish community-based cross-sectional study (Derks et al., 2016a). As will be described in the section on peri-implant maintenance, supramucosal positioning of a restoration margin significantly improves the rate of recovery from peri-implant mucositis (Heitz-Mayfield et al., 2011) but whether it provides a protective effect against the development of peri-implant disease is not known.

Early crestal bone loss within healthy peri-implant parameters (i.e. bony remodelling) or aesthetic complications after implant placement in relation to different implant collar designs or platform switching have been widely investigated (Canullo et al., 2010; Heitz-Mayfield et al., 2013; Linkevicius et al., 2015; Peñarrocha-Diago et al., 2013; Schwarz et al., 2014a; Veis et al., 2010) but must be differentiated from long-term inflammatory peri-implant outcomes for which there are very few reports. Smooth-necked implants placed with supracrestal implant-abutment interface had a significantly lower incidence of peri-implantitis than rough-necked implants placed with crestal interface position (Sanchez-Siles et al., 2015), but the causative interplay between neck surface and crestal position as well as other confounding factors is not known.

With the advent of customisable abutments, cross-brand "compatibility" and CAD-CAM design, *in vitro* assessment of non-original abutments has shown significantly greater leakage (Berberi et al., 2014) and misfit (Berberi et al., 2014; Gigandet et al., 2014), likely due to vastly different groove and surface characteristics (Gigandet et al., 2014; Mattheos et al., 2015). There may be clinical implications for success/survival and long-term peri-implant health outcomes, which are yet to be determined. Same-brand implant and abutment usage has been recommended to minimise unexpected failures and adverse clinical handling, but it will be interesting to follow the likely increase in uptake of these new technologies by practitioners.

1.2.4.4.3 Implant brand/surface

Differently textured implant surfaces have been developed to improve the quality and speed of osseointegration, but the exposure of rough surfaces may lead to increased plaque accumulation (Rimondini et al., 1997) and peri-implant disease. Rough abutment surfaces above a threshold of Ra=0.2µm and with higher surface free energy facilitate bacterial colonisation and plaque formation (Subramani et al., 2009; Teughels et al., 2006). In animal model studies, the spontaneous progression of ligature-induced peri-implantitis is significantly worse in implants with TiUnite (Nobel Biocare AB, Göteborg, Sweden) (Albouy et al., 2012) or sandblasted large grit acid-etched (SLA) (Berglundh et al., 2007) surfaces compared with turned surfaces.

Comparisons of implant surfaces in analysing human peri-implant disease outcomes have shown that rough implant surfaces may (Sayardoust et al., 2013) or may not (Gotfredsen & Karlsson 2001) show greater long-term peri-implant bone loss and may (Astrand et al., 2004) or may not (Wennström et al., 2004; Zetterqvist et al., 2010) increase peri-implantitis incidence, with confounding factors such as a history of periodontitis (Karoussis et al., 2003) or smoking (Balshe et al., 2008; Sayardoust et al., 2013) likely to have an influence. One cross-sectional study found no differences in clinical stability, inflammation, mucositis, and peri-implantitis between implants with machined or medium rough surfaces, but the mean follow-up time was markedly different at >11 years for the former and 4 years for the latter (Mir-Mari et al., 2012). The comparable results at 11 years for the medium rough surface group remain to be seen and are likely be comparatively worse.

Laser-microtextured groove modifications developed to promote bone and connective tissue connection to the implant surface have shown no differences in plaque or bleeding indices and significantly shallower probing depths and less crestal bone loss compared with machined overdenture abutment collars in the short term (Botos et al., 2011). Further research on the long-term results of implants restored with all prostheses types is indicated.

Other surface modifications have been shown to reduce bacterial adhesion compared with uncoated titanium, including titanium nitride *in vivo* (Scarano et al., 2003), silver-coated titanium (Ewald et al., 2006) and vancomycin-modified titanium (Jose et al., 2005; Lawson et al., 2007), the latter two exhibiting bacteriocidal effects *in vitro*. Further research is needed in these areas to establish the effects of these compounds and their clinical suitability.

1.2.4.5 Implant positioning

Implant positioning has recently been proposed as a separate local factor contributing to peri-implant disease. Three experienced implantologists visually assessed clinical photographs of

peri-implantitis cases published in the peri-implantitis treatment literature, in terms of implant horizontal bucco-lingual position, vertical position, angulation, keratinised mucosa, distance from adjacent teeth/implants, tissue biotype, accessibility for plaque control, and implant surface (Monje et al., 2016b). “Too-buccal implant position” was the only factor to have almost perfect inter-examiner agreement, with moderate agreement found for minimal keratinised tissue and thin tissue biotype; these three factors seemed to be important determinants of peri-implant pathology, within the limitations of the study, and without calling the main aetiological role of biofilm into question. The suggested mechanism for too-buccal positioning is that post-placement bone remodelling (affected also by early or immediate loading, particularly in the anterior maxilla) may expose implant threads, favouring biofilm accumulation and possible peri-implant disease. In a study of 30 immediate-replacement implants in the maxillary anterior region, the risk of mucosal recession and adverse aesthetic outcomes after 3 years was found to be reduced where buccal positioning was avoided (Chen et al., 2007).

Implant malpositioning was also the strongest factor (OR 48.2) associated with peri-implantitis, in a predictive profile model proposed and developed using data mining and machine learning algorithms (Canullo et al., 2016b). Peri-implantitis cases were categorised into surgically-triggered (malpositioning, failed bone reconstruction), prosthetically-triggered (excess cement and/or crown margin ≥2mm below soft tissue margin, overloading, prosthetic component breakdown) or plaque-induced (plaque accumulation without any surgical/prosthetic complications) subtypes, which showed predictive values of 82.35% accuracy but requires further validation and replication.

Multidimensional patient risk assessment tools have been developed for periodontitis progression, given that isolated risk factors gave predictive values of 30% at best (Lang et al., 2015); similar continued investigation into the multifactorial nature of peri-implantitis (Canullo et al., 2016b; de Araujo Nobre et al., 2015) rather than individual risk factors (Karbach et al., 2009) is indicated, which may change the understanding and categorisation of peri-implantitis, e.g. into the previously proposed cause-related subtypes. A comprehensive predictive model of peri-implant disease risk such as the Implant Disease Risk Assessment functional diagram recently proposed by Heitz-Mayfield et al. (2020) could help to streamline the implant treatment planning process according to the risk profile of each patient and each implant site, to minimise disease risk, simplify individualised maintenance and management in the event of disease occurrence and improve peri-implantitis treatment outcomes by targeting the relevant causative factors.

1.3 Information flow from education to treatment provision

1.3.1 Implant education and clinical implementation

There is limited literature on the sources of dentists' implant knowledge. While curricula vary across all dental disciplines, there appears to be a wide range of implant education sources in Australia, from undergraduate teaching, to continuing professional development courses, diplomas and specialty programs. As implant dentistry is also a relatively new discipline, there are courses aimed at expanding the knowledge of those who did not receive implant training during their undergraduate degree. Furthermore, the endpoint of implant education varies for each individual practitioner depending on their clinical goals, which can range from no involvement, implant maintenance only, implant restoration, to implant surgery and complex rehabilitation cases. Is it possible for implant education to be standardised?

The implant dentistry curriculum in undergraduate/graduate dental degrees (leading to registration as a dentist) and university-based teaching of general dentists in Australia has been recommended to be standardised by consensus (Mattheos et al., 2010). Undergraduate/graduate dental degree competencies in the provision of clinical procedures are limited to diagnostic and planning procedures, design and delivery of single unit implant crowns in non-aesthetic zones and mandibular implant-retained removable prostheses, the planning and execution of best-evidence maintenance protocols, diagnosing peri-implant complications and the treatment of peri-implant mucositis. Knowledge of and familiarity with more complex procedures are also expected.

A postal survey in Wales took the rare step of surveying general dentists' opinions on the adequacy of undergraduate prosthodontic training compared to their clinical practice, where over 96% rated their surgical or restorative implant training as "none or poor" (Patel et al., 2010). In contrast, similar majorities rated their training in dentures (~95%), bridges (~85%) and resin-bonded bridges (~60%) as "adequate" or "good or excellent". No other such reviews of undergraduate implant training or implant maintenance teaching have been published.

Implant education available to dentists in Australia after graduation from the undergraduate/graduate dental degree can be divided into 3 levels (Ivanovski et al., 2010):

1. Non-degree continuing professional development (CPD) courses "may be provided by scientific or professional bodies or associations, university CPD programmes, independent or private bodies related to implant dentistry, or industry in the case of product training", which "do not aim to address specific clinical competencies and do not include summative assessment of the students...this type of training alone is

insufficient to provide the competencies and skills necessary for the safe and effective practice of general practitioners who are not otherwise trained in implant dentistry."

2. Formal postgraduate university-based award programs (non-specialist)
3. Formal training programs leading to specialist registration

As non-degree CPD appears to introduce the most variability in implant education worldwide, the following review will focus mainly on the available evidence of attendance within this category.

A postal survey of 176 general dentists in Victoria (Cheung et al., 2016) found that the most popular education courses for restorative implant training were short 1-2 day courses run by implant companies (attended by 55.1%) and universities (attended by 19.9%), with low attendance at year-long company-run courses (3.4%) or postgraduate university-based diplomas (5.1%). With regard to surgical training, 26.7% of respondents had attended a 1-2 day company course and 2-7% had attended each of the other course types. It can clearly be seen that the vast majority of courses attended fall into the non-degree CPD category. Greater attendance at CPD and further training was significantly associated with provision of more complex procedures (Cheung et al., 2016). High demand for implant education in the Asia-Pacific region has been demonstrated in surveys of general dentists with 71-85% interested in future implant CPD (Chan et al., 2006; Ng et al., 2011b).

Similarly, a 2011 representative survey of general dentists in Hong Kong (Ng et al., 2011b) found 74% of implant providers received training from short courses run by implant companies or the University of Hong Kong, 14% attended formal postgraduate courses, while 12% were self-taught from books and manuals. Researchers in the UK expressed concern regarding a small percentage of general dentists who "were not looking for a course but...would self-teach using available texts and media" in order to provide implant treatment in the future (Gibson & Barclay 2006).

In the USA, dentists and specialists who surgically place implants in private practice had most commonly attended manufacturer-sponsored courses (90.8%), privately sponsored courses (80.9%) and university-based continuing education (63.5%). Formal training from dental school, specialty or hospital residency programs were each only attended by 30% of respondents or less (American Dental Association 2008).

As part of the 2nd European Consensus Workshop on Implant Dentistry Education, a literature review and survey of European opinion leaders and implant education stakeholders (Ucer et al., 2014) found CPD to be "generally poorly structured with little regulation or harmonisation

across Europe", with great variation in the accreditation or quality control of CPD education across countries. Without providing further detail, the authors described the perception that the most popular CPD types are 1-2 day short courses run by implant companies, followed by study club meetings, while structured modular programs with clinical mentoring were relatively rare. Special mention was made of the UK's mentoring requirement for dentists wanting to provide implant treatment, with few if any similar requirements in other countries.

Both the European (Mattheos et al., 2009) and Australian (Ivanovski et al., 2010; Mattheos et al., 2010) education consensuses recommend that CPD programs be standardised, with education provider accreditation and quality assurance, and formative assessment related to specific competency levels. In particular, universities are put forward as the organisations best placed to do so in Australia (Mattheos et al., 2010). The role of industry was strongly suggested to be limited to "product training", with sponsorship openly disclosed. In the event of industry-run courses being the only source of CPD in some countries, national or European accreditation was recommended.

Furthermore, attendance at continuing education programs does not necessarily result in implementation in clinical practice. While there is little research into this area, a survey of attendees at rotary endodontics and implant CPD courses at the University of Melbourne found that implant participants felt significantly greater barriers to clinical implementation than did endodontic participants, with significant factors being the need for further study and practical experience (John & Parashos 2007). Participants had also suggested that different program delivery methods from the traditional theory and workshop format might be more suitable for implant dentistry.

The integration of a formalised mentoring program into the implant training process has been strongly recommended (Donos et al., 2009), to facilitate the transition from theory to clinical practice. The addition of recorded self-assessment and self-directed reflection is another highly desired tool recommended to identify clinical strengths and weaknesses (Ucer et al., 2014).

Even with best-evidence maintenance protocols mandated in current undergraduate teaching, the lack of strong evidence for maintenance practices in the literature (as will be outlined further in this literature review), varied historical teaching depending on the time of graduation, and in particular, the unknown teaching of implant maintenance in the absence of non-degree CPD standardisation may induce uncertainty and inconsistency in clinical practice.

The delivery methods and content of implant maintenance information to dental hygienists, dental therapists and oral health therapists is rarely documented in the literature, with only one

published survey on the information sources and interest levels of dental hygienists in the USA (Ward et al., 2012). Over half (51%) had not received any implant maintenance training in their formal degree, 52% had attended implant maintenance CPD and 93.9% were interested in future implant maintenance CPD.

1.3.2 Provision of implant services

In Australia in 2019, there were 17,799 registered dentists, 1,974 dental hygienists, 1,965 oral health therapists and 1,370 dental therapists, including individuals with multiple registrations (AHPRA 2019). Dental implants are provided by increasing numbers of general dentists, as well as prosthodontists, oral surgeons and periodontists. The proportion of general dentists providing implant treatment increased from 50.6% in Victoria in 2008 (Cheung et al., 2016) to 66.4% in a country-wide online survey in 2014 (Guo et al., 2017). In Hong Kong, this proportion increased from 39% in 2004 (Chan et al., 2006) to 61% in 2008 (Ng et al., 2011b), while in the USA an increase of general practitioners surgically placing implants from 8.8% in 1996 to 12.3% in 2006 was found (American Dental Association 2008). A survey in New Zealand repeated after 10 years found that the proportion of dentists and specialists providing implant treatment has increased from 49.5% (Reid et al., 2005) to 68.0% in 2014 (Murray et al., 2016). In Wales, a survey of general dentists found that while 27.1% provided implant treatment, 81.4% lacked confidence in providing implants, and this was a greater contraindication to providing implants (60.3%) than in other prosthodontic treatments (<20%) (Patel et al., 2010). Only one study in Australia of general dentists in 2014 outlined their provision of restorative only (51.42%), surgical only (6.22%) or both types of services (42.52%) (Guo et al., 2017).

Prosthodontists appear to be the recipients of the most referrals for implant treatment from general dentists in Australia, followed by periodontists, oral surgeons, and increasingly, other general dentists who have implant experience (Brandt et al., 2000; Guo et al., 2017; John & Parashos 2007), perhaps reflecting the current emphasis on prosthetically-driven implant treatment planning. Surveys have found an increase in the provision of surgical implant placement by American prosthodontists from 12.2% (Eckert et al., 2002) to 39% in 2009 (Cardoso et al., 2013).

Surveys of implant patients in Northern Europe revealed that the majority of implant surgeries (67-74%) were performed by specialists while the majority of prostheses (60-76%) were provided by general practitioners in the Netherlands (Cune et al., 1995) and Sweden (Derks et al., 2015b), with similar results even with 20 years between these two studies.

Only one representative survey has outlined the relative proportions of implant treatment provided in private practice to the community by general dentists or specialist groups, in the USA in 2005-6 (American Dental Association 2007). Percentages shown here have been calculated from the published data. The national annual average of services provided in private practice estimated that oral maxillofacial surgeons surgically placed 37.9%, periodontists 32%, general practitioners 25%, prosthodontists 5%, and endodontists 0.07% of a total 2.07 million implants. General practitioners were estimated to have provided 88% of 2.3 million implant-supported crowns and 0.62 million implant-supported removable dentures; the remainder were provided by prosthodontists, who also provided all 81,640 implant-supported retainers for fixed partial dentures and 66,510 implant-supported fixed dentures. Periodontists provided implant repair or removal in 59%, and prosthodontists in 41% of 78,330 total cases. There has been no published data since then to observe changing patterns.

1.4 Implant maintenance standards

In evidence-based practice, information flows from research findings published in the literature, to readers of the literature or via education programs, to clinical practice and finally patient education. The current literature on routine clinical implant assessment and maintenance, and home care recommendations, as outlined below, varies in its quality and quantity, thereby influencing clinical practice and possibly patient outcomes.

1.4.1 Professional maintenance

1.4.1.1 Diagnostic criteria

The 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions came to consensus on the case definitions and diagnostic criteria for peri-implant health, peri-implant mucositis and peri-implantitis (Berglundh et al., 2018; Renvert et al., 2018). It is important to understand the great variability in the epidemiological and interventional peri-implant literature prior to this, as outlined below.

Peri-implant health has previously been assumed in the absence of disease, but the recently developed criteria specifies the absence of inflammatory signs, lack of profuse bleeding on probing, stable probing depths over time, and absence of radiographic bone loss greater than that expected with bony remodelling, which should not exceed 2mm (Renvert et al., 2018).

Peri-implant mucositis has been described as a plaque-induced inflammatory process similar to gingivitis around natural teeth (Pontoriero et al., 1994; Zitzmann & Berglundh 2008), with current criteria requiring profuse bleeding and/or suppuration on probing in combination with visual signs of inflammation, and no evidence of radiographic bone loss after remodelling (Renvert et al., 2018). It is reversible with removal of the aetiological agent although peri-implant soft tissues demonstrated a stronger inflammatory response than did gingivae to experimental plaque accumulation (Salvi et al., 2012). However, in a parallel fashion to the different implant success criteria used across the literature, the diagnostic threshold for pocket depths in mucositis has also varied, from ≥4mm (Roos-Jansåker et al., 2006b), <5mm (Ferreira et al., 2006) to ≥5mm (Karbach et al., 2009). Bone loss thresholds in mucositis varied from “no bone loss” (Koldsland et al., 2010, 2011) to radiographic bone loss up to 3 threads after the first year of loading (Roos-Jansåker et al., 2006b). The American Academy of Periodontology (2013) described pocket depths in peri-implant mucositis as “usually... ≥4mm” without specifying a minimum or maximum threshold. This variability may have been due to the fact that absolute

probing depth values must take into account variability in surgical implant positioning, such as in aesthetic zones where the implant may be significantly submucosal compared with posterior regions (Salvi & Lang 2004), and led to difficulty in comparing disease prevalence across studies.

Peri-implantitis by definition involves soft tissue inflammation and additional loss of bone in this inflammatory process, beyond that which occurs on initial bony remodelling after implant placement (Renvert et al., 2018; Zitzmann & Berglundh 2008). However, this comparison ideally requires baseline radiographs at the time of implant placement and prosthesis delivery (American Academy of Periodontology 2013; Renvert et al., 2018), and in the absence of these radiographs, calculation methods for the expected remodelled marginal bone level and thresholds for relative bone loss have been highly variable in the literature. Eight different diagnostic thresholds for probing depths, baseline bone level and radiographic bone loss were used in twelve widely cited studies (Tomasi & Derks 2012). This clearly affected the collective understanding of the true prevalence, incidence, and severity of peri-implantitis as well as inducing uncertainty in clinical practice, as clinicians may have followed different systems or patterns of practice. The current diagnostic criteria aim to address this lack of "globally accepted classification" (Romanos et al., 2015), and also improves upon previous limitations by providing probing depth and radiographic bone loss guidelines for diagnosis in the absence of baseline records (Renvert et al., 2018).

The new classification definitions for peri-implant health, peri-implant mucositis and peri-implantitis provide specific clinical and radiographic criteria, allowing for the absence of baseline data, and make particular mention that the context of variable implant brands, surfaces, designs as well as protocols for surgical placement, loading and restoration be considered (Berglundh et al., 2018). They are intended for use in both day-to-day clinical practice and research studies, and provide a standard by which to interpret the existing literature and future research, particularly acknowledging the lack of previous definitions for peri-implant health. There is, however, no definition for implant success (which must additionally consider aesthetics and patient satisfaction) or whether this is a suitable determination to make. There may also be an increasing number of implants with soft-tissue conditions analogous to the patient with a reduced periodontium and no history of periodontal disease or the periodontally stable patient with successfully treated periodontal disease (Chapple et al., 2018).

1.4.1.2 Diagnostic procedures

1.4.1.2.1 Soft tissue and hygiene assessment

The methods used for evaluating the peri-implant soft tissues have largely been appropriated from the periodontal literature, and have generally been validated for use in peri-implant diagnosis. The presence of plaque as an aetiological factor is well established, and thus plaque indices to assess oral hygiene over the long-term such as the modified plaque index (Mombelli et al., 1987) as well as conventional plaque indices such as the O'Leary index may be used (O'Leary et al., 1972). Plaque may also be detected visually and with the aid of plaque disclosing solutions.

Bleeding on probing (BOP) is one of the main diagnostic parameters of soft tissue inflammation (Heitz-Mayfield 2008; Salvi & Lang 2004), with absence of BOP shown to have a very high negative predictive value of 97% at a site level (Jepsen et al., 1996), and BOP showing higher positive predictive value around implants than teeth (Luterbacher et al., 2000). However, a recent systematic review established that there may be a high false positive rate in using BOP to diagnose peri-implantitis (Hashim et al., 2018). Bleeding caused by traumatic probing must be carefully distinguished and BOP should occur profusely or in the presence of visual inflammation to be considered significant in the latest diagnostic criteria (Renvert et al., 2018). Suppuration is a clear indicator of inflammation and infection indicating the need for further evaluation and management (American Academy of Periodontology 2013).

Gingival indices have been modified by some (Apse et al., 1991; Mombelli et al., 1987) for use in peri-implant diagnosis but may not correlate to changes in peri-implant bone level (Salvi & Lang 2004). Mombelli's index (1987) can be considered a numerical grading of BOP severity, whereas the index by Apse et al. (1991), which assesses visual variations in inflammation (colour, degree of oedema) without probing, may be susceptible to the fact that there is inherent variation in mucosal type and contour depending on implant location, gingival biotype and surgical procedures performed, even in healthy tissues, and that non-keratinised mucosa normally has a redder colouration than keratinised tissue. Furthermore, mucosal keratinisation type may affect the ability to perform adequate oral hygiene, as described previously, and the combination of these two factors must be considered in any visual changes over time. The new diagnostic criteria by Renvert et al. (2018) specifies the detection of visual signs of inflammation (redness, swelling, shininess) in the soft tissues, to differentiate peri-implant health and disease. Standardised photographic records may be a future tool for recording visual assessment of each individual implant, and to monitor for longitudinal change.

1.4.1.2.2 Probing methods

With variable diagnostic thresholds used in research, there is no strict recommendation for a peri-implant probing depth as an indicator of inflammation or disease, although clinical recommendation has been made recently that probing depths generally should not exceed 5mm in healthy tissues (Renvert et al., 2018). Previous studies have shown 3mm to be a depth to which successful implants allow probing (Apse et al., 1991; Buser et al., 1990), but the direction of supracrestal collagen fibres parallel to the implant rather than perpendicularly to a tooth may affect probe penetration, precluding the use of average periodontal probing depths in implant assessment (Salvi & Lang 2004). Average pocket depths around implants have been reported at 2.2-2.3mm, significantly greater than 1.7-1.8mm measured around teeth (Christensen et al., 1997).

Rather than a depth threshold, of greater importance is the detection of probing depth changes over time compared with a baseline reference point fixed after implant restoration, more similarly to clinical attachment level assessment around natural teeth (Heitz-Mayfield 2008; Renvert et al., 2018; Salvi & Lang 2004). Deeper probe penetration into the connective tissues around implants in the presence of inflammation has been shown in animal studies (Lang & Nyman 1994; Schou et al., 2002). As probing inaccuracies may occur due to compromised access around the prosthesis (Salvi & Lang 2004), implant surface texture and shape, and exposed threads (Mombelli et al., 1997), accurate probing highly correlated to intra-surgical measurements requires prosthesis removal (Serino et al., 2013) but whether routine removal would be performed by clinicians is questionable, at least in general practice.

Probing with a conventional periodontal probe using a light force of 0.25N allows complete re-establishment of the mucosal seal after 5 days in dogs (Etter et al., 2002), and has been consistently recommended (American Academy of Periodontology 2013; Heitz-Mayfield 2008; Renvert et al., 2018). A study assessing three automated probes with different forces of 0.2N, 0.25N and 0.3-0.45N found they all had acceptable reproducibility around teeth and implants, with the 0.25N probe showing highest consistency and ease of use (Christensen et al., 1997). However, conventional manual periodontal probing has been shown to be more consistent than an electronic force-controlled probe (Wang et al., 1995). Thus far there appears to be no evidence regarding probe design for implant assessment, either in design or material (Heitz-Mayfield 2008).

1.4.1.2.3 Radiographic assessment

As described above, the recording of radiographic baselines is ideal, at the time of implant placement and implant restoration. Baseline radiographs should show the suprastructure, a

reproducible reference point and “distinct visualization of the implant threads” (Renvert et al., 2018). As implant threads are currently perpendicular to the implant surface, this clear delineation indicates that a radiograph is as parallel as possible to the implant, allowing more accurate assessment of the crestal bone level in relation to fixed reference points and threads. Radiographic assessment should be performed when signs of inflammation are present, and where clinical judgement dictates after other diagnostic procedures are performed (Renvert et al., 2018).

However, the limitations to conventional intra-oral radiographs in periodontics are well known and include the inability to detect disease activity or progression (Wolf & Lamster 2011) and underestimation of attachment and bone loss (Akesson et al., 1992; Bragger et al., 1988; Goodson et al., 1984; Suomi et al., 1968). Additionally, as a two-dimensional representation of a three-dimensional area, conventional radiography does not accurately show buccal and lingual bone levels if at all. These same concerns exist for peri-implantitis, where interproximal bone levels measured radiographically were significantly less than those measured intra-operatively during surgical treatment (García-García et al., 2016). Buccal and lingual bone heights predicted as the mean of mesial and distal measurements were overestimated compared with surgical measurements, although statistical significance was not reported.

Technological advancements continue to be developed to overcome these limitations. Subtraction analysis especially with digital radiography allows detection of smaller changes in bone density, at around 5% compared with 30-50% in conventional visual comparison (Dreyer 1993; Jeffcoat & Reddy 1991; Reddy & Jeffcoat 1993; Wolf & Lamster 2011). However, this technique is not commonly used clinically and may be more suitable for identifying bone loss trends in groups rather than individuals, when using non-standardised panoramic radiographs (Geraets et al., 2012). Very little research has been published in recent years regarding subtraction analysis of periapical radiographs, especially when considering the increasing accessibility of high-quality digital radiography.

Another imaging mode which is gaining in popularity is that of cone-beam computed tomography (CBCT). It is increasingly used as a tool in implant research, including in the monitoring of bony changes following implant placement (Roe et al., 2012; Vera et al., 2012). However, it is apparent that CBCT does not yet provide the level of detail needed for peri-implant bone assessment, and also delivers greater radiation and is more costly than periapical imaging. A consensus report from the International Congress of Oral Implantologists states that CBCT bone-density measurements and post-implant artefacts require further research (Benavides et al., 2012). Few human studies appear to have been published since, with CBCT

significantly underestimating interproximal bone levels compared with periapical radiographs at the 1-year follow-up of immediately loaded implants (Raes et al., 2013). Digital long-cone periapical radiographs showed greater sensitivity, specificity, and inter- and intra- examiner reliability in detecting circumferential peri-implant bone defects than CBCT in a laboratory study (Dave et al., 2013). Animal studies have shown similar underestimation of marginal bone levels by periapical radiographs and CBCT (dos Santos Corpas et al., 2011; Ritter et al., 2014), and CBCT limitations in the measurement of bone density (dos Santos Corpas et al., 2011) and buccal/lingual bone dimensions (Fienitz et al., 2012; Gonzalez-Martin et al., 2016; Ritter et al., 2014; Wang et al., 2013).

While CBCT provides better imaging quality than conventional CT, which produced an artefact immediately adjacent to the implant surface (Mengel et al., 2006), artefacts affecting the regions close to the implant surface in CBCT are well-documented, such as those due to scatter, noise, motion, beam hardening and adjacent missing data reconstruction (Draenert et al., 2007; Schulze et al., 2010). Further improvements in CBCT hardware and software such as image artefact-reducing algorithms have been called for (Draenert et al., 2007; Raes et al., 2013; Ritter et al., 2014; Schulze et al., 2010), but the validity of algorithmic data reconstruction in accurately representing clinical bone levels must then be confirmed prior to recommendation for clinical peri-implant diagnosis.

1.4.1.2.4 Mobility and resonance frequency analysis

Implant fixture mobility is an indication of osseointegration failure and thus is not a good diagnostic indicator of initial peri-implant disease (American Academy of Periodontology 2013; Heitz-Mayfield 2008; Salvi & Lang 2004). However, resonance frequency analysis is a method that can be used to assess the interface between the bone and implant surfaces, to test primary stability on implant placement and monitor implant stability over time (Salvi & Lang 2004). It applies a lateral bending load to the implant to assess the stiffness of the bone-implant interface, without the potential destruction of a shear force as applied in a reverse torque test (Sennerby & Meredith 2008). High implant stability quotient values indicate successful implant integration, whereas low or decreasing implant stability quotient values may indicate an increased risk of implant complications including marginal bone loss or implant failure (Sennerby & Meredith 2008). However, further research is needed before clinical recommendations can be made, as the threshold values for clinical diagnosis of specific peri-implant conditions are yet to be determined; additionally, the prosthesis must be removed to perform the measurement. Distinguishing between mobility of the implant body and that of the prosthesis is also critical for accurate diagnosis.

1.4.1.3 Frequency of review/recall

The lack of standardised maintenance protocols in the implant literature which include an appropriate recall frequency has been acknowledged in recent years (Sanz & Chapple 2012; Wilson et al., 2014), yet recall recommendations have until recently been excluded from otherwise comprehensive reviews of non-surgical and surgical treatment options (Romanos et al., 2015). The current diagnostic consensus made a clinical recommendation of at least yearly evaluation (Renvert et al., 2018). Over twenty years after the suggestion from Lang & Nyman (1994) that periodontal concepts be applied to the regular maintenance and recall of patients with implants, there has not yet been a confirmation of these concepts through research: "Current approaches to implant maintenance are somewhat haphazard and not standardized. It is therefore suggested that information gathered at maintenance visits for patients with implants be modelled on the data gathered for individuals with periodontal diseases" (Wilson et al., 2014).

The need for regular periodic observation of implants, with routine baseline and appropriate follow-up radiographs, oral hygiene and occlusal assessment, and greater frequency of review for patients with peri-implant risk factors has been strongly justified (Bidra et al., 2016a; Wilson et al., 2014), particularly given the great variation in time of disease onset (Wilson et al., 2014).

The "Clinical Practice Guidelines for recall and maintenance of patients with tooth-borne and implant-borne dental restorations" from the American College of Prosthodontists (Bidra et al., 2016b) appeared to be the first of its kind, with the lack of high-quality evidence in many areas acknowledged, and minimum of 6-monthly recall recommended only on the strength of expert opinions. Appropriate recall interval should be individualised for each patient in periodontal disease management, but minimal evidence is available to assess implant recall frequency with or without implant pathology, with no studies comparing two different recall regimens (Bidra et al., 2016a; Salvi & Zitzmann 2014). However, it was adherence to the individualised recall recommendation that was associated with lower incidences of peri-implantitis and implant loss, compared with lack of attendance as recommended (Salvi & Zitzmann 2014). A more recent meta-analysis found that longer intervals were significantly associated with greater incidences of mucositis and peri-implantitis at both the implant and patient level (Monje et al., 2016a). By analysing reported interval periods, the authors suggested that a period of 5-6 months might be suitable because of its significant positive effect on peri-implantitis incidence, while continuing to support individualisation of recall periods where appropriate and the need for further research. The quality of evidence provided by retrospective studies is limited by the confounding factors of clinical risk assessment influencing recommended recall frequency, and risk factors

affecting the incidence of pathology (de Araujo Nobre et al., 2014; Monje et al., 2016a). Furthermore, very few studies have been performed in a private practice setting and may not be representative (Bidra et al., 2016b). A strong caveat was included that the Clinical Practice Guidelines are to serve as a baseline framework with modifications as future evidence is established.

As discussed previously, multidimensional risk assessment tools for periodontal disease (Darcey & Ashley 2011; Lang et al., 2015) may be suitable for adaptation to peri-implant disease management. These will be outlined in the following section given the lack of peri-implant literature. Nevertheless, the recall frequency required to maintain implant health in the absence of disease may be a different consideration.

1.4.1.3.1 Frequency of recall for periodontal disease management

The therapeutic goals of a regular monitoring program are to prevent or minimise disease progression, tooth or implant loss, and to identify and treat conditions in a timely manner, according to the American Academy of Periodontology Position Paper on periodontal maintenance (Cohen et al., 2003). Several recall intervals ranging from 2 weeks to 18 months have been studied, with a general conclusion that patients with a severe chronic periodontal disease history should attend at least every 3-4 months (Armitage & Xenoudi 2016), as a lower frequency of attendance led to an increased risk of disease progression (Cohen et al., 2003). Even so, these conclusions have been made at a literature review level of evidence, with the 3-4 month interval generally used as part of study design, rather than being compared with different intervals in a controlled trial (Renvert & Persson 2004). It may not be suitable to apply this recommended interval to patients with milder or even no periodontal disease, with a range of 3-12 month recall intervals not adversely affecting periodontal health in patients of limited susceptibility, although attachment loss was noted at 18 months in this group (Rosen et al., 1999). Nevertheless, excellent oral hygiene is the ultimate objective, with no disease progression in patients who were able to maintain good oral hygiene, even with less frequent recalls (Axelsson et al., 1991; Lindhe et al., 1984); recall interval is a tool with which to assist the patient in maintaining good oral hygiene and therefore periodontal health.

It is widely accepted that the individualisation of recall interval and procedures performed is important, with the level of oral hygiene and attendance compliance being critical factors (Armitage & Xenoudi 2016; Cohen et al., 2003; Darcey & Ashley 2011; Renvert & Persson 2004).

Objective methods of determining patient-specific risk of periodontal disease progression have been developed, with dentists tending to underestimate risk (Persson et al., 2003). Risk factor

compilers such as the Previser Risk Calculator (www.previser.com) and the periodontal risk assessment functional diagram (Lang & Tonetti 2003) weigh patient signs and risk factors and have been proposed for use in calculating a recommended recall interval (Darcey & Ashley 2011; Lang et al., 2015), for which the clinical impact is yet to be established.

When considering "routine scaling and polishing" for patients without periodontal disease and its appropriate frequency, the evidence appears to be insufficient to determine any significant effects of professional mechanical plaque removal at any particular frequency or even at all (Needleman et al., 2015; Worthington et al., 2013). Large long-term trials carried out in combination with oral hygiene instruction and ideally in primary care settings have been recommended, to determine clinical significance and assess patient-centred outcomes and economic factors. Whether this information is transferrable to the maintenance of implant health would then need to be determined.

1.4.1.4 Peri-implant disease treatment

A widely-cited maintenance protocol for implants called Cumulative Interceptive Supportive Therapy (CIST) (Lang et al., 2000) is based on the concept of "a sequence of therapeutic procedures with increasing antibacterial potential depending on the severity and extent of the lesion", measured by the presence or absence of plaque, bleeding on probing, suppuration, probing depths, radiographic bone loss in successive order. The cumulative stages of treatment were, in order: mechanical therapy where plaque/calculus is present, antiseptic chlorhexidine where BOP is present, antibiotics (systemic and/or local) where probing depths ≥6mm and/or suppuration is present, regenerative or resective surgery after infection is controlled and explantation when it is not. The evidence cited for most of the treatment phases was limited, and as will be described below, mostly remains inconclusive.

According to the American Academy of Periodontology Position Paper on periodontal maintenance which includes maintenance of dental implants, maintenance is defined as management which follows periodontal or implant therapy, and it is discontinued when disease or pathology is detected necessitating the resumption of non-surgical or surgical therapy (Cohen et al., 2003). It is not clear whether implant therapy refers to treatment of peri-implantitis or the initial provision of an implant, although maintenance is required in either case. Confusion may arise as periodontal maintenance specifically follows comprehensive periodontitis treatment, use of which as a term is not directly transferable to implants; implant maintenance currently includes the entire spectrum of post-restoration peri-implant therapy, from the preservation of peri-implant health in a preventative manner, to the treatment of mucositis and

peri-implantitis, and subsequent maintenance after the re-establishment of peri-implant health. Perhaps clarifications in terminology or alternatives to the word “maintenance” are needed.

1.4.1.4.1 Non-surgical peri-implant health preservation and mucositis management

Unlike the treatment of gingivitis and periodontitis, for which non-surgical therapy is similar or on a continuous spectrum, peri-implant mucositis therapy is generally non-surgical, and efficacious peri-implantitis therapy is generally surgical (Heitz-Mayfield & Mombelli 2014; Muthukuru et al., 2012; Romanos et al., 2015; Romanos & Weitz 2012). The maintenance of health i.e. prevention of gingivitis or mucositis can be considered to be similar to the treatment of these same conditions. Thus, the section that follows will describe literature regarding non-surgical prevention and treatment of peri-implant mucositis, which is essential in current general practice.

1.4.1.4.1.1 Primary prevention

While health preservation protocols are likely to be similar to mucositis management, a distinction must be made as preventive management is performed to manage risk factors before a diagnostic threshold is reached. The 11th European Workshop on Periodontology acknowledged that there are no studies currently available on the primary prevention of mucositis (Jepsen et al., 2015), which follows the consensus statement from the 8th European Workshop on Periodontology identifying the need for “a standard preventive measure with demonstrated efficacy to preserve peri-implant health, which could be used as a standard control treatment in future intervention trials” (Sanz & Chapple 2012). Coronal rubber cup polishing has been suggested as appropriate management for a finding of peri-implant health (Armitage & Xenoudi 2016) but this has not been substantiated.

1.4.1.4.1.2 Mechanical debridement

While it is commonly held that oral hygiene instruction and mechanical debridement alone are effective in managing peri-implant mucositis (Renvert & Polyzois 2015; Renvert et al., 2008b; Salvi & Ramseier 2015) and reducing clinical inflammation (Jepsen et al., 2015), others have drawn back from this conclusion, describing a lack of consensus on protocols (Romanos et al., 2015), lack of reliable evidence (Grusovin et al., 2010) or incomplete resolution of clinical signs (Schwarz et al., 2015b). Very few studies have compared different professional interventions in maintenance and prevention of peri-implant mucositis in periodontally healthy patients (Bidra et al., 2016a), with most of the data available related to implant-retained complete fixed dentures or removable overdentures.

There is great variation in the studies investigating the effectiveness of mechanical debridement methods, a recurring theme in peri-implant therapy research. Often, the specific instruments

and procedures used are compared not with a non-treatment control, but with or used in combination with another treatment protocol, such as adjunctive antimicrobials or air-abrasion polishing in the case of non-surgical mechanical debridement. It appears that mechanical implant debridement is assumed by researchers to have a proven efficacy and established evidence base as per its periodontal equivalent, but this is not the case: "there is a clear need to properly define a standard control protocol for the treatment of peri-implant mucositis" (Schwarz et al., 2015b).

Investigated mechanical debridement methods have included plastic, Teflon or carbon-fibre curettes (Heitz-Mayfield et al., 2011; Maximo et al., 2009; Porras et al., 2002; Thöne-Mühling et al., 2010) in combination with rubber cup polishing (Blasi et al., 2016; Heitz-Mayfield et al., 2011; Porras et al., 2002; Riben-Grundstrom et al., 2015), sodium carbonate air-abrasion (Maximo et al., 2009) or glycine powder air polishing (GPAP) (Mussano et al., 2013); titanium-coated curettes (Blasi et al., 2016; Heitz-Mayfield et al., 2011); plastic or carbon-fibre tipped ultrasonic scalers (Blasi et al., 2016; Riben-Grundstrom et al., 2015; Thöne-Mühling et al., 2010) with or without additional GPAP (Ji et al., 2014); and GPAP alone (Blasi et al., 2016; Mussano et al., 2013; Riben-Grundstrom et al., 2015). Some treatment protocols also included the removal of prosthesis overhangs (Maximo et al., 2009), which could greatly affect treatment and oral hygiene outcomes.

In general, all of these methods have resulted in improvements in BOP and other clinical parameters, but long-term effects are not known and incomplete inflammation resolution (Blasi et al., 2016; Heitz-Mayfield et al., 2011; Maximo et al., 2009; Riben-Grundstrom et al., 2015) or reversion to baseline bacterial load (Thöne-Mühling et al., 2010) were also reported. Longer term studies are needed to understand an appropriate period at which resolution can occur, with most of these studies reporting outcomes at 3 months (Heitz-Mayfield et al., 2011; Ji et al., 2014; Maximo et al., 2009; Porras et al., 2002) and a maximum of 12 months (Riben-Grundstrom et al., 2015).

Of note, implants with supramucosal restoration margins showed greater improvement than those with submucosal margins (Heitz-Mayfield et al., 2011), while difficulty in reaching the depths of the threads and peri-implant pockets with the carbon fibre curette sizes available has been reported (Maximo et al., 2009).

1.4.1.4.1.3 Glycine powder air polishing

Glycine powder air polishing (GPAP) involves a nozzle-directed spray of powder, water and air, able to remove biofilms from titanium surfaces without causing significant surface damage *in vitro* (Schwarz et al., 2009a). In clinical research, GPAP has proven to be as effective as plastic-

tipped ultrasonic scalers in treating mucositis (Riben-Grundstrom et al., 2015) and more effective than plastic curettes in reducing inflammation parameters (Mussano et al., 2013), but was associated with a subsequent increase in plaque accumulation in one study (Blasi et al., 2016). As an adjunct, GPAP improved the outcomes of mucositis treatment with plastic curettes (De Siena et al., 2015) but not carbon-fibre ultrasonic tips (Ji et al., 2014). Variations in GPAP application technique and instrument settings may impact outcomes as well. Concerns have been raised as to the possible adverse effect of emphysema formation with the use of pressured air delivery close to or within the mucosal tissues, with case reports in the restorative literature (Brown et al., 1992; Liebenberg & Crawford 1997), but although the clinical safety of the device has reportedly been demonstrated for non-surgical peri-implantitis therapy (Schwarz et al., 2015a), there is a published case report of subcutaneous emphysema following non-surgical peri-implantitis therapy using GPAP, which resolved completely after seven days (Bassetti et al., 2014a).

1.4.1.4.1.4 Rationale for instrumentation

The use of these debridement methods is shadowed by the existing clinical availability of stainless steel instruments for periodontal treatment. Considerable investigation into the relative suitability of instrument use around implants has been undertaken *in vitro* as irregularity of the implant surface would increase plaque retention and calculus retention and adherence (Matarasso et al., 1996). *In vitro* macroscopic surface damage and scratching of the titanium implant neck was worst when metal curettes and ultrasonic tips were used (Agar et al., 1997; Baek et al., 2012; Mann et al., 2012; Matarasso et al., 1996; Mengel et al., 2004), with titanium (Matarasso et al., 1996; Mengel et al., 2004) and gold–plated scalers (Agar et al., 1997) producing shallower but still significant scratches; metal instruments and burs were only recommended for the smoothing of surface roughness (Louropoulou et al., 2012). Plastic curettes and ultrasonic tips (Agar et al., 1997; Baek et al., 2012; Mann et al., 2012; Matarasso et al., 1996), a novel copper alloy ultrasonic tip (Baek et al., 2012), and rubber cups and air abrasion systems (Matarasso et al., 1996; Mengel et al., 2004; Ramaglia et al., 2006) produced very shallow surface changes if at all. The surface damage caused by metal ultrasonic scalers and lack thereof by carbon or plastic ultrasonic tips have been corroborated in one *in vivo* study (Kawashima et al., 2007) but without reporting any subsequent clinical diagnostic outcomes.

Moving closer to clinical applicability, the cleaning efficacy of these instruments has also been investigated, primarily *in vitro* with laboratory contamination models. Instrumentation that did not cause surface damage include air abrasive systems (sodium carbonate or glycine) that can remove plaque from a variety of titanium surfaces (machined, modified SLA, TPS, grit-blasted) (Schmage et al., 2014; Schwarz et al., 2009a; Tastepe et al., 2012), non-metal ultrasonic tips that

remove plaque from a variety of titanium surfaces (Schmage et al., 2012) and titanium brushes from SLA surfaces (John et al., 2014). Non-metal curettes (Augthun et al., 1998; Schmage et al., 2012) and rubber polishing cups (Schmage et al., 2012) appear to be ineffective (Louropoulou et al., 2014a), while metal curettes (John et al., 2014) and ultrasonic tips were effective but caused surface damage (Louropoulou et al., 2012). There are no studies evaluating the plaque-removing efficacy of titanium curettes (Louropoulou et al., 2014a). Calculus-removing efficacy of any of these instruments is not known. The only *in vivo* study showed equal plaque-removing efficacy in the use of metal, carbon and plastic ultrasonic tips (Kawashima et al., 2007). The biocompatibility of treated titanium surfaces for soft tissue re-adaptation at transmucosal components is not known (Louropoulou et al., 2015).

One concern is that of residual deposits left behind *in vitro* by plastic ultrasonic tips (Bertoldi et al., 2017; Mann et al., 2012) and curettes (Ramaglia et al., 2006), and air-abrasion (Mouhyi et al., 1998; Ramaglia et al., 2006). No evidence is yet available as to their clinical impact. The same can be said of surface damage caused by metal instruments – little *in vivo* evidence and none as to subsequent clinical outcomes currently exists. Conversely, stainless steel ultrasonic tips have been used (after prosthesis removal) to successfully stabilise and maintain implants for 5 years after surgical peri-implantitis treatment (Serino et al., 2015).

Perhaps it can be concluded here that non-metal ultrasonic tips and air powder polishing are the current effective recommendations from the limited available evidence. However, methods with possibly varied and unproven efficacies have been used in clinical research (without appropriate controls), as described previously. It presents a confusing picture for the uptake of implant-specific instrumentation in clinical practice.

1.4.1.4.1.5 Adjunctive antimicrobials

Chlorhexidine has been described as being “the most effective and most thoroughly tested antiplaque and antigingivitis agent” (Lang & Brecx 1986) particularly when used in twice daily 0.2% solution rinsing or daily 2% gel application (Löe & Schiott 1970), and is recommended in the Clinical Practical Guidelines previously mentioned (Bidra et al., 2016b), possibly in the hope of transferable application to peri-implant tissues. However, the evidence does not bear this out.

Adjunctive chlorhexidine use in randomised clinical trials, whether using 0.5% gel at home (Heitz-Mayfield et al., 2011), professional 0.12% irrigation and gel application and at-home rinsing (Porras et al., 2002), or professional subgingival and tongue 1% gel application, at-home 0.2% rinsing and tonsil spray (Thöne-Mühling et al., 2010) did not enhance the results of non-surgical mechanical debridement of mucositis-affected implants with plastic curettes, ultrasonic

tips and rubber cup polishing. In one study, the bacterial load at 8 months was not significantly different from baseline in either the chlorhexidine or control groups (Thöne-Mühling et al., 2010).

Attempts have been made to minimise bacterial reservoir development in the internal implant space, and while bacterial counts were reduced at 6 months after internal placement of 1% chlorhexidine gel, clinical parameters did not change (Paolantonio et al., 2008).

The adjunctive use of antibiotics also appears to have little to no effect, with some reduction in BOP with local tetracycline hydrochloride fibres (Schenk et al., 1997) and no significant difference with systemic azithromycin (Hallström et al., 2012), such that systemic antibiotics have been deemed unjustifiable in the management of mucositis (Salvi & Ramseier 2015).

1.4.1.4.2 Non-surgical treatment of peri-implantitis

There appears to be a consensus that non-surgical treatment of peri-implantitis is not particularly effective (Muthukuru et al., 2012; Renvert et al., 2008b; Romanos & Weitz 2012), with lack of complete disease resolution a common finding. Adjunctive locally-delivered antibiotics may improve results and novel developments such as lasers are being tested.

Comparison of different non-surgical instrumentation methods such as titanium hand instruments and the Vector system® ("flexible Vector® carbon fiber tip combined with aerosol spray of Vector® fluid polish with hydroxyapatite particles [grain size approximately 10µm]") (Karring et al., 2005; Renvert et al., 2009), or carbon curette and GPAP (John et al., 2015; Sahm et al., 2011), have shown lack of complete resolution of disease in each of the methodologies, although GPAP significantly reduced BOP and may improve non-surgical treatment efficacy.

1.4.1.4.2.1 Antimicrobials

Comparisons of local antimicrobials as adjuncts to mechanical debridement have shown significantly greater reductions in probing depths with the use of minocycline microspheres (Arestin®) (Renvert et al., 2006; Renvert et al., 2008a) and 8.5% doxycycline hyclate (Atridox™), which also showed greater BOP reduction (Buchter et al., 2004), compared with subgingival chlorhexidine application, in the short-term (4-6 months). Mixed findings in the retention of these outcome differences in the 6-12 month timeframe were observed (Renvert et al., 2006; Renvert et al., 2008a). Tetracycline fibres (Actisite®) have produced probing depth reductions (from increased tissue tone rather than shrinkage of the tissues), BOP and microbial reductions at 12 months, without comparison to control (Mombelli et al., 2001). Disease progression with subject withdrawal has been reported in these local antimicrobial studies (Mombelli et al., 2001;

Salvi et al., 2007) and repeated use to improve long-term effects has been suggested (Renvert et al., 2008a).

Thus far, the efficacy of antibiotics in the treatment of peri-implantitis is unanswered (Heitz-Mayfield & Lang 2004; Javed et al., 2013), with no blinded randomised placebo-controlled clinical trials available. In the only study available of antibiotic use in non-surgical therapy, debridement and chlorhexidine irrigation with systemic ornidazole (1000mg for 10 days) resulted in significantly reduced probing depths and bleeding after 12 months in a group of nine patients (Mombelli & Lang 1992). The criteria for choosing antibiotic type and dosage remain to be established (Javed et al., 2013) and evidence-based guidelines are critically needed given the consequences of overuse (Mattheos et al., 2012).

1.4.1.4.2.2 Laser and photodynamic therapy

Various forms of laser and photodynamic therapy have been investigated as alternative decontamination methods for peri-implantitis, although concerns exist as to their ability to access the implant surface when no mucosal flap is raised, given the straight-line delivery of laser and the impeding contours of implant threads. E*rbium*-doped yttrium aluminium garnet laser (Er:YAG) showed only short term reductions in BOP compared with plastic curettes (Schwarz et al., 2006a; Schwarz et al., 2005) and no difference to GPAP, although some short-term improvements were noted and treatment repetition has been suggested (Renvert et al., 2011a).

The 4-monthly adjunctive use of 810-nm diode laser produced significantly greater improvement in probing depths than plastic ultrasonic and titanium curette non-surgical debridement alone, and a larger reduction in BOP (significance not reported) after 12 months, in implants with BOP and probing depth ≥4mm (either mucositis or peri-implantitis) (Lerario et al., 2016). These preliminary results are promising despite limitations in the study.

The laser-assisted peri-implantitis protocol (LAPIP™) is an implant-specific modification of the non-surgical laser-assisted new attachment protocol (LANAP) for periodontal therapy (Romanos et al., 2015). Theoretically, laser-ablation using neodymium-doped yttrium aluminium garnet (Nd:YAG) laser removes inflamed tissue and decontaminates the implant surface, ultrasonic debridement is performed, and the laser is used to form a stable blood clot. Little non-commercial literature exists and no controlled trials or human studies on the efficacy of LAPIP™ have been published (Natto et al., 2015; Romanos et al., 2015). Nd:YAG laser has also been reported to cause implant surface damage and significant increases in temperature, and deemed to be strictly contraindicated in peri-implant treatment (Romanos et al., 2013).

However, the methodology and equipment settings may vary considerably (Natto et al., 2015). This remains an area of continuing development.

Photodynamic therapy used as an adjunct to titanium curettes and GPAP may be as successful as adjunctive minocycline microspheres, although overall success rates were low (Bassetti et al., 2014b). Advantages may exist over antibiotics where possible microbial resistance with repeated applications might develop.

As with peri-implant mucositis management, there is a lack of a true control group in almost all studies, as the effectiveness of submucosal debridement with curettes or ultrasonics, commonly used as the control in clinical trials, is not established (Muthukuru et al., 2012), limiting any possible conclusions as to efficacy. Little to no information on progressing or arrested bone loss following non-surgical treatment has been reported thus far, with short follow-up periods of a maximum of 12 months (Muthukuru et al., 2012).

1.4.1.4.3 Surgical management of peri-implantitis

There are no trials published in the literature comparing non-surgical and surgical interventions in managing peri-implantitis (Esposito et al., 2012a; Heitz-Mayfield & Mombelli 2014; Romanos et al., 2015).

Despite similar shortcomings to those described previously in the non-surgical intervention literature, with heterogeneity of study designs, small sample sizes, the lack of a standard control with most studies being prospective cohorts or case series, and extremely varied treatment protocols, surgical therapy may be predictable and beneficial, when involving surgical flap access, debridement and decontamination, systemic antibiotics and post-operative oral antiseptics, while defect fill may be achieved with bone or bone substitutes and resorbable or non-resorbable membranes (Chan et al., 2014; Heitz-Mayfield & Mombelli 2014; Mombelli et al., 2012; Renvert et al., 2012). Furthermore, these results may be sustained for several years. The long-term outcome differences in the achievement of defect fill versus true re-osseointegration in regeneration procedures remain to be seen.

The question of randomised controlled clinical trials must be raised. It cannot be denied that prospective cohort or case series studies show clinical improvements, compared with peri-implantitis progression without treatment. With so many steps and procedures involved in surgical treatment, the components of the entire treatment protocol which are essential to the outcome cannot be accurately identified without randomised controlled trials, particularly where procedures with separate aims of infection removal and regeneration are combined. Inter-study comparison is not possible.

1.4.1.4.3.1 Anti-infective procedures

The surgical raising of a mucosal flap overlying an infected implant allows direct access for decontamination and debridement procedures to remove biofilm from the implant surface.

Improvements in clinical parameters have been demonstrated using open debridement (plastic curettes and sodium carbonate air-abrasion) and post-operative rinsing (with only short term results available from the same research group) (de Mendonca et al., 2009; Duarte et al., 2009; Maximo et al., 2009); "mechanical cleaning" with 10% hydrogen peroxide and saline rinsing with abutment re-sterilisation and individualised systemic antibiotics (Leonhardt et al., 2003); and a comprehensive anti-infective protocol (oral hygiene instructions, non-surgical debridement, granulation tissue removal, open curettage, saline irrigation and rubbing, post-operative systemic antibiotics, antiseptic rinsing) (Heitz-Mayfield et al., 2012). About 60% of treatments were still successful where reported after 5 years with maintenance (Heitz-Mayfield et al., 2016; Leonhardt et al., 2003). None of these studies controlled for any elements of the treatment protocol and relative efficacies are not known.

When combined with recontouring or regeneration procedures, some studies have performed only non-surgical debridement, despite the lack of strong supporting evidence for non-surgical debridement methods for peri-implantitis, prior to surgical flap reflection (Khoury & Buchmann 2001; Romeo et al., 2005; Wiltfang et al., 2012), while others performed only intra-surgery debridement, or both. Pre-surgery debridement methods, where described, include the use of plastic curettes (Khoury & Buchmann 2001; Romeo et al., 2005; Schwarz et al., 2006b) and Er:YAG laser (Schwarz et al., 2014b; Schwarz et al., 2010). Debridement during surgery has been performed with plastic or carbon curettes (Froum et al., 2012; Roccuzzo et al., 2011; Schwarz et al., 2006b; Schwarz et al., 2014b; Schwarz et al., 2010), stainless steel ultrasonic (Serino & Turri 2011), titanium curettes or tips (Aghazadeh et al., 2012; Froum et al., 2012; Roccuzzo et al., 2016a), titanium brushes (Roccuzzo et al., 2016a), and air abrasion (Behneke et al., 2000; Froum et al., 2012; Matarasso et al., 2014). There have been no known reports of emphysema development after air-abrasive debridement in surgical peri-implantitis therapy.

Where debridement methods have been compared, it is often novel technologies compared with conventional techniques (i.e. those commonly used but of unproven specific efficacy). Although high defect bone fill has been achieved with xenograft or autogenous bone grafting after CO_2 laser decontamination (Romanos & Nentwig 2008), results after 4-5 years were not different after air abrasion was used with or without additional CO_2 laser, with further subdivision into soft tissue resection or augmentation groups (Deppe et al., 2007), or where

debridement with Er:YAG laser was compared with plastic curettes and saline swabbing, both with subsequent regeneration procedures (Schwarz et al., 2013).

The re-establishment of titanium implant surface biocompatibility after decontamination is needed to ultimately allow true re-osseointegration, which has only been demonstrated to a limited extent in animal studies (Claffey et al., 2008) and otherwise appears impossible to achieve (Suarez et al., 2013). *In vitro* assessment has compared decontaminated titanium surfaces with pristine surfaces. Air-abrasion with sodium bicarbonate affected fibroblast or osteoblast-like cell viability less than amino acid glycine powders (Schwarz et al., 2009a) or hardly at all (Augthun et al., 1998) while other commonly used instruments (plastic and stainless steel curettes, Vector® system, titanium brushes, GPAP) significantly reduced cell viability. Further research into effects on cell re-attachment both for re-osseointegration and re-establishment of a soft tissue seal is needed (Louropoulou et al., 2015).

Surgical treatment protocols report the use of systemic antibiotics (amoxycillin, metronidazole, clindamycin, clavulanic acid, and/or azithromycin) much more often than not, although there is little to no evidence supporting their use (Claffey et al., 2008; Javed et al., 2013) in reducing post-operative complications or improving treatment outcomes, unlike where their use in periodontitis treatment is well known (Haffajee et al., 2003). However, there may be advantages that are not yet understood, for example in a controlled trial where systemic amoxycillin improved surgical treatment of peri-implantitis in implants with modified surfaces but not in non-modified surface implants, which nevertheless showed significantly better outcomes overall (Carcuac et al., 2016).

Another area where protocols are used without strong evidence is that of chemical implant decontamination, likely adapted from periodontal surgery. Saline is always and hydrogen peroxide is generally used in combination with other agents and thus their efficacy have been poorly demonstrated (Suarez et al., 2013). Chlorhexidine has been widely used but recent controlled trials have found no benefit compared with saline (Carcuac et al., 2016) or when used in higher concentrations, questioning its biofilm cleaning and killing efficacy (de Waal et al., 2015). Citric acid has shown a greater potential compared with other agents *in vitro* in removing biofilms from contaminated titanium surfaces (Ntrouka et al., 2011) and improving the adhesion of clot-blended hydroxyapatite graft to peri-implantitis affected surfaces (Gamal et al., 2013). It also improves bone formation (Rezende et al., 2014) and pre-osteoblast spreading (de Rezende et al., 2015) in animal studies. Some studies have applied medicaments usually used on dentine in periodontal surgery such as ethylenediaminetetraacetic acid (Roccuzzo et al., 2011; Roccuzzo et al., 2016a), orthophosphoric etching gel (Matarasso et al., 2014) or tetracycline (Froum et al.,

2012, 2015) to the implant surfaces, without particular justification. More often than not, a varied or new combination of medicaments is used in each study. Without the development of systematic evidence, cost-effectiveness must be questioned, with a shotgun approach apparently common, as researchers amalgamate elements of previously successful protocols without the evidence available for each component.

The lack of standardised decontamination and debridement procedures must be considered where study results and interpretation of which were intended to represent the effect of a particular surgical method or regenerative material, as outlined below.

1.4.1.4.3.2 Resection of bone or implant threads

The surgical recontouring of the alveolar bone and elimination of pockets to resolve peri-implantitis was more effective in implants with shallower bone loss (Serino & Turri 2011), while the addition of implantoplasty in a randomised controlled trial improved the clinical results (Romeo et al., 2005; Romeo et al., 2007). Meanwhile, implantoplasty followed by grafting with demineralised bovine bone mineral (BioOss®) (DBBM) and a resorbable membrane (BioGide®) (Matarasso et al., 2014) or a 1:1 mix of autologous and demineralised equine-derived bone graft material (Wiltfang et al., 2012) improved clinical parameters and showed bony defect fill of up to 93.3% (Matarasso et al., 2014). Of note, *in vitro* findings have shown that narrow diameter implants are more prone to failure by fracture after thread removal in implantoplasty, whereas the strength of wide implants did not appear to be affected (Chan et al., 2013).

1.4.1.4.3.3 Regenerative materials

Following the removal of biofilm, many materials and procedures can be used which have been developed with the aim of regenerating bone which has been lost during development of the peri-implantitis lesion.

Autogenous bone has been used in attempts to fill peri-implant bone defects and encourage bony regeneration, with 90% bone fill reported especially in vertical angular defects and in lesions of earlier onset (Behneke et al., 2000). The additional use of resorbable or non-resorbable membranes in a submerged healing protocol did not improve already acceptable outcomes and are not recommended for routine use (Khoury & Buchmann 2001), with higher complication rates, and resorbable membranes showing less improvement in probing depths.

Similarly, calcium carbonate has been used successfully as a bone substitute grafting material but is not improved by the use of a synthetic resorbable membrane (Roos-Jansåker et al., 2007b), although a submerged healing protocol with the membrane may achieve more

favourable results (Roos-Jansåker et al., 2007a) which continued to be stable after 5 years (Roos-Jansåker et al., 2014).

In comparisons of DBBM grafting material and resorbable collagen membrane against autogenous bone and resorbable membrane (Aghazadeh et al., 2012), or nanocrystalline hydroxyapatite alone (Schwarz et al., 2006b; Schwarz et al., 2009b; Schwarz et al., 2008), DBBM and resorbable membrane showed generally better results, although the success rate was still low at 38.5% (Aghazadeh et al., 2012). DBBM has also been used without a control comparison with mixed success rates. In combination with connective tissue grafts in the absence of keratinised tissue, implants with SLA surfaces showed significantly better results with DBBM than did TPS surfaces but only 25% had complete defect fill (Roccuzzo et al., 2011). DBBM with resorbable membranes showed reduced success where buccal dehiscences developed (Schwarz et al., 2010), which were addressed with additional implantoplasty (Schwarz et al., 2011) and with further connective tissue grafting (Schwarz et al., 2014b) to address mucosal recession. DBBM with additional 10% collagen was used (with titanium instrument and brush debridement) with a 52% success rate (Roccuzzo et al., 2016a).

The success of periodontal intrabony defect regeneration using enamel matrix derived proteins (EMD) (Heden & Wennström 2006), enhanced in combination with allograft (Gurinsky et al., 2004) or DBBM (Lekovic et al., 2000), and recombinant human platelet-derived growth factor (rhPDGF-BB) combined with synthetic beta tricalcium phosphate matrix (McGuire et al., 2009; Nevins et al., 2005), has led to the combined use of these techniques to peri-implant defects. The application of EMD or rhPDGF-BB, with allograft or DBBM hydrated with rhPDGF-BB showed high overall success rates but there was a lack of standardised protocol in materials and membranes used, and repeated surgeries in a small number of cases (Froum et al., 2012, 2015).

Another relatively new graft material is porous titanium granules, the use of which demonstrated significantly better radiographic defect fill at 12 months than without in a manufacturer-sponsored randomised controlled trial (Wohlfahrt et al., 2012), and also showed high success rates in an independent preliminary study (Mijiritsky et al., 2013). This material theoretically takes advantage of a very large surface area of osteoconductive titanium oxide in order to enhance bone growth and regeneration, and further large long-term studies are warranted.

It is not yet known whether apparent clinical resolution of peri-implantitis due to obstruction of the previous osseous defect with a radiographically indistinguishable material (Claffey et al., 2008) is sufficient, or if a gradual transition to complete bone regeneration and re-

osseointegration is needed (Behneke et al., 2000; Schwarz et al., 2009b), particularly without human histological assessment being performed routinely in clinical research. Long-term clinical distinctions or difference in the risk of disease recurrence are also unknown.

Mucosal recession can be a negative aesthetic outcome, is commonly reported after peri-implant surgery (Behneke et al., 2000; Matarasso et al., 2014; Romeo et al., 2007; Wiltfang et al., 2012) and is also associated with the baseline absence of keratinised tissue (Roos-Jansåker et al., 2014). Recession has been successfully compensated for with the use of additional simultaneous soft tissue grafting, without affecting peri-implant improvement (Schwarz et al., 2014b). The effect of apically or coronally-positioned flaps with non-submerged healing on recession outcomes is not clear, with a lack of protocol clarity and outcome reporting. The impact of the related alternative of submerged healing has not yet been made clear, with some suggestions that the undisturbed healing may confer advantages more generally (Roos-Jansåker et al., 2007a).

1.4.1.4.3.4 Post-therapy maintenance

A supportive maintenance program is reported in most of the surgical peri-implantitis literature, and generally involves 3-6 monthly regular recall (Heitz-Mayfield et al., 2016; Khoury & Buchmann 2001; Matarasso et al., 2014; Roccuzzo et al., 2011; Roccuzzo et al., 2016a; Roos-Jansåker et al., 2007a, 2007b; Schwarz et al., 2009b; Serino & Turri 2011; Wiltfang et al., 2012), in some studies only for the first year, followed by annual review (Behneke et al., 2000; Romanos & Nentwig 2008; Romeo et al., 2005). This rigorous recall frequency is to be expected in research and in specialist periodontist practice, but even so, the reported success rates are varied and can be relatively low. A comparison of surgically treated and healthy implants maintained 6-monthly for 5 years (including prosthesis removal and debridement) demonstrated further clinical attachment loss in only 13% of the treated implants, which had previously showed residual pockets after surgical treatment, with otherwise successful retention of surgical results or peri-implant health (Serino et al., 2015). It is clear that a strict maintenance program is the minimum standard following surgical therapy, with high survival rates and successful treatment of peri-implantitis reported in a systematic review (Roccuzzo et al., 2018). Again, clarifications for the use of the term “maintenance” should be considered.

Overall, in the management of peri-implantitis, limitations include the relatively short-term nature of the studies, high selective bias, high incidence of commercial sponsorship which may influence the types of interventions studied (Esposito et al., 2012a), and the possible different effects of interventions on different implant surface micro- and macrostructures (Heitz-Mayfield & Mombelli 2014). While some treatments may be effective or show some favourable short-

term outcomes, there is currently insufficient evidence to adequately compare the effectiveness, cost-efficiency or side effects of any one intervention with another (Esposito et al., 2012a). Of note, difficulties in recruiting sufficient numbers of patients with peri-implantitis are reflected in the small sample sizes, unclear inclusion criteria and disease definitions, and variable exclusion criteria (Heitz-Mayfield & Mombelli 2014).

Recommendations have been made for future research to compare single procedures believed to be most effective, rather than combining numerous procedures, with more uniform reporting of outcomes (Heitz-Mayfield & Mombelli 2014) and consideration of measures beyond implant survival (Roccuzzo et al., 2018). A composite criterion ("implant survival with the absence of peri-implant probing depths ≥5mm, with no concomitant bleeding on probing with light pressure and no suppuration, in addition to no further bone loss") has been proposed to describe the threshold at which peri-implantitis either requires further treatment or can be considered to be successfully treated, with only non-surgical maintenance required (Heitz-Mayfield & Mombelli 2014). Analysis of research and treatment outcomes could be more effective were this criterion to be used widely to measure peri-implantitis treatment success.

1.4.2 Implant home care

There is a lack of evidence for best self-performed oral hygiene practices around implants (Hultin et al., 2007; Louropoulou et al., 2014b), whether in a preventive manner or in recovering peri-implant soft tissue health. More randomised controlled trials with longer follow-up are needed (Grusovin et al., 2010). The 2017 World Workshop on the Classification of Periodontal and Peri-implant Diseases and Conditions recommended the individualisation of oral hygiene instructions for each patient to prevent mucositis as a precursor to peri-implantitis (Heitz-Mayfield & Salvi 2018). The recommendations currently made by Australian dentists to their patients, and patient-reported sources of implant home care information are not known.

As described previously, although clinical parameters of peri-implant mucositis improve with tested and control interventions, the complete resolution of peri-implant health has not been strongly shown to occur (Heitz-Mayfield et al., 2011; Schwarz et al., 2015b). The re-institution of oral hygiene measures for 3 weeks after experimental plaque accumulation does not appear to resolve all mucosal inflammation parameters (Salvi et al., 2012). Oral hygiene measures and instructions are included as an adjunct in most studies and trials of peri-implant mucositis and peri-implantitis interventions, but while subjects often receive "instruction in optimal oral hygiene practices" (Salvi et al., 2012), these are rarely described in any further detail. Just as

there is great variety in control interventions for maintenance, there may be even more variety in the oral hygiene instructions (OHI) given in these studies, with no established gold standard in the literature for patient-administered plaque control around implants. Few studies have assessed the oral hygiene performance of patients with implants at all, with one survey of patients after 10 years finding that most patients were unlikely to have changed their hygiene habits after implant installation (Pjetursson et al., 2005) and another finding generally poor oral hygiene around full-arch implant-retained prostheses (Kreve et al., 2016).

The tailoring of OHI to each patient is important given individualised implant positioning, depth, surface characteristics and prosthesis shape. Any hygiene difficulties need to be considered at the treatment planning, OHI delivery and maintenance stages and to determine recall frequency. Supramucosal restoration margins should be considered given they show better improvement following mucositis treatment (Heitz-Mayfield et al., 2011) as described previously.

1.4.2.1 Brushing and interproximal cleaning

Powered toothbrushes improved BOP and implant probing depths over 12 months in cohort studies, with about 95% of patients reporting satisfaction with the brush (Rasperini et al., 2008; Vandekerckhove et al., 2004). Compared with manual toothbrushes, powered brushes improved plaque and bleeding indices in some studies (Truhlar et al., 2000; Wolff et al., 1998) but showed no difference in a blinded randomised controlled trial (Swierkot et al., 2013) or for implants retaining mandibular overdentures (Tawse-Smith et al., 2002). Some studies included notable confounding factors such as incidental floss usage (Wolff et al., 1998).

There is also a lack of evidence present for interproximal cleaning around implants (Louropoulou et al., 2014b). While normal interproximal flossing is mentioned briefly in the studies above and in other reviews, flossing technique is rarely outlined. Some reviews of the literature recommend flossing circumferentially around the implant (Chen & Darby 2003; Kracher & Smith 2010), which is described in the hygienist literature: “it is also recommended to loop the floss around the implant on buccal and lingual surfaces to ensure all the plaque is removed” (Wingrove 2011). The origin of this recommendation is not known. Given the different volumetric configuration of the peri-implant mucosa and embrasure, flossing technique variation may affect surface coverage significantly.

A recent report described a possible negative outcome in the use of floss at exposed rough implant surfaces, with floss remnants found during exploratory surgery in all 10 cases of peri-implantitis which did not respond to the initial stages of CIST management, over 3 years in a

hospital clinic in the Netherlands (van Velzen et al., 2016). *In vitro* testing in the same study found that floss remnants could be left on the rough implant surface after 10 seconds of rubbing with waxed dental floss and Superfloss® (Oral-B) but not with interdental brushes.

In the use of interdental brushes, brush shape may be important, with a "waist-shaped" brush (widest at the tip and handle ends) removing plaque more efficaciously than a straight brush at posterior teeth and implants, particularly at the line angles, when applied by a hygienist (Chongcharoen et al., 2012). Interdental brush was also the hygiene method most significantly taken up by patients with full-arch implant-retained prostheses, in a study of the effects of oral hygiene instruction on patient habits, but oral hygiene levels were still poor overall (Kreve et al., 2016). Clinical outcomes following regular patient usage of interdental brushes are otherwise not yet reported in the literature.

1.4.2.2 Adjuncts and dentifrices

The use of antiseptics adjunctive to mechanical plaque control has also shown mixed results. Plaque and gingival indices improved with essential oil rinse (Ciancio et al., 1995) but not 0.12% chlorhexidine rinse (Truhlar et al., 2000), compared with which 0.06% chlorhexidine subgingival irrigation also demonstrated better results (Felo et al., 1997). Compared with control fluoride toothpastes, the use of a 0.3% triclosan-containing toothpaste significantly improved clinical parameters (Sreenivasan et al., 2011) and also mucositis despite no difference in plaque levels, reflecting an anti-inflammatory effect (Ramberg et al., 2009). The confounding factor of interproximal hygiene was not accounted for. All the studies described here received industry funding, which should be considered when interpreting their findings.

The 11th European Workshop on Periodontology concluded that the efficacy of powered toothbrushes, triclosan toothpaste and adjunctive antiseptics remain to be established, and that mechanical plaque control alone (professional and patient-performed) should be considered the standard of care in managing peri-implant mucositis (Salvi & Ramseier 2015).

1.4.2.3 Oral irrigators

Powered oral irrigators are becoming more widely available and industry-funded studies have investigated their use around implants. Plain water irrigation using a tufted tip at the gingival margin and interdentally around implants significantly reduced BOP, compared with string floss as adjuncts to brushing (Magnuson et al., 2013). However, baseline probing depths or diagnosis and associated outcomes were not reported. As described above, submucosal chlorhexidine irrigation reduced mucositis inflammation more than rinsing with a higher concentration (Felo et al., 1997). Again, the consideration of these studies should include their industry funding.

1.4.2.4 Interdental cleaning in the periodontal literature

Given the little evidence in the literature regarding interdental cleaning around implants, some of the relevant periodontal literature will be reviewed below.

The use of floss adjunctively to toothbrushing may have a statistically significant (Sambunjak et al., 2011) but clinically questionable effect in reducing gingivitis (Sälzer et al., 2015), and weak evidence has suggested that it reduces plaque at 1 and 3 months (Sambunjak et al., 2011). Although overall evidence supporting the use of floss was weak, individualised rather than routine flossing instruction has been recommended, particularly where "high-quality flossing is an achievable goal", and in locations where floss may be the only suitable tool (Sälzer et al., 2015).

Adjunctive triangular wooden toothpick use appears to significantly reduce BOP compared with toothbrushing alone (Barton & Abelson 1987; Caton et al., 1993; Finkelstein & Grossman 1984) although without any apparent reduction in plaque (Hoenderdos et al., 2008). Improvements in gingival health (BOP scores) were also found with water irrigation adjunctive to toothbrushing (Rosema et al., 2011) or regular oral hygiene habits in some studies (Flemmig et al., 1995; Flemmig et al., 1990; Newman et al., 1994), but no significant differences were found in others (Frascella et al., 2000; Walsh et al., 1989). Reductions in plaque have not been found (Flemmig et al., 1990; Rosema et al., 2011). However, interproximal areas are not readily visible, which may explain why plaque indices scoring visible surfaces did not show reductions while gingival parameters improved in these studies (Sälzer et al., 2015). Other proposed explanations include the effect of supragingival irrigation on pathogen populations, removal of soft deposits, reduction in plaque thickness, and the possible effect of water pulses in mechanically stimulating the gingiva or affecting subgingival host-microbial interaction (Rosema et al., 2011). Compared with flossing, oral irrigation reduced BOP scores significantly more after a 4 week period (Rosema et al., 2011).

Interdental brushes improved plaque removal when used in addition to toothbrushing (Jared et al., 2005; Kiger et al., 1991). When compared with flossing as an adjunct to toothbrushing, interdental brushes resulted in significantly better reduction in plaque index (Christou et al., 1998; Gjermo & Flotra 1970; Jackson et al., 2006; Kiger et al., 1991; Rosing et al., 2006), pocket depths (Christou et al., 1998; Jackson et al., 2006) and in a meta-analysis, gingivitis at one month (Poklepovic et al., 2013), although some studies showed no significant differences (Ishak & Watts 2007; Jared et al., 2005). Interdental brushes also showed better plaque removal than woodsticks (Gjermo & Flotra 1970).

Patients have shown a preference for interdental brushes over floss (Christou et al., 1998; Ishak & Watts 2007). This is an important consideration as cleaning efficacy is limited by patient ability and motivation rather than a particular method (Warren & Chater 1996). It has been noted that interdental brushes are the only tool able to reach interdental grooves and fissures, and this morphological variability, or different brush designs (Sälzer et al., 2015), as well as long-term outcomes and the link between specific instructions and subsequent compliance (Poklepovic et al., 2013) have yet to be significantly researched.

Given the available evidence, interdental brushes are currently the most effective interdental plaque control method (Sälzer et al., 2015; Slot et al., 2008).

1.5 Provision of implant hygiene instruction and maintenance services

There is little available in the literature as to which types of practitioners provide implant hygiene instruction or maintenance services to patients. The survey of patients with implants from the Swedish registry found that implant maintenance was performed by the patient's general dental practitioner in over 80% of cases, with 14-17% being performed by specialists and the remaining 3-4% not receiving any maintenance (Derks et al., 2015b). The other available publications primarily focus on specialists' preferences and experiences.

A survey of all periodontists and oral maxillofacial surgeons (OMFS) in New Zealand (Russell et al., 2014) found that 71% and 58% respectively acknowledged the role of the general dentist in preventing and diagnosing peri-implantitis. The specialists recommended that they themselves be referred cases for disease management, while periodontists placed greater emphasis on prevention in all areas and risk factors than did OMFS.

Periodontists in the USA (Papathanasiou et al., 2016), Australia and the UK (Mattheos et al., 2012) reported experiencing a prevalence of peri-implant mucositis and implantitis up to 25% in their patients, while predicting a higher prevalence in the general population. American periodontists favoured simple surgical debridement to treat peri-implantitis, choosing to perform regenerative or resective procedures less often, and also commonly performing surgical debridement for mucositis. A high proportion used systemic antibiotics, especially after peri-implantitis treatment but even for mucositis treatment (Papathanasiou et al., 2016). Australian periodontists used systemic antibiotics significantly more than their UK counterparts (Mattheos et al., 2012). In all three countries, combinations of amoxycillin or metronidazole were most commonly prescribed, and the urgent development of evidence as to appropriate systemic antibiotic usage in peri-implant treatment was recommended (Mattheos et al., 2012). Ultrasonic instruments (material not specified) were most popular in all three countries; this was followed by titanium, plastic and then stainless steel instruments in the USA and UK, while Australian specialists preferred stainless steel instruments. Compared with the current literature, there are some discrepancies evident in practice, particularly regarding systemic antibiotics and instruments for debridement. Most American periodontists believed peri-implantitis treatment to be moderately effective, and perceived treatment effectiveness increased with years of implant experience. After peri-implantitis treatment the majority of specialists in all three countries preferred a maintenance frequency of 3 months and radiographic evaluation of treatment after 6 months.

Little to no current information is available as to the preferences and involvement of general practitioners. A limited survey of 106 general dentists in the UK found that 66% believed general dentists should be involved in implant maintenance in 2004 (Gibson & Barclay 2006). There do not appear to be any studies evaluating the maintenance provision and preferences of dentists who do or do not provide implant therapy, which might be an important influencing factor.

Updated information is needed to better ascertain maintenance provision and referral patterns, and to understand and further develop inter-practitioner coordination and communication in this multidisciplinary field, particularly with regards to long-term implant care. There is a precedent for long-term multidisciplinary management in dentistry, in the area of hypodontia (Nunn et al., 2003), with long-term monitoring and maintenance in general practice (Hobson et al., 2003). Further, the concept of a designated care coordinator could be borrowed from the medical field to "fully assess needs, coordinate appointments, provide patient education, and bridge any gaps in patient–provider or provider–provider communication across disciplines" (Wiederholt et al., 2007).

When considering the potential role of auxiliary dental practitioners in implant maintenance, the most recent account of Australia's dental workforce in 2013 reported that "56 dentists, 5 dental hygienists, 3 dental therapists and 3 oral health therapists [were] employed per 100 000 people" (AIHW et al., 2016), while a survey of a random sample of Australian dentists in 2009 found that 62.2% did not employ any allied dental practitioners (Kempster et al., 2015). Surveys of service provision by auxiliary dental practitioners in Australia have not differentiated between periodontal-focused and implant-focused examination and OHI, and the provision of implant-specific maintenance and treatment of peri-implant pathology has not been reported. Nevertheless, in the provision of overall periodontal and preventive services, most auxiliary practitioners performed oral examinations and scale and clean, and gave oral hygiene instructions, in Australian (Teusner et al., 2016) and UK-based (Gibbons et al., 2000, 2001; Godson et al., 2009) surveys. Root debridement or periodontal maintenance were performed by less than half of auxiliary practitioners in Australia (Teusner et al., 2016).

One survey of implant maintenance practices of dental hygienists in the USA (Ward et al., 2012) investigated their preferences in clinical and radiographic assessment of implants, maintenance procedures provided, armamentarium and recall interval. No other surveys of auxiliary practitioners' implant-specific preferences appear to have been published.

1.6 Supportive periodontal therapy compliance and influencing factors

The compliance of patients, particularly those with dental implants, in attending supportive periodontal therapy (SPT) regimens, could be considered a realistic baseline of compliance to recommended implant maintenance intervals, and has been recently investigated in a few studies. In a 3-monthly supportive program following implant therapy completed at a private implant centre in Germany, high SPT attendance rates of 94.5% in the first year decreased to 86.6% after three years (Frisch et al., 2014). Compliance decreased significantly with greater geographical distance that the patient had to travel and peri-implant pocket probing depths significantly increased in patients with lower attendance, while patients with previous experience in a SPT program showed significantly better compliance in the first year. After 5 years of individualised supportive periodontal maintenance at a specialist periodontal clinic in Italy, 77.1% of 96 subjects were found to have complete SPT compliance, and of those who dropped out from regular maintenance, the large majority (81.8%) had done so by the end of the second year (Cardaropoli & Gaveglio 2012), a drop-out time similar to previous periodontal studies (Checchi et al., 1994; Mendoza et al., 1991). Implant patients who were smokers were found to be less compliant in a retrospective study (Monje et al., 2017b), in agreement with similar findings in a periodontal disease population (Ramseier et al., 2014). Compared with those who did not have dental implants placed as part of their treatment, patients who did had significantly higher compliance to SPT attendance (64.8% vs. 88.1% respectively) (Cardaropoli & Gaveglio 2012), as did those with a higher number of implants in the third year of the German study (Frisch et al., 2014). It is suggested that an “additive” procedure may increase patient motivation to return for SPT (Cardaropoli & Gaveglio 2012). More periodontal surgery has been shown variably to increase SPT compliance (Checchi et al., 1994; Mendoza et al., 1991) or have no effect (Cardaropoli & Gaveglio 2012); increased complexity of initial implant therapy did not affect compliance either (Frisch et al., 2014). The impact of a peri-implant pathology diagnosis and treatment on subsequent compliance is not known, and would appear to be the next logical area of investigation.

There are only a small number of studies into SPT compliance reporting on long-term periods of at least 5 years (Lee et al., 2015), which do not include implant patients. Definitions of acceptable compliance varied greatly from irregular attendance, to 66.7-100% attendance, or not extending the SPT interval, and are not necessarily comparable. In studies assessing complete attendance, a range of 36.2% (Costa et al., 2012) to 73.75% (Matuliene et al., 2010) of the cohorts did so, whereas 11.2% (Kim et al., 2014) to 87.5% (Ng et al., 2011a) attended satisfactorily in studies with a range of acceptable regular attendance. Mostly, compliance rates were low at 11-45%

(Fardal 2011). Private and hospital clinics both showed high and low compliance results. Rates of tooth loss were significantly increased in poor compliers (Costa et al., 2012; Kim et al., 2014; Matuliene et al., 2010; Ng et al., 2011a).

There are many factors which can explain these varied compliance rates, including but not limited to cultural, social, behavioural, economic and geographical factors, population mobility (Fardal 2011), general public health awareness (Wilson et al., 1993), dental fears or lack of satisfaction with treatment, age and gender (Demetriou et al., 1995; Novaes & Novaes 1999), and whether maintenance is carried out by general dentists or specialists (Mendoza et al., 1991).

Within the clinic environment, compliance has been improved with targeted appointment administration (flexible availability, future appointments, reminders), patient education about periodontal disease and the importance of maintenance, positive reinforcement techniques and staff education (de Carvalho et al., 2010; Wilson et al., 1993). However, complete compliance remained low even after the implementation of these behaviour modification techniques, improving from 16% to 32% in a private practice study (Wilson et al., 1993), and non-responders far outnumbered those amenable to behaviour modification (de Carvalho et al., 2010).

There is no current behavioural model to explain SPT non-compliance (Fardal 2011). Patients who rated their self-efficacy for self-care (attendance, brushing and diet) lower (Kakudate et al., 2010) and patients with higher periodontal disease risk profiles (Matuliene et al., 2010) also had lower compliance. Non-compliance is associated with a higher frequency of stressful life events and can involve psychological factors including “an individual's health beliefs, emotional intelligence, psychological stressors and personality traits” such as “high neuroticism and low conscientiousness” (Costa et al., 2011; Umaki et al., 2012). It is suggested that if clinicians increase their understanding of personality factors and associated health behaviours, non-compliance to periodontal maintenance may be more effectively predicted and pre-empted by using particular informational, motivational or reinforcement strategies (Umaki et al., 2012) or by enhancing self-efficacy (Kakudate et al., 2010). Whether these psychological factors and motivational strategies are different in implant maintenance is unknown and remain to be investigated.

1.7 Oral hygiene compliance

The other major factor requiring patient compliance in periodontal and peri-implant health is in the performance of oral hygiene at home. It may be surprising to find that there have been few surveys investigating the baseline frequency of oral hygiene methods or flossing in the general population. Adherence to professional recommendations is astonishingly low (Wilder & Bray 2016). The type and frequency of oral hygiene techniques performed by implant patients at home and further, any correlations to the condition of their peri-implant tissues and general level of oral hygiene are not known.

1.7.1 Community oral hygiene levels

While regular surveys of the oral health status and frequency of dental visits of Australians are conducted by Australian Institute of Health and Welfare, they do not measure the frequency of oral hygiene habits (either brushing or flossing). Baseline information on oral hygiene performance, at the individual, study or societal level would be useful in contributing to the continuing development of public health education and preventive programs.

A survey of nursing home residents in Victoria (Hopcraft et al., 2012) found that 21.2% of 263 subjects brushed twice daily, with 54.1% brushing once daily and the remainder less frequently. Those who needed assistance with oral hygiene were significantly less likely to brush twice a day. Another survey was conducted in an Adelaide hospital of post-natal women's understanding and practice of oral hygiene, with 91% of 388 subjects reporting brushing once or more a day, and 57% flossing once or more a week (Thomas et al., 2008).

It is clear that baseline information for the general population is very limited and greater data collection would be useful not least in being able to properly evaluate the findings for the groups being researched, as in the above studies, but in directing improvements in oral hygiene in Australia.

A study comparing patients in a hospital dental clinic and a private periodontal practice in the USA found that 13.5% flossed daily, with females and private periodontal patients significantly more likely to floss than males and hospital patients respectively (Segelnick 2004). Even though the periodontal patients would presumably be more aware of the need to floss, only 19.3% of them flossed daily. Interestingly, flossers were 20% more likely to floss around the teeth rather than just up and down; the basis for different technique recommendations is usually not specified in the literature.

Similarly, toothbrushing recommendations (technique, frequency, duration) from dental associations, dental textbooks and research-based sources, and commercial companies vary "unacceptably" and "should be a matter of concern for the dental profession and dental regulatory bodies", with a "surprising" lack of research in this area and an urgent need to compare brushing method effectiveness in order to develop guidelines (Wainwright & Sheiham 2014).

1.7.2 Oral hygiene instruction methods and effectiveness

As has been demonstrated, there is no established protocol in the literature regarding peri-implant hygiene performed at home, and little research therefore into the associated instruction methods or patient compliance, or the implant hygiene instruction preferences of practitioners. However, the existing literature on general oral hygiene instruction and compliance is likely comparable.

The ultimate aims of OHI and behaviour modification strategies, via increased patient compliance with hygiene techniques or frequency, are to improve hygiene performance and hence clinical gingival and periodontal health outcomes, which are more important than strict patient adherence to one regime or another. In research terms, compliance itself is therefore "a surrogate endpoint for change in behaviour in relation to gingival host response" (Htoon et al., 2007). However, the associated communication and behavioural issues are central in achieving clinical success.

In a consensus report from the 11th European Workshop on Periodontology, repetition of tailored OHI was recommended as the key component in maintaining gingival health (Tonetti et al., 2015). The fundamentals of OHI involve communication of information to the patient about their condition and treatment plan so that the patient desires to change their behaviour, individualised instructions and goal-setting, and continued positive reinforcement (Baker 1995). Compliance is increased with a lower complexity or frequency of hygiene procedures and greater convenience (Baker 1995). Active patient involvement and responsibility should be a goal (DiMatteo et al., 2002): communication of their concerns, self-image, and satisfaction with dental treatment assist in improving their compliance, whereas anxiety about dental care can have negative effects (Baker 1995). A team-approach, that considered dentists, peer teachers (trained dental assistant trainees) and patients as equal partners in planning, improved technique adherence significantly compared with education from dentists or peer-teaching alone (Reinhardt et al., 2012).

Varied modes of OHI delivery (one-to-one personalised instruction, self-education with manual, video) showed no clinical differences in one study (Lim et al., 1996), but individualised intra-oral demonstration to overcome a patient's particular skill deficits showed better results than standard written information or face-to-face instruction utilising a model in another (Harnacke et al., 2012). Additional written or visual medical instructions, particularly pictographs, are better remembered and adhered to than spoken advice only, while the addition of video or multimedia has mixed results (Kessels 2003); the latter may be useful in OHI, where intra-oral camera usage improved hygiene and compliance (Willershausen et al., 1999). It may be that clinical intra-oral demonstration of individual hygiene inadequacies and strategies to overcome them are most useful, particularly when "the greatest challenge is to develop effective interproximal care" (Armitage & Xenoudi 2016), but there are no studies available investigating this to date. The establishment of an internal locus of control is also very important (Galgut et al., 1987) and could be achieved by demonstrating the effects of the patient's own efforts without professional intervention (Ower 2003).

However, long-term behavioural changes generally have not been achieved with traditional hygiene education (Wilder & Bray 2016) and additional behavioural modification techniques have been developed and assessed. When psychological approaches to changing plaque management behaviour in periodontitis patients are compared with social cognition models in the psychology literature, the interventions have often been insufficiently described, or purport to adopt a particular approach while overlapping with other psychological models in implementation (Newton & Asimakopoulou 2015). For example, the unsuccessful use of a single short session of motivational interviewing (Brand et al., 2013; Stenman et al., 2012) was subsequently described as "at odds with the spirit and practice of Motivational Interviewing" (Newton & Asimakopoulou 2015). Nevertheless, the questions addressed in a motivational interview session aimed to increase self-awareness through directed patient-centred discussion and planning and may improve oral hygiene outcomes (Godard et al., 2011) especially when used over the longer term (Jonsson et al., 2006). The impact of whether the psychological intervention such as the interview session is provided by a dental practitioner (Godard et al., 2011; Jonsson et al., 2006) or a non-dental clinician e.g. counsellor (Brand et al., 2013) or psychologist (Stenman et al., 2012) is not known but may be significant.

It has been recommended that future research in this area should consider established taxonomies of behaviour change (Newton & Asimakopoulou 2015) and distinguish between patients who are in the motivational or volitional psychological stages (Renz & Newton 2009; Schuz et al., 2007), in order to better specify their interventions.

Overall, patient understanding of the benefits of behaviour change and the sequelae of periodontal conditions is related to better compliance, while interventions utilising goal-setting, planning, an oral hygiene diary, or self-assessment and feedback discussion in addition to traditional explanation and demonstration of oral hygiene methods have been effective in significantly improving clinical parameter outcomes (Fjellström et al., 2010; Jonsson et al., 2006; Newton & Asimakopoulou 2015; Philippot et al., 2005), particularly in patients who are already well-motivated (Renz & Newton 2009).

It must be noted that many of the follow-up periods in the published literature are very short, ranging from 1-12 months (Newton & Asimakopoulou 2015). Baseline oral hygiene methods may vary greatly, depending on social and cultural norms and periodontal disease histories of the study populations. Improvements in plaque score where patients were encouraged generally to brush, floss and use interdental aids, also cannot be directly compared with those where flossing was the main focus of improvement.

Self-efficacy is strongly predictive of oral hygiene behaviours and the removal of psychological and physical barriers are important in encouraging self-care (Buglar et al., 2010). An individualised 5-10 minute session of PreViser Risk Calculator assessment and discussion significantly improved patient reporting of self-efficacy, confidence in the effectiveness of periodontal treatment, perceptions of the seriousness of periodontal disease and intentions to adhere to periodontal management, compared with routine periodontal consultation and a general oral health question and answer session which did not discuss the risk of disease (Asimakopoulou et al., 2015). Changes in clinical outcomes remain to be seen with this intervention.

Interventions which have targeted flossing or interproximal cleaning adherence in addition to pre-existing oral care regimes in the periodontal literature may be the most relevant to performance of implant-specific oral hygiene. However, they have been limited to an oral hygiene lecture and questionnaire (Sniehotta et al., 2007), planning of when, where, how to floss including in the face of barriers (Schuz et al., 2006) or a flossing diary without a control group (Suresh et al., 2012), and the level of evidence is low. Interestingly, a hypnosis session was more successful than traditional OHI alone in initiating and maintaining a flossing habit (Kelly et al., 1988).

1.8 Patient knowledge and expectations

Patients' level of knowledge and sources of information on implant treatment and the oral hygiene needs of implants have been surveyed in various countries within the last decade. Awareness of dental implants as a tooth replacement option was found in 79% of a representative population sample in Austria in 2010 (Pommer et al., 2011a), 23.24% of 10,000 urban dental patients in India (Chowdhary et al., 2010), 27.7% of Turkish patients referred to a university dental hospital (Tomruk et al., 2014), 76.2% of patients attending Malaysian dental hospitals and private clinics (Kohli et al., 2014), and 66.4% of patients at dental hospitals in Saudi Arabia (Al-Johany et al., 2010).

In surveys performed more than 10 years ago, 77% of a sample of American adults (Zimmer et al., 1992), 70.1% of a representative sample of Norwegian adults in 1998 (Berge 2000), and 72% of a representative sample in Austria in 2001 (Tepper et al., 2003b) had heard of dental implants. The only available survey of an Australian-based population was published in 1993, with 63.8% of private dental patients being aware of implants compared with 27.3% of public dental hospitals patients (Best 1993), and patients' main source of information was the media. The latter was also the case for studies in the USA (Zimmer et al., 1992), Norway (Berge 2000) and Japan (Akagawa et al., 1988), but not in Austria (Tepper et al., 2003b) where dentists were the most common source.

Dentists were the most common first source of information on implants in most of the recently surveyed countries (Chowdhary et al., 2010; Pommer et al., 2011a; Rustemeyer & Bremerich 2007; Tomruk et al., 2014) except Saudi Arabia, where family and friends were a slightly more common source (Al-Johany et al., 2010). The internet is an increasingly common source of oral health information, for which concerns exist about its quality and the potential for misinterpretation by patients (Pommer et al., 2011a; Rustemeyer & Bremerich 2007).

When the Austrian participants were asked about their knowledge of the possible reasons for implant failure in 2001 and 2010, the proportions of respondents blaming the dentist significantly increased from 47% to 53%, and respondents blaming the patient themselves increased from 13% to 18%, while "allergies and incompatibilities" were cited by 49-51% and poor oral hygiene by 28-29% at both time points (Pommer et al., 2011a; Tepper et al., 2003b). Table 1.1 outlines patient expectations of implant durability in the Austrian, German and Turkish surveys, with a variable spread of respondents believing implants should last up to 10 years, 10-20 years, or over 20 years.

Table 1.1 Patient expectations of implant durability, in published surveys

Survey population	Up to 5 years	Up to 10 years	10-20 years	20 years and over
Austria 2010 (Pommer et al., 2011a) Representative of Austrian population	5%	27%	30%	24%
Austria 2010 (Hof et al., 2014) Prospective implant patients in a dental hospital	-	9%	31% (at least 10 years)	59% ("a lifetime")
Germany 2007 (Rustemeyer & Bremerich 2007) Prospective implant patients in clinical centres and oral surgery practices	-	3%	66%	12%
Turkey 2014 (Tomruk et al., 2014) Dental hospital patients	6.8%	26.8%	17.8%	33.0%

Awareness of the additional hygiene needs for implants had decreased from 46% in 2001 to 39% in 2010 in the Austrian studies, a significant change (Pommer et al., 2011a). Table 1.2 outlines patient expectations of oral hygiene requirements for implants, in the Austrian and German surveys, with about 50% believing requirements to be the same as natural teeth, and about 40% believing additional care is needed. Comparatively, in a multi-centre study In Hong Kong and China, 31.8% of prospective implant patients surveyed thought that dental implants needed less care than natural teeth (Yao et al., 2017).

Table 1.2 Patient expectations of oral hygiene requirements for implants, in published surveys

	Less care	Same as natural teeth	Additional care
Austria 2001 (Tepper et al., 2003b)	4%	44%	46%
Austria 2010 (Pommer et al., 2011a)	6%	49%	39%
Germany 2007 (Rustemeyer & Bremerich 2007)	7%	58%	31%

It appears that unrealistic expectations are widespread in the general community, especially concerning the functional and aesthetic outcomes of treatment (Yao et al., 2014) but also the oral hygiene needs and the expected survival of implants, particularly compared with their (un)willingness to pay higher costs (Rustemeyer & Bremerich 2007). This was confirmed in a study where patients described their initially high expectations of implant therapy and subsequent disappointment and expectation modification after developing peri-implantitis and being referred for specialist management (Abrahamsson et al., 2017). There is therefore a great need for dentists and the dental community to better "recognise their potential as an information source for their patients" (Best 1993), in order to pre-empt and correct misconceptions, improve general information dissemination and marketing of their implant services, and to set realistic patient expectation levels (Pommer et al., 2011a), with appropriate discussion of treatment alternatives, risks and oral self-care requirements (Abrahamsson et al., 2017).

1.9 Patient-reported outcomes, satisfaction and oral hygiene after implant treatment

There have been a few surveys, primarily in Europe, of patients' experiences during implant therapy and improvements in their comfort, function, aesthetic satisfaction and overall quality of life. It has been noted that there is great variation and non-standardisation in the scales used in published studies to measure patient satisfaction, from visual analogue scales to ad hoc scales and questionnaires. There is therefore limited validity, reliability and comparability of the findings, although most studies were randomised clinical trials with a potentially high level of evidence (McGrath et al., 2012). While some studies which performed baseline assessment have been published more recently, many prior to 2010 did not do so and therefore do not provide objective evidence of the patient-perceived benefits of the implant therapy. Psychometrically validated patient-reported outcome measure scales are available which can be appropriately amended for assessment of dental implants and their widespread use should be encouraged. Further, a distinction should be made between patient satisfaction, which reflects the treatment experience, and oral health status or quality of life assessments, which reflect the outcomes of therapy (McGrath et al., 2012). Most of the studies additionally assess only convenience samples of small size, with only the Swedish community study surveying randomly sampled implant patients with a wide range of implant treatment providers and experiences (Derks et al., 2015a), while another surveyed a representative sample of 1000 Austrian adults (Pommer et al., 2011b).

Studies with pre- and post-treatment assessment allow the best comparison and representation of patient perception of the outcomes of implant therapy. Patients' satisfaction scores with function and aesthetics after treatment have been found to greatly exceed their expectations (Baracat et al., 2011). Factors such as smoking, implant location, gender and education level did not affect aesthetic or functional expectations, while patients of increasing age had lower functional expectations. When differentiating between different implant therapies, patients who had received an implant-supported fixed partial denture had higher expectations before treatment than reported satisfaction afterwards with the aesthetic outcomes, while patients with single implant crowns had their expectations met (de Lima et al., 2012). Patients who received full-arch maxillary prostheses (whether fixed or removable) rated their self-esteem and quality of life, as well as aesthetics, comfort, function, speech and taste significantly higher after treatment was completed (Zitzmann & Marinello 2000).

Patients who have experienced implant therapy themselves have reported higher satisfaction ratings than the expectations of those who have not have implants but have heard second-hand

information from others, possibly due to the greater dissemination of negative impressions or experience during the immediate post-surgical or prosthodontic stage rather than reflections on fully integrated and functionally adapted prostheses (Tepper et al., 2003a). However, those without first-hand implant experience who reported their acquaintances were satisfied with their implants increased from 65% in Austria in 2001 (Tepper et al., 2003a) to 83% in 2010 (Pommer et al., 2011b), indicating an improvement in the public image of implant dentistry (Pommer et al., 2011b).

In the Swedish community-wide study of over 3000 randomly-selected patients with implants, 94% reported overall and aesthetic satisfaction, with ratings higher in the 65-74 age group compared with the 45-54 age group (Derks et al., 2015a). Patients who were treated by specialists were more likely to report aesthetic satisfaction and improved chewing ability, as did those who received more extensive reconstructions; however, the latter group also reported more complications. In the representative Austrian sample, 87-89% of patients with implants were satisfied with their function and aesthetics, including 70% who were very satisfied, significantly higher than 37% of patients who were very satisfied with their conventional fixed or removable dentures (Pommer et al., 2011b). Males were more frequently satisfied with aesthetics than females in both of these studies.

In follow-up studies of patients treated in a single clinic, usually a university or hospital department, over 90% of patients reported high levels of overall and aesthetic satisfaction after implant treatment (Kaptein et al., 1998; Pjetursson et al., 2005; Simonis et al., 2010; Vermylen et al., 2003). A strong correlation has been reported between a positive relationship with the clinician and the patient's satisfaction scores (de Lima et al., 2012), while patients were less discerning about aesthetic outcomes than the assessing clinicians (Tey et al., 2016; Vermylen et al., 2003). Removable maxillary implant-supported overdentures were rated significantly higher in general satisfaction compared with full fixed prostheses (Heydecke et al., 2003). Overall, patient reports of aesthetic satisfaction have been shown to be around 90%, and slightly lower for the adjacent mucosa, in a systematic review of studies utilising visual analogue scales (Wittneben et al., 2018).

Over 80% of patients in various studies have reported high satisfaction levels with function, chewing, speech and/or comfort (Pjetursson et al., 2005; Pommer et al., 2011b; Simonis et al., 2010; Tey et al., 2016; Vermylen et al., 2003). A lower 70% of patients rated their chewing function as improved in the Swedish community study (Derks et al., 2015a), and similar ratings were found after atrophic maxilla reconstruction and implant-retained prosthesis provision (Kaptein et al., 1998). Satisfaction ratings and quality of life with overdentures retained by two

implants has been found to be higher than conventional dentures, in both the mandible (Thomason et al., 2003; Wismeijer et al., 1997) and maxilla (Zembic & Wismeijer 2014).

Interviews with patients about their experience of tooth loss and eventual implant replacement revealed that increasing oral problems affected their well-being (self-esteem, shame, social isolation, eating problems), while facing up to the fact of tooth loss was often described as a "huge crisis period in their life", followed by acceptance. Often, the temporary prosthesis period was frustrating and affected their psychosocial life, and finally, implant therapy improved their chewing, aesthetics, and consequently their quality of life and psychological and social well-being (Johannsen et al., 2012). Personality factors such as agreeability and conscientiousness were positively correlated to patient satisfaction with implant appearance, comfort and performance following therapy, while neuroticism may be the best predictor of satisfaction ratings with significantly negative correlations overall (Abu Hantash et al., 2006).

Improved self-confidence was reported after implant therapy by 65% of patients in the Swedish community study (Derks et al., 2015a), while full-arch maxillary implant-retained prostheses (whether fixed or removable) significantly improved oral health-related quality of life (Zitzmann & Marinello 2000) and resolved problems with social isolation attributed to the patients' previous prostheses (Kaptein et al., 1998).

Although high cost was considered by some patients to be one of the main downsides to implant treatment (Johannsen et al., 2012; Pommer et al., 2011b), 74-95% of various patient cohorts considered the cost to be justified by the outcome (Pjetursson et al., 2005; Simonis et al., 2010; Tey et al., 2016; Vermylen et al., 2003), including 84.4% in the Swedish community survey (Derks et al., 2015a). Over 80% would recommend the treatment to others (Derks et al., 2015a; Pjetursson et al., 2005; Tey et al., 2016; Vermylen et al., 2003).

However, a recent study found subsequent further costs in the event of peri-implantitis development to be a barrier for patients, with not-insignificant costs already invested into the now unsuccessful implant and no guarantee of treatment success (Abrahamsson et al., 2017). The authors strongly recommended that dental practitioners consider the "psychosocial and emotional aspects" of severe peri-implant disease including patient stress, anxiety, guilt and/or shame, when assuring and managing these patients.

The self-rated ability of patients to perform oral hygiene around their implants has been investigated in a few studies, and varying majorities of 62% (Tey et al., 2016) and 94-95% (Pjetursson et al., 2005; Vermylen et al., 2003) of the respective cohorts reported that they could clean their implant well or were positive about the oral hygiene measures. However, 11-30%

reported that they needed more time or found it more difficult to clean their implant compared with their teeth (Pjetursson et al., 2005; Tey et al., 2016) or compared with their expectations from pre-operative discussion, although there was no pre-operative assessment reported and retrospective recall bias is likely (Kaptein et al., 1998). The understanding of the significance of soft tissue bleeding around the teeth and implants was found to be generally poor (Tey et al., 2016) but there do not appear to be any other reports on the adequacy of patients' implant hygiene knowledge after treatment. The ease of cleaning as well as general satisfaction and speech were rated significantly higher in patients who received removable maxillary implant-supported overdentures, compared with those who had full-arch fixed prostheses (Heydecke et al., 2003). Female patients performed oral hygiene significantly more often and for longer duration (Kaptein et al., 1998). In one study, the increased economic costs of hygiene supplies were accepted by 81% of the cohort (Kaptein et al., 1998). The specific oral hygiene measures recommended or performed around the implants in these studies are not reported and hence any correlations to clinical parameters of peri-implant health or pathology are not known.

No known surveys of patient-reported outcomes after implant therapy in Australia have been published.

Objectives of the thesis

As can be seen in this review of the literature, understanding of peri-implant diseases and maintenance is still in its infancy, yet millions of implants have and continue to be placed during this time. Current practitioner knowledge and clinical practice must be understood, in order to guide the continued development of teaching and learning in implant dentistry, to ultimately improve treatment outcomes and patient experiences.

The objectives of this thesis were therefore to:

1. Survey the implant treatment experiences of patients in private general dental practice in Australia, including patient-reported outcomes, their implant oral hygiene habits and clinical outcomes;

2. Survey the training, clinical experience and treatment preferences of Australian dental practitioners in implant dentistry;

3. Investigate Australian dental practitioners' provision of implant-specific oral hygiene instructions, implant review procedures and professional implant maintenance;

4. Investigate the teaching of peri-implant maintenance in Australian implant dentistry education programs;

5. Compare between the implant home hygiene and professional maintenance preferences of educators and practitioners, as well as with patient-reported oral hygiene performance, from the above surveys, to assess the flow of implant maintenance information from the literature to clinical realities in the Australian context;

6. Outline recommendations and future research directions regarding the role of oral hygiene practices and professional maintenance in preventing and managing peri-implant diseases.

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Chapter 2: Patient-reported oral hygiene and implant outcomes in general dental practice

A manuscript submitted to *Clinical Oral Implants Research*.

Abstract

Objectives: This study aimed to investigate patient-performed implant hygiene, patient-reported outcomes, peri-implant success and disease, in a community-based cohort.

Materials and methods: Fifty-one patients (78 implants) from two private general practices were surveyed on their dental implant treatment history, oral hygiene instructions (OHI) received, their home hygiene habits and any current implant concerns. Their dentition, implant clinical parameters, including current (within 1 year) radiograph assessment of crestal bone levels were examined. Peri-implant survival and peri-implant disease status were determined. Correlations between hygiene habits, risk factors, success and disease were assessed.

Results: Implants had a patient-reported mean time in function of 6.7 years. Adjunctively to toothbrushing, flossing (74.4%), interdental brush (44.9%) and mouthwash (39.7%) were most commonly reported, while 7.7% of implants were only cleaned by brushing. Over half (56.4%) of implants fulfilled the success criteria, 61.5% had peri-implant health, 24.4% had mucositis and 7.7% had peri-implantitis. Implants that were only brushed had significantly more peri-implant disease ($p<0.001$), while those without detectable plaque/calculus were significantly more likely to be healthy ($p<0.001$). Local prosthetic factors affecting cleaning accessibility significantly reduced implant success ($p<0.001$). Factors affecting success or disease were found to correlate in plaque- or prosthetic-related clusters. Patients reported mixed provision of implant OHI, that 7.7% of implants were aesthetically unsatisfactory, 9.0% had peri-implant symptoms and 2.6% were uncomfortable to clean.

Conclusions: Oral hygiene is critical in preventing peri-implant disease and implants should be easily cleansable. More effective and repeated OHI should be provided to patients and interproximal cleaning should be emphasized.

Introduction

Plaque-induced peri-implant disease is a biological complication that can occur around dental implants and includes peri-implant mucositis, marginal inflammation of the adjacent soft tissues without significant bone loss, and peri-implantitis, which also involves alveolar bone loss after initial healing (Renvert et al., 2018). These conditions have been reported in recent meta-analyses to have weighted mean prevalence at the patient level of about 45% for peri-implant mucositis, and about 20% for peri-implantitis (Derks & Tomasi 2015; Lee et al., 2017). Studies of peri-implant disease prevalence have mostly been conducted in university or specialist-based clinics (Derks et al., 2015), with only a few studies examining disease prevalence in community-based cohorts (Da Silva et al., 2014; Derks et al., 2015; Pommer et al., 2011; Vermylen et al., 2003).

Plaque is considered a primary aetiological factor in the development of peri-implant disease, with higher plaque levels at the implant (Canullo et al., 2016a; Costa et al., 2012; Ferreira et al., 2006; Roos-Jansåker et al., 2006) or lack of accessibility for cleaning the implant (Serino & Ström 2009) significantly associated with peri-implantitis. Patient-performed home hygiene is therefore a key component of peri-implant disease prevention (Heitz-Mayfield & Salvi 2018; Salvi & Ramseier 2015) but the efficacy of specific hygiene methods and their impact on peri-implant outcomes is not established (Louropoulou et al., 2014). The implant-specific oral hygiene instructions (OHI) given to patients in otherwise controlled studies of peri-implant disease management (Heitz-Mayfield et al., 2012; Riben-Grundstrom et al., 2015) is also rarely described. While some studies have compared clinical outcomes of powered and manual toothbrushes around implants (Swierkot et al., 2013; Truhlar et al., 2000; Wolff et al., 1998), interproximal cleaning methods have been inconsistent in these studies, and whether hygiene methods additional to toothbrushing have any impact has not been shown. Interdental brush (IDB) cleaning efficacy has been studied in a comparison of brush designs when applied by a hygienist (Chongcharoen et al., 2012) but there are very few studies of patient use. In a study where individualised implant OHI were given for full-arch implant-retained prostheses, IDB was taken up by patients at the highest rate compared to other hygiene methods, although clinical parameters did not improve overall (Kreve et al., 2016). Whether IDB, floss or variations on flossing e.g. thick floss with threader, circumferential flossing method (Chen & Darby 2003) are more effective in maintaining peri-implant health or managing peri-implant disease is not known.

Of the studies examining peri-implant outcomes in community-based cohorts (Da Silva et al., 2014; Derks et al., 2015; Pommer et al., 2011; Vermylen et al., 2003), only one reported patients' home hygiene habits (Vermylen et al., 2003) and did not investigate any subsequent correlation

to disease. Whether having a dental implant affects patients' oral hygiene behaviour is also unclear, as hygiene habits were reported to be largely unchanged in one study (Pjetursson et al., 2005), although having an implant has been shown to increase patient compliance to attendance at supportive periodontal therapy (Cardaropoli & Gaveglio 2012).

Prosthetic design and clinical execution can also affect peri-implant health, such as cemented prostheses showing greater rates of biological complications (Jung et al., 2012; Sailer et al., 2012) and peri-implant disease (Korsch et al., 2014; Linkevicius et al., 2013; Wilson 2009), particularly when incompletely seated (Chen et al., 2013). Oral hygiene accessibility is an important factor in peri-implant disease prevention (Serino & Ström 2009) and interproximal food impaction around implants has been documented in recent studies (Koori et al., 2010; Wang et al., 2016; Wong et al., 2015). Plaque-retaining features may also be present in different locations (e.g. multi-unit, cantilever or splinted prostheses, prosthesis to abutment margin, abutment to fixture margin).

Surveys of patients' implant experiences have previously investigated patient satisfaction with function and aesthetics (Baracat et al., 2011; Derks et al., 2015; Pjetursson et al., 2005; Pommer et al., 2011; Simonis et al., 2010; Tey et al., 2016; Vermylen et al., 2003; Zitzmann & Marinello 2000), and less commonly, self-rated ease of oral hygiene (Pjetursson et al., 2005; Tey et al., 2016; Vermylen et al., 2003). Again, only a few have surveyed community-based cohorts.

This cross-sectional study therefore aimed to investigate patients' oral and implant hygiene habits, their implant treatment and OHI histories, and evaluate the implant outcomes (clinical parameters, implant success, peri-implant disease prevalence, patient-reported concerns) of a community-based patient cohort. The study aimed to identify possible correlations, trends, risk factors and shortcomings as well as further areas of clinical research and practical implications in the field of implant dentistry.

Materials and methods

This cross-sectional study involved patients from two private general practice clinics in Sydney, Australia who were known to have pre-existing completely restored dental implants. They were recruited via mail invitation, waiting room advertisement, or on attending a routine recall appointment with one of the investigators (MC). Any patient who had had their implant treatment completed by the examiner, and pregnant women for whom radiographic examination might be needed, were excluded. Patients who fit the inclusion criteria and attended an appointment with investigator MC between November 2015 and May 2017 were

enrolled consecutively in the study, upon their consent. Participants agreed to complete a questionnaire and undergo a clinical examination. A prize draw to encourage participation was conducted. Ethics approval for this study (Ethics ID 1443625) was granted by the Health Sciences Human Ethics Sub-Committee of the University of Melbourne.

All questionnaires and clinical examinations (Appendix I) were administered by one examiner (MC). The subjects completed a paper questionnaire, providing information about their background demographics, medical and dental history, oral hygiene habits in general, implant treatment history and any subsequent problems, recollection of implant-specific OHI received, and their ongoing maintenance routine. Any necessary clarifications were made immediately by the examiner.

Clinical examination of the patients' dentition in general (teeth, soft tissues, restorations, periodontal disease status, O'Leary plaque control index – the percentage of tooth surfaces with plaque detected using disclosing solution, six surfaces per tooth (O'Leary et al., 1972)) and their implant(s) (visual assessment, bleeding on probing, pocket depths, Mombelli modified gingival index (Mombelli et al., 1987), suppuration, keratinised mucosa around the implant, mucosal recession, prosthetic gaps or local factors affecting accessibility for cleaning) was performed. If no periapical radiograph of the implant from within the previous 12 months was available for bone level assessment, then a new radiograph was taken. The vertical distance from the implant platform to the level of bone-implant contact was measured and fixture depth, prosthetic fit and interproximal embrasure shapes (between the contact point and crestal bone, mesially and distally) were assessed on the radiographs. During the examination patients were also asked about their implant-specific hygiene habits and any current symptoms or concerns, including aesthetic concerns.

Implant success was determined according to criteria described by Karoussis et al. (2004):

- Absence of mobility;
- Absence of persistent subjective complaints (pain, foreign body sensation, and/or dysaesthesia);
- No PPD > 5 mm;
- No PPD = 5 mm and bleeding on probing (BOP);
- Absence of a continuous radiolucency around the implant (Buser et al., 1990);
- After the first year of service, the annual vertical bone loss should not exceed 0.2 mm.

The presence of any of these findings deemed an implant to be unsuccessful.

Diagnosis of peri-implant health, mucositis or peri-implantitis was determined according to the latest recommendations for standardised criteria in implant research by Renvert et al. (2018):

- Peri-implant health – absence of visual inflammation; lack of profuse (line or drop) bleeding on probing; and absence of further bone loss following initial healing, which should not be ≥2mm
- Peri-implant mucositis – visual inflammatory signs; profuse bleeding and/or suppuration on probing; and absence of bone loss beyond initial crestal bone remodelling
- Peri-implantitis – visual inflammatory signs; profuse bleeding and/or suppuration on probing; and bone level ≥3mm from the implant platform, or bone loss ≥2mm after initial crestal bone remodelling and/or probing depth ≥6mm

Implants which lacked inflammation at the time of examination but showed bone loss ≥2mm after initial remodelling were excluded from analysis between healthy, mucositis and peri-implantitis groups, as they did not fit the above diagnostic criteria. Data were described and correlations between implant outcomes and variables were assessed. At the patient level, medical history (age, smoking), dental history (periodontal disease status, regularity of dental attendance, whether patients recalled having their implant(s) checked during recall appointments, history of failed implant, history of peri-implant soft tissue complication, number of implants, O'Leary plaque control index) and implant hygiene (brushing only, flossing, other interdental cleaning methods, presence of plaque/calculus at the implant) risk factors were compared with each patient's most severe peri-implant health/disease and success finding, to assess the influence of known risk factors.

At the implant level, these same factors, as well as implant history (reported years in function, whether the implant was surgically placed or restored by a general dental practitioner or a specialist, whether implant OHI was received on implant completion or any time subsequently, whether the implant was completed in Australia or elsewhere) and local implant factors (presence of keratinised mucosal margin, screw or cement retention of prosthesis, single crown or multi-unit prosthesis, any local factor affecting cleaning accessibility, deep fixture position, presence of natural mesial/distal embrasure shape) were compared to implant outcomes to assess their influence.

Possible associations between known risk factors and variables found to be positively correlated to implant outcomes, were also examined at the implant level. The statistical software SPSS version 23.0 (SPSS, Chicago IL, USA) was used for data analysis, using Pearson's Chi-squared tests to compare between categorical variables, Pearson correlation to compare between two continuous variables and independent sample t-tests to compare the means of two groups ($p<0.05$). This study was conducted in compliance with the STROBE guidelines for cross-sectional studies.

Results

Patient-reported medical and dental history:

Fifty-one eligible subjects with 78 pre-existing dental implants with completed prostheses gave their consent to be enrolled in the study, of whom 51.0% were female (n=26) and 49.0% male. The subject group had a mean age of 56.6 years (SD=14.2 years, range 25-84 years). Four subjects (7.8%) smoked cigarettes daily, averaging 9.0 (SD=4.6) per day.

When asked to rate their dental treatment history as minimal, average or extensive, 33.3% of the subjects considered their history average and 62.7% extensive. On the day of examination, 15.7% of the group reported that they have periodontal disease and 5.9% recalled a family history of periodontal disease. Almost all subjects (96.1%) reported regular dental attendance (92.2% attending at least 12-monthly, 3.9% 18-24 monthly), while the remainder attended only when they had a problem.

Patient-reported home hygiene:

The oral hygiene habits performed by the subjects at home, the average reported frequency, and methods specifically used to clean their implant(s) are shown in Table 2.1. At the implant level, 7.7% of implants were reported by subjects to be brushed only, while regular flossing (77.4%), interdental brush (IDB) (44.9%) and mouthwash (39.7%) were the most common additional techniques.

Table 2.1 Home dental hygiene habits and mean performance frequency at subject level (n=51) and implant-specific hygiene at implant level (n=78)

Home hygiene method	Performed in general at subject level (n=51)	Mean times (SD) performed per day by subjects using the method	Performed regularly for each implant (n=78)
Toothbrushing	100.0%	2.0 (0.4)	7.7% (only cleaned with brushing)
Regular flossing	76.5%	1.1 (0.7)	74.4%
Interdental brush (IDB)	43.1%	1.5 (0.7)	44.9%
Superfloss™	13.7%	0.6 (0.4)	9.0%
Circumferential floss	33.3%	0.7 (0.5)	24.4%
Mouthwash	35.3%	1.4 (0.8)	39.7%
Oral irrigator	5.9%	1.3 (0.8)	9.0%

Patient-reported implant history and outcomes:

The reasons for tooth replacement that patients reported for each implant are shown in Table 2.2. The most common causes were tooth decay and failure of endodontically treated teeth, which were also commonly fractured or had a history of trauma.

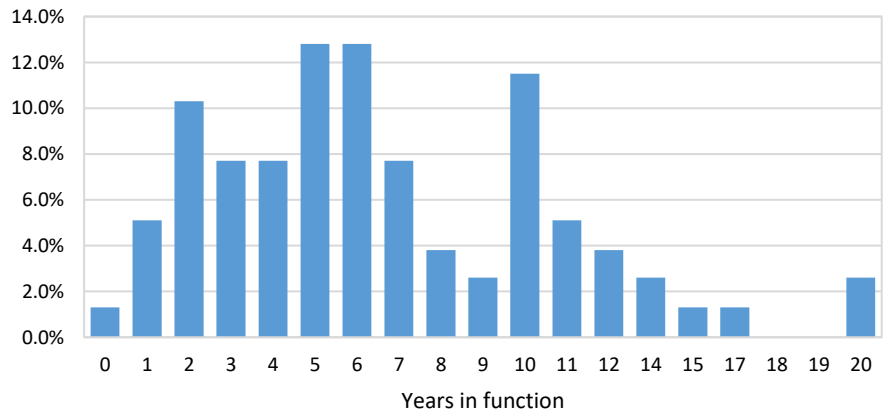
Table 2.2 Reasons for tooth replacement (multiple causes permitted) reported by patients, at implant level (n=78)

Tooth decay	25.6%
Endodontic failure	17.9%
Tooth fracture	15.4%
Trauma history	12.8%
Failed single crown	11.5%
Failed fixed partial denture	10.3%
Periodontal reason	6.4%
For implant-retained full-arch or other occlusal reconstruction	6.4%
Aesthetic reasons	5.1%
Congenitally missing	3.8%
Unknown	1.3%

Regarding practitioner type, subjects recalled that dental specialists performed implant surgery for 60.3% of the implants while general dental practitioners (GDPs) restored 53.8% of the implants. The 39.7% of implants in the sample which were placed and restored by GDPs consisted of 19.2% provided by the patient's regular GDP and 20.5% provided by another GDP with a special interest in implant treatment. Most implants (84.6%) were placed and restored in Australia and the remainder in other countries.

Using patient-reported estimates, the implants in this study had a mean of 6.7 years in function (SD=4.3 years, range 0-20 years, Figure 2.1), which was positively correlated to patient age (p=0.032, r=0.243). Subjects recalled that OHI was given specifically for each implant at the time of implant completion for 53.8% of implants, which included 21.8% given OHI by the GDP providing implant treatment, 29.5% by the specialist and 2.6% receiving OHI from both. Any subsequent OHI that subjects remembered was given by a GDP for 51.3% of the implants and by a periodontist for 6.4%, while 42.3% of implants did not have additional OHI that patients could recall. For 11.5% of the implants, OHI was not recalled to have been given either at treatment completion or subsequently.

Figure 2.1 Patient-reported implant years in function (implant level, n=78)



Most patients (84.3%) recalled having their implant(s) checked during their regular recall appointments, while 19.6% reported separate routine appointments specifically to check their implant(s) (2.0% with a general dentist, 17.6% with a specialist). One in seven patients (13.7%) did not recall having their implant(s) checked at either regular recall or implant-specific review appointments.

When asked about any complications with their dental implant(s), three subjects (5.9%) reported a history of having had a failed implant. Eleven subjects (20.4%) reported previous complications with their existing implants. This included five subjects (9.8%) who reported a history of a soft-tissue (biological) complication around their implant(s) requiring treatment, involving 8 implants (10.3%), and 7 subjects (13.7%) who reported a history of a prosthetic complication, involving 7 implants (9.0%). At the implant level, prosthetic issues were recalled by subjects to have occurred at a mean of 3.5 years (SD=2.8 years, range 1-9 years) and soft-tissue complications at a mean of 4.4 years (SD=2.9 years, range 1-10 years).

At the time of examination, three subjects (5.9%) reported a soft tissue aesthetic issue involving 6 implants (7.7%). Seven subjects (13.7%) reported peri-implant symptoms involving 7 implants (9.0%), including “tenderness” or “sensation” in the gum, food impaction and the implant feeling “too forward”. Two subjects (3.9%) reported pain or discomfort when cleaning two implants (2.6%).

Dental examination findings and peri-implant outcomes:

The subject group had a mean O’Leary plaque control index of 63.4% (SD=17.6%, range 28.0-100.0%). The majority of subjects had no current or previous periodontal disease (74.5%), while 15.7% had a reduced but healthy periodontium and 9.8% had at least one periodontal pocket of ≥4mm.

Over half (58.8%) of the subjects had one implant, 31.4% had two, 7.8% had three and 2.0% had four implant fixtures. Two thirds (66.7%) of the implants were restored with single crowns, 29.5% were part of a multi-unit fixed prosthesis and 3.8% had ball-caps for retaining a removable overdenture (at the time of examination, the case involving the overdenture abutments had been recently converted from retaining a cemented full-arch fixed prosthesis). Prostheses were retained by direct screw to fixture in 53.8% of implants, cement in 39.7% and cross-pin in 2.6%.

The prevalence of some common clinical parameters are shown in Table 2.3. Of the implants with inflammatory bleeding on probing (29.5%), this included a Mombelli modified gingival index (mGI) of grade 1 (17.9%), grade 2 (10.3%) and grade 3 (1.3%), with a mean mGI of 0.4 (SD=0.7, range 0-3).

Table 2.3 Prevalence of clinical parameters at implant level (n=78)

Visual soft tissue inflammation	10.3%
Non-keratinised	16.7%
Inflammatory bleeding on probing (BOP)	29.5%
Suppuration	3.8%
Plaque or calculus present	41.0%
Probeable fixture threads	15.4%
Visible fixture threads	11.5%

Radiographic bone loss was defined as any loss greater than the expected initial crestal bone remodelling appropriate for each implant system/type and was found in 41.0% of implants (Table 2.4). Bone loss of ≥2mm after initial crestal bone remodelling was found in 13.0% of implants. The implants had a mean estimated bone loss of 0.8mm (SD=1.2mm) ranging from 0-4.5mm; among the 41.0% of implants with bone loss, the mean estimated bone loss was 1.9mm (SD=1.1mm).

The mean probing pocket depth (PPD) of each implant (6 sites per implant) ranged from 0.5-4.7mm, at an average of 2.2mm (SD=0.7mm) across the sample. When considering the deepest PPD of each implant, the mean deepest PPD across the sample was 3.2mm (SD =1.1mm, range 1-6mm). Only one implant demonstrated recession (2mm) as well as visible fixture threads, while 6 implants (7.7%) had a more apical mucosal margin compared to the contralateral or adjacent teeth, ranging from 1-5mm (mean 3.2mm, SD=1.7mm). Eight more implants demonstrated visible fixture threads but their mucosal margins were not more apical than the contralateral or adjacent teeth.

Table 2.4 Frequency of estimated bone loss depths at implant level (n=78)

Estimated bone loss (mm)	Percentage
0	59.0%
0.5	6.4%
1.0	14.1%
1.5	7.7%
2.0	2.6%
2.5	2.6%
3.0	2.6%
3.5	1.3%
4.0	2.6%
4.5	1.3%

The prevalence of local prosthetic factors that may affect plaque retention, ease of cleaning or accessibility are shown in Table 2.5. At least one of these factors was found in 64.1% of implants. Radiographically, 3.8% of implants had a detectable gap between the fixture and abutment and 14.1% had a deep fixture position (notably more apical compared to contralateral or adjacent

teeth). One-third of implants (30.8%) were classified from radiographs as having interproximal embrasure shapes similar to natural teeth while the remainder had at least one embrasure that was not naturally shaped.

Table 2.5 Frequency of local and radiographic-detected prosthetic factors at implant level (by %, n=78)

	Percentage	
Local prosthetic factor affecting cleaning		**Implants with any of the local factors affecting cleaning**
Gap between abutment and crown	20.5%	64.1%
Ridge lap prosthesis (bucco-lingually)	10.3%	
Overcontoured or cantilevered pontic (mesio-distally)	24.4%	
Splinted crowns or implant bridge	33.3%	
Open contact point	7.7%	
Radiographically-detected prosthetic factor		
Deep fixture position	14.1%	
Gap between fixture and abutment	3.8%	

According to the success criteria outlined by Karoussis et al. (2004), 51.0% of subjects had all their implant(s) meet the success criteria, while at the implant level 56.4% met the success criteria.

According to the diagnostic criteria outlined by Renvert et al. (2018), 52.9% of subjects had all healthy implants, 33.3% had any implant(s) with mucositis at worst and 7.8% had any implant(s) with peri-implantitis. At the implant level, 61.5% of implants had peri-implant health, 24.4% had mucositis and 7.7% had peri-implantitis. A small number of implants (6.4% of implants in 5.9% of patients) demonstrated no signs of inflammation yet had ≥2mm bone loss and were not included in the above peri-implant status groups or subsequent analysis between groups.

Impact of patient-reported hygiene, implant history, age, years in function on peri-implant outcomes:

Whether an implant was reportedly only brushed (p=0.001) or was not flossed (p=0.026) significantly affected peri-implant health status at the implant level, especially between health and peri-implantitis (Table 2.6). Being cleaned by brushing alone was also significantly associated with peri-implantitis over mucositis (p=0.009). The other interdental cleaning methods (IDB, circumferential flossing, superfloss, oral irrigation) and mouthwash did not correlate to peri-implant status.

Peri-implant health was significantly correlated to the absence of plaque/calculus at the implant level (p<0.001) (Table 2.6). At the implant level, a history of a failed implant (p<0.001) or a history

of a soft-tissue complication (p=0.005) significantly affected peri-implant health status overall and were significantly associated with peri-implantitis.

Table 2.6 Significant factors impacting implant success (n=78), health/mucositis/peri-implantitis status (n=73) at the implant level.

	Implant success	Healthy vs mucositis vs peri-implantitis	Healthy vs mucositis	Healthy vs peri-implantitis	Mucositis vs peri-implantitis
Years in function	**0.007**				
Age at time of exam				**0.020** (95% CI: 2.3-26.2 years older)	
Previous history of soft tissue complication (n=8)		**0.005**		**0.001**	**0.035**
History of other failed implant (n=5)		**<0.001**		**<0.001**	**0.009**
Plaque/calculus present (n=32)		**<0.001**	**<0.001**	**<0.001**	
Implant brushed only (n=6)		**0.001**		**<0.001**	**0.009**
Implant not flossed (n=20)		**0.026**		**0.01**	
Crown retention by cement (n=34)				**0.042**	**0.026**
Implant with multi-unit prosthesis (n=26)					**0.016**
Gap at abutment to crown (n=16)	**0.004**				
Any local factor affecting cleaning difficulty (n=50)	**<0.001**			**0.038**	

p values <0.05 shown

More severe pathology at the implant level was associated with older patient age, reaching significance when comparing healthy (average age 57.6 years) and peri-implantitis (average age 71.8 years) groups (p=0.020), with the mucositis group averaging 58.3 years. While older patient age was correlated to higher reported years in function, the latter showed only a trend with peri-implant disease status that was not statistically significant (the healthy group averaged 6.6 years, the mucositis group 7.0 years and the peri-implantitis group 7.3 reported years in function). Implants that were unsuccessful had significantly lower reported years in function (5.4 years) compared to successful implants (7.8 years) (p=0.007, 95% CI: 0.7-4.2 years less).

Correlations between risk factors:

At the implant level, several factors were correlated strongly in implants with peri-implant pathology although multiple logistic regression analysis was not possible due to the small sample size. These were: history of a failed implant, previous soft-tissue complication requiring treatment, older age of the patient, implant only cleaned with brushing, implant not flossed, and presence of plaque/calculus (Table 2.7).

Additionally, implants with a history of a soft-tissue complication were significantly more likely to have been surgically placed by a GDP (22.6%) rather than a specialist (2.1%) (p=0.004), to have been restored by a GDP (19.0%) rather than a specialist (0.0%) (p=0.006) and to have a deep fixture position relative to the adjacent or contralateral teeth (45.5% deep position vs 4.5% not deep, p<0.001) (Table 2.7).

Table 2.7 Significant comparisons between factors significantly correlated to outcomes in this study (columns) and other variables (rows) at implant level (n=78 if not otherwise indicated).

	History of other failed implant (n=5)	**Previous history of soft tissue complication (n=8)**	**Plaque/calculus present (n=32)**	**Implant only brushed (n=6)**	**Implant not flossed (n=20)**	**Crown retention by cement (n=34)**	**Implant with multi-unit prosthesis (n=26)**	**Gap at abutment to crown (n=16)**	**Any local factor affecting cleaning difficulty (n=50)**
Years in function									
Age at time of exam	**0.007** (95% CI: 5.2-31.2 years older)	**<0.001** (95% CI:8.8-21.0 years older)	**0.021** (95% CI:1.2-14.3 years older)		**0.019** (95% CI: 1.5-16.2 years older)		**0.003** (95% CI:3.1-2.9 years older)		
Smoking (n=4)									
Patient's current periodontal condition - no periodontal history (n=55), reduced healthy periodontium (n=15), deep pocket present (n=8)									
History of other failed implant (n=5)		**<0.001**	**0.006**	**<0.001**	**0.004**				
Previous history of soft tissue complication (n=8)	**<0.001**			**0.001**					
Implant(s) not checked during routine checkup (n=12)					**0.036**				
Restored by GDP (n=42) or specialist (n=36)	**0.032** restored by GDP	**0.006** restored by GDP							
Surgery by GDP (n=31) or specialist (n=47)		**0.004** surgery by GDP							
OHI received when treatment completed (n=42)									
Any OHI received when completed or later (n=69)									
Implant done in country other than Australia (n=12)						**<0.001**	**0.008**	**<0.001**	**0.030**
Non-keratinised mucosa (n=13)									**0.020**
Plaque/calculus present (n=32)	**0.006**								
Crown retention by cement (n=34)							**0.006**	**<0.001**	**0.003**
Implant with multi-unit prosthesis (n=26)						**0.006**		**<0.001**	
Gap at abutment to crown (n=16)						**<0.001**	**<0.001**		
Any local factor affecting cleaning difficulty (n=50)						**0.003**			
Deep fixture (n=11)		**<0.001**							

p values <0.05 shown

Comparing implant hygiene habits at the patient level, patients who recalled having their implant(s) checked during routine recall appointments were significantly more likely to floss their implant(s) (p=0.033). Older patients were more likely to use an irrigator (p=0.021, 95% CI: 6.1-27.8 years older) (at the implant level, implants with splinted prostheses or which were not flossed were more likely to be present in older patients). At the implant level, shorter reported time in function was correlated to implants that were cleaned with IDB (a mean 5.6 years vs 7.7 years if not cleaned with IDB, p=0.020, 95% CI: 0.4-4.0 years less) while a similar trend for implants that were flossed (6.3 years vs 8.0 years if not flossed) was not statistically significant. No other correlations were found for other implant hygiene habits and other risk factors.

Impact of local hygiene accessibility on peri-implant outcomes:

The presence of any local prosthetic factor affecting cleaning accessibility significantly reduced implant success (58.0% unsuccessful vs 17.9% without any of these factors, p<0.001) (Table 2.6) and trended towards more severe pathology but only reached significance between the healthy and peri-implantitis groups (p=0.038). A detectable gap between the crown and abutment was itself also a significant factor corresponding to lower implant success (75.0% with a gap were unsuccessful vs 35.5% without a gap, p=0.004). Implants with crowns that were cemented (p=0.026) or splinted (p=0.016) were more likely to have peri-implantitis than mucositis.

Correlations between risk factors:

Several prosthesis-related factors were correlated strongly in unsuccessful implants although multiple logistic regression analysis was not possible due to the small sample size. These were: cement-retained prosthesis, multi-unit prosthesis, having an abutment-crown gap, having any local factor affecting cleaning accessibility, implant having been done in a country other than Australia (Table 2.7).

Other trends:

Some other risk factors and variables showed trends in implant success or peri-implant status that were not statistically significant. Implants in patients with any deep periodontal pockets were more likely to have mucositis while implants in patients with a reduced healthy periodontium had more peri-implantitis, but overall, periodontal disease history showed no clear correlation to peri-implant disease or the presence of plaque/calculus. Implants with a close to natural embrasure shape mesially and distally had a higher success rate (66.7% vs 51.9% with any irregular embrasure shape) but showed no correlation to peri-implant health/mucositis/implantitis. At the patient level, those with more severe pathology tended to

have higher average O'Leary plaque control scores and were of older age, though not statistically significant.

Generally, gender, smoking, whether OHI was given at the time of implant completion or any time subsequently, and presence of keratinised mucosal margin did not show any correlation to implant success or peri-implant diagnoses, or any correlations to the significant risk factors found in this study. The presence of plaque/calculus at the implant was not significantly associated with any factors apart from older patient age and a history of a failed implant (Table 2.7).

Discussion

Patient cohorts surveyed on their implant treatment experiences and outcomes have mostly been drawn from "convenience samples" in university or specialty clinics (Derks et al., 2015) while cohorts from the general community have only rarely been surveyed (Derks et al., 2015; Pommer et al., 2011; Vermylen et al., 2003). This study investigated a community-based private practice patient cohort in Australia.

The oral hygiene habits of patients with implants is rarely reported in the literature. Reported regular flossing (76.5% of patients) was higher in this study than the 45% found in a study of 40 private practice patients with implants (Vermylen et al., 2003), while reported IDB use was similar at about 40%. In this study, reported flossing around implants was also significantly correlated to whether patients recalled their implants being checked during regular recall, perhaps due to the feeling of greater oversight, or a similar phenomenon to patients with implants having greater compliance to periodontal maintenance (Cardaropoli & Gaveglio 2012).

Surveyed aspects of the patient experience vary widely in the literature, and in this study, patient reports of peri-implant history, OHI history and current peri-implant status were emphasized. Self-reported reasons for implant replacement of teeth were similar to other studies, where endodontic failure, tooth fracture, caries, trauma and aplasia are commonly reported main reasons (Avivi-Arber & Zarb 1996; Henry et al., 1995; Jemt et al., 1991; Krennmair et al., 2002; Priest 1999).

The 5.9% of patients in this study who were less than satisfied with the aesthetics of their implant treatment was similar to the 4.4-7% found in community or general practice cohorts (Derks et al., 2015; Pommer et al., 2011) and 3-8.7% in university/specialist-based cohorts (Pjetursson et al., 2005; Simonis et al., 2010; Tey et al., 2016; Vermylen et al., 2003) in the

literature. This study found that 20.4% of patients recalled a biological and/or prosthetic complication, a lower figure than the 31% reported in a study of 3827 patients drawn from the Swedish implant registry (Derks et al., 2015), and this metric is little documented elsewhere. Patient-reported discomfort around the implant or on performing implant hygiene is also rarely reported, with 13.7% reporting discomfort in this study, a small but notable proportion.

In this study, the rates at which patients recalled receiving implant OHI at the implant level appeared to be less than ideal, with 53.8% recalling it from the time of implant completion, 42.3% not recalling any subsequent OHI, and 11.5% not recalling any OHI at all, but whether patients did not remember or OHI was not provided cannot be estimated. Patient recall of implant OHI received is rarely reported, and instructions given may not translate to patient knowledge or hygiene methods performed in any case. This was apparent in this study's results, as peri-implant disease outcomes correlated to reported hygiene habits but not to whether any implant OHI was received, and implant-specific hygiene knowledge levels were mixed in this study's cohort of regularly attending patients. Perhaps patients' oral hygiene habits and levels prior to implant treatment have an impact not just on implant failure rates (van Steenberghe et al., 1993) but possibly peri-implant pathology. A 10-year follow-up study of 104 implant patients concluded that three-quarters of them did not make any major changes to their oral hygiene habits after implant therapy (Pjetursson et al., 2005). There are implications for careful hygiene assessment by clinicians when considering implant therapy, or else OHI efficacy needs to be improved. For the latter, in addition to the traditional importance of repeated individualised OHI in periodontal prevention (Tonetti et al., 2015), hygiene compliance in periodontal disease patients is improved when they understand possible benefits and disease sequelae, while clinical hygiene parameters are improved when goal-setting, hygiene diary, self-assessment or feedback discussion methods are used (Newton & Asimakopoulou 2015). Clinical outcomes using promising tools such as the PreViser Risk Calculator in patient discussion (Asimakopoulou et al., 2015) are yet to be reported. Whether these tools and strategies are applicable to peri-implant disease prevention has not been shown. Hence the challenges of long-term OHI communication and current best practices for behaviour change should be emphasised in implant education programs for practitioners, as there may be much room for improvement in patient-performed implant hygiene and peri-implant disease outcomes as a result.

Implant success rates in the literature depend greatly upon the criteria used in each study (Papaspyridakos et al., 2012). Compared to other studies (university/specialist-based) using the same criteria by Karoussis et al. (2004), this study's success rate of 56.4% after a mean 6.7 patient-reported years in function is similar to the success rates reported in the original studies using this criteria (59.4% to 79.1% after 10 years depending on periodontal disease history and

implant design (Karoussis et al., 2004; Karoussis et al., 2003), while other recent studies using this success criteria have reported success rates of 51-90% (Apostolopoulos & Darby 2016; Bazrafshan & Darby 2014). One study of patients in a private general practice research network reported a success rate of 81.3% after a mean 4.2 years (Da Silva et al., 2014) when using the criteria by Albrektsson et al. (1986), concluding it to be lower than studies in specialist/university settings. In the current study, implant success was significantly correlated to a longer mean time in function, perhaps an unexpected result compared to the positive correlation found in meta-analysis between years in function and peri-implantitis prevalence (Derks & Tomasi 2015). However, success considers patient-reported symptoms where the disease criteria do not, and symptomatic implants having a shorter mean time in function in this study (although not statistically significant) may explain the finding. Comparisons of implant success to time in function are rarely reported.

The diagnostic criteria for reports of peri-implant health and disease prevalence again vary widely in the literature (Renvert et al., 2018). The recent consensus criteria outlined by Renvert et al. (2018) was used in this study to allow future standardised comparison. This study's findings of mucositis (24.4%) and peri-implantitis (7.7%) prevalence at the implant level were similar to weighted mean prevalence (30% and about 9% respectively) calculated in recent meta-analyses (Atieh et al., 2013; Lee et al., 2017). At the patient level, this study's findings (33.3% for mucositis and 7.8% for peri-implantitis) were lower than the weighted mean prevalence of 43-63% and 18-22% respectively calculated in recent meta-analyses (Derks & Tomasi 2015; Lee et al., 2017). Peri-implant health prevalence (52.9% at patient-level, 61.5% at implant-level) was higher, mucositis prevalence was similar and peri-implantitis prevalence was lower in this study compared to the Swedish implant registry study (Derks et al., 2016), which reported 23.0% patient-level and 39.3% implant-level health, 32.0% patient-level and 35.1% implant-level mucositis, 45.0% patient-level and 24.9% implant-level peri-implantitis in 588 patients. These differences may be due to the smaller sample size or the demographics of the private practices in this study, compared to two age groups included from Sweden's data registry. Rates of peri-implant health have otherwise been seldom reported.

Some limitations in the consensus diagnostic criteria of peri-implant health and disease (Renvert et al., 2018) were found in analysing the results of this study, where implants without signs of inflammation but which demonstrated bone loss could not be categorised and were therefore excluded from analysis. Signs of inflammation can only be detected during examination, and while bone loss in the absence of inflammation was suggested to be rare in a recent systematic review (Schwarz et al., 2018), it cited the Swedish study which reported up to 37% of implants with bone loss having no soft tissue inflammation signs (Derks et al., 2016). The propensity of

peri-implant mucosal structures to bleed more than gingivae has been described in a recent systematic review establishing the "considerable false-positive rate of BOP to diagnose peri-implantitis" (Hashim et al., 2018). The diagnostic criteria also include visual assessment of inflammation to address this issue, but this is limited to buccal and lingual aspects and may be further limited by prosthetic design. The negative predictive values of peri-implant BOP or visual signs of inflammation are not yet known. More research with long-term follow-up is needed to determine if progressive bone loss can occur in the absence of inflammatory signs. Alternatively, whether the peri-implant bone level can be reduced but stable, without mucosal inflammation, e.g. after peri-implantitis treatment, may be a category perhaps analogous to a reduced but stable periodontium after therapy (Chapple et al., 2018) that is not yet defined for peri-implant tissues.

This study's results are in agreement with the established literature on poorer oral hygiene as a significant risk factor for peri-implant disease (Canullo et al., 2016a; Costa et al., 2012; Ferreira et al., 2006; Roos-Jansåker et al., 2006; Serino & Ström 2009), with the absence of plaque/calculus on examination strongly correlating to peri-implant health, and patient reports of brushing alone strongly correlated to peri-implantitis. Reported flossing was correlated to health over peri-implantitis, but the effect of other interproximal cleaning methods was not clear. The overall plaque levels exhibited by patients in this study appeared to be high, with all patients exhibiting O'Leary plaque control scores >20%, considered to be a threshold for "good" oral hygiene in a multicentre study in Sweden, met by 88.3% of peri-implantitis patients in that study (Charalampakis et al., 2012). At the implant level, 59% of implants in this study demonstrated no plaque present, compared to 32.6% in a private practice-based study (Vermylen et al., 2003), while findings in specialist/university settings ranged from 47.5% (Simonis et al., 2010) and 56% (Lambrecht et al., 2003) up to over 87% (Blanes et al., 2007; Buser et al., 1990; Krennmair et al., 2002). In this study's implant level findings, peri-implantitis, presence of plaque/calculus, and splinted prostheses were significantly associated with older age. While there was no direct correlation between age and overall plaque control in this study's patient group, patient age and hygiene ability should be carefully considered in planning implant treatment, prosthesis design and hygiene accessibility. Greater patient age and reported time in function were also correlated at the implant level in this study, but greater time in function demonstrated a non-significant trend towards greater peri-implant disease prevalence, compared to the positive correlation previously reported in a meta-analysis (Derks & Tomasi 2015). This non-significant finding may be due to factors such as the sample size, and other possible confounding factors such as oral hygiene, age or periodontal disease status, or the average of 6.7 patient-reported years in function in this study, compared to the predominance

of implants with >10 years' function in those diagnosed with peri-implantitis in one study of 266 implants (Marrone et al., 2013).

The efficacy of patient-performed interdental cleaning methods for peri-implant health is not established (Louropoulou et al., 2014) and usually is not explicitly described in mucositis intervention studies. One study of patient-performed hygiene around full-arch implant-retained prostheses after instruction found it to be generally poor (Kreve et al., 2016) but there are no similar studies for fixed partial denture or single crown prostheses. With the results of this study showing that brushing alone is unlikely to be adequate in preventing peri-implant disease, further research into peri-implant efficacy of interproximal cleaning methods is warranted. While IDB use in this study did not demonstrate a clear relationship to peri-implant status, it is recommended as the most efficacious (Sälzer et al., 2015) and patient-preferred method (Noorlin & Watts 2007) in the periodontal literature. For peri-implant use, only one study has compared IDB design efficacy when applied by a hygienist (Chongcharoen et al., 2012), and Kreve et al. (2016) found it to be significantly taken up by patients after instruction, compared to other hygiene methods. One encouraging finding in this study was that implants that were cleaned more interproximally, especially with IDB, had fewer reported years in function (i.e. were completed more recently), perhaps reflecting a greater emphasis on thorough implant hygiene by practitioners in recent years.

In this study, risk factors for peri-implant disease or lack of implant success appeared to be correlated in two distinct groupings. The first group involved implants with cemented or multi-unit prostheses, a local prosthetic factor affecting cleaning and/or implants done in a country other than Australia, and none of these factors showed any direct correlation to the presence of plaque/calculus around the implant. The second group involved implants in patients of older age, previous histories of failed implants or soft tissue complications, implants only brushed and/or plaque/calculus present. The sample size was not large enough to conduct multiple logistic regression analysis, but these groupings may represent the prosthetic- and plaque-induced peri-implantitis subtypes suggested by Canullo et al. (2015) in their development of predictive profiles using data mining. The prosthetic factor group is in agreement with systematic reviews showing greater biological complications associated with cemented prostheses (Jung et al., 2012; Sailer et al., 2012) and a study showing greater marginal bone loss associated with cemented implant crowns which had marginal misfit (Chen et al., 2013). Peri-implant disease risk profiles found in future clinical studies will be of interest.

There are risk factors for peri-implant disease which have been established or investigated in the literature, which were not statistically significant or had no apparent effect in this study. The

small number of smokers in this study may have hidden its strong effect on peri-implantitis (Rinke et al., 2011; Roos-Jansåker et al., 2006). Active periodontal disease (Canullo et al., 2016a; Costa et al., 2012; Derks et al., 2016; Ferreira et al., 2006; Marrone et al., 2013) or residual pockets (Cho-Yan Lee et al., 2012; Pjetursson et al., 2012) are also risk factors for peri-implant disease, and this study showed non-significant trends for peri-implantitis in patients with a reduced but stable periodontium, and peri-implant mucositis in patients with residual periodontal pockets. The effects of the periodontal status variables compared to the three peri-implant statuses are likely unclear due to the sample size. The effect of a higher implant to subject ratio (Lee et al., 2017) (i.e. the extent of peri-implant disease) may have been limited by the low number of patients with multiple implants in this study. Keratinisation of the mucosa as a risk factor has been studied using variable criteria (Brito et al., 2014) and recently reviewed to have limited evidence of impact upon self-performed hygiene (Schwarz et al., 2018), and this study found no direct correlation to detectable plaque/calculus or peri-implant disease status.

The design of implant prostheses to facilitate oral hygiene accessibility is recommended (Heitz-Mayfield & Salvi 2018) given its high negative predictive value for peri-implantitis (Serino & Ström 2009), but prosthetic design guidelines are not available. In this study, implant outcomes were analysed according to whether the radiographic embrasure shapes between proximal contact to crestal bone were close to natural (i.e. as expected between teeth) or not, and while no significant correlations to peri-implant health/disease were found, there was a non-significant trend towards greater implant success with more naturally shaped embrasures. The possibility of placement in non-ideal sites is one of the advantages of implant therapy, but with the additional concerns of proximal contacts loosening over time and food impaction (Abduo et al., 2017; Byun et al., 2015; Koori et al., 2010; Wang et al., 2016; Wong et al., 2015), further research is warranted into interproximal implant hygiene, prosthetic design and optimal cleaning methods in non-anatomical situations.

In this study, according to patient recollection, a soft tissue complication history was significantly correlated to placement or restoration of the implant by a general dentist rather than a specialist. Similarly, a research network of general practitioners reported lower success and survival rates compared to the specialist-dominated literature (Da Silva et al., 2014). In the Swedish registry study, patient-reported aesthetic and chewing ability ratings were lower for implants provided by general practitioners (Derks et al., 2015) and odds ratios for moderate/severe peri-implantitis were higher for implants restored by general practitioners compared to specialists (Derks et al., 2016). These findings are in general agreement with other dental fields, such as the higher survival rates for endodontic treatments performed by endodontists compared to general dentists (Alley et al., 2004). In general, the question of who provides implant surgery, restoration

and maintenance services in the community, given the multidisciplinary nature of implant dentistry, is rarely reported. Greater provision of surgical procedures by specialists and restorative procedures by general dentists was reported in the Swedish registry study (Derks et al., 2016) and in analysis of services provided in 2005-6 in private practice in the USA (American Dental Association, 2007) . These trends were similar but more evenly distributed in this study, with patients recalling 60.3% of implants placed by specialists and 53.8% restored by general practitioners. Around 80% of patients had implant maintenance performed by general practitioners in the Swedish registry study (Derks et al., 2016) and a very similar proportion was reported by patients in this study. Maintenance provision by which practitioner types has otherwise rarely been outlined in the literature dominated by specialist/university-based samples.

This study was cross-sectional and established a snapshot of implant patients in private general practice. Comprehensive treatment records or baseline data were lacking in many cases due to patients having moved between dental practices, or having seen specialists for part of the treatment, whose records were not available. This is a practical challenge to implant record-keeping which may be addressed with the development of digital implant registries. Several possible impacting variables such as time in function, OHI history or a previous soft-tissue complication were therefore reliant on patient recall where records were not available. Patients' reports of oral hygiene performed might also be different from their actual habits. The sample size was limited to the patients seen by one practitioner in general private practice over an 18 month period, but was similar to other studies with general practitioner and community-based cohorts, such as 40 patients with 43 implant crowns examined after implant placement by periodontists and restoration by general dentists (Vermylen et al., 2003), and 54 patients with implants in a sample of 1000 Austrian adults (Pommer et al., 2011). The study by Derks et al. sampled the Swedish data registry to survey 3827 implant patients with 588 examined (Derks et al., 2015; Derks et al., 2016). It is hoped future implant registries will allow similar large-scale evaluation of implant outcomes in community settings.

Conclusions

Patient-performed oral hygiene was associated with peri-implant outcomes in this community-based study, which were similar to reported prevalence in the literature. Implants being cleaned by brushing alone was significantly correlated to peri-implantitis, while absence of plaque/calculus was significantly correlated to peri-implant health. Previous histories of failed

implants or soft tissue complications were also significantly correlated to peri-implantitis. The presence of any local prosthetic factor affecting cleaning significantly reduced implant success. Risk factors tended to cluster in prosthetic- and plaque-related groups. This study recorded oral and implant hygiene habits and peri-implant symptoms reported by patients in the community, and implant OHI was poorly recalled. Further research should continue into interproximal implant hygiene, practitioners' OHI strategies and peri-implant outcomes in community cohorts. The challenges of long-term record-keeping for implant review and maintenance should also be addressed.

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Chapter 3: Implant education patterns and clinical practice of general dentists in Australia

A manuscript published in *Australian Dental Journal* 2019; 64(3):273-281.

Abstract

Background: This study aimed to understand trends in dentists' implant training attendance and correlation to treatment provision. Implant-specific oral hygiene instruction coverage in training programs was investigated.

Methods: A cross-sectional web-survey of dentists registered in Australia was conducted. Respondents were asked about their background, implant training history and treatment provision. Results were analysed by implant provision characteristics and graduation decade.

Results: Three hundred and three responses from general dentists (GDPs) were received and analysed. The highest implant training levels attained post-graduation were postgraduate non-specialist qualification (7.9% of respondents), continuing professional development (CPD) (73.6%) versus none (18.5%), with differences between implant providers and non-providers ($p<0.001$), different graduation decades ($p<0.001$) and those restoring implants or performing surgery as well ($p<0.001$). University-based CPD was attended less than dental association/society or implant-company CPD. Non-providers were significantly less likely to recall implant oral hygiene instruction sources ($p<0.001$). Most GDPs (74.9%) provided implant services, with younger GDPs beginning earlier after graduation. About 16% of respondents did not provide implants once established career-wise.

Conclusions: Dentists might be providing implant treatments increasingly earlier in their careers. Respondents with more training were significantly more likely to perform more complex procedures, while implant training attendance trends varied by graduation decade.

Introduction

The development of the field of implantology in Australia since the 1980s has been accompanied by the evolution of implant education. A baseline curriculum for implantology within the undergraduate/graduate dental degrees in Australia was established by consensus in 2010 (Mattheos et al., 2010) and includes treatment planning, diagnostic procedures, limited restorative services and maintenance. Dentists who graduated prior to 2010 or who want to provide more complex services may seek training of their own volition. Postgraduate courses leading to formal qualifications have been available since the 2000s. There are many non-degree continuing professional development (CPD) programs available, for which there are no regulations or standards required for academic content or assessment (Ivanovski et al., 2010). Evaluation of CPD training programs in Europe found them to be highly variable in structure and content (Ucer et al., 2014). Furthermore, there is no such thing as a generic implant and the role of implant companies in implant education must be considered. While some surveys in the literature have included dentists' brand preferences (Guo et al., 2017; Murray et al., 2016; Ng et al., 2011), the relationship to usage in training, as well as the popularity of implant-company training courses among the CPD-level options available to dentists have rarely been investigated.

Previously published surveys of general dentists have investigated the characteristics of implant providers, their interest in further training, implant case types treated, referral patterns, patient enquiries and their main sources of training (Cheung et al., 2016; Guo et al., 2017; Murray et al., 2016; Ng et al., 2011). A survey of general dentists in Victoria in 2008 surveyed the different types of implant training programs attended and found training and higher levels thereof to be correlated to greater provision of more complex cases as well as more complex implant maintenance services (Cheung et al., 2016). Overall, the implantology training paths taken by different generations of dentists, and possible correlations to their subsequent and/or current clinical practice remain unclear.

As research continues into peri-implant diseases (with patient-level weighted mean prevalences of peri-implant mucositis of about 45% and peri-implantitis of about 20% reported by Derks & Tomasi in 2015 and Lee et al. in 2017), their prevention and management, the role of oral hygiene as a risk factor for disease (Ferreira et al., 2006; Roos-Jansåker et al., 2006; Serino & Ström 2009) and in long-term implant maintenance (Heitz-Mayfield & Salvi 2018; Salvi & Ramseier 2015) is becoming clearer. However, the literature on implant-specific oral hygiene techniques performed by patients for disease prevention and as part of peri-implant management is lacking (Grusovin et al., 2010; Louropoulou et al., 2014). It is unknown therefore whether dentists are receiving any information from their training programs about implant-

specific oral hygiene instructions (OHI) to give to their patients, and whether this varies according to the type of program.

This study aimed to investigate dentists' historical attendance at implant training programs after graduation, their current provision, complexity and volume of implant treatment, and any association with time since graduation. The coverage of implant oral hygiene information within training programs and the impact of implant companies on training and clinical usage of their products was also explored.

Methods

The research protocol for this study was approved by the Health Sciences Human Ethics Sub-Committee of the University of Melbourne (Ethics ID 1443625). Dentists and dental specialists who were registered in Australia were anonymously surveyed using a web-based questionnaire (Appendix II) via the SurveyMonkey™ website (San Mateo, CA, USA). To maximise the number of responses, the Australian Dental Association's seven state branches, the Australian Society of Periodontology and the Royal Australasian College of Dental Surgeons assisted by distributing the survey electronically to their memberships, and a prize draw was advertised as part of these communications. Data were collected between March and September 2016.

Respondents provided information about their gender, dental qualifications, graduation year and university, registration type, practice location and practice sector. They were asked about their history of attendance at implant training programs (both restorative and surgical), their recollection of implant oral hygiene education, provision of implant treatment services, estimated annual case volume and implant brands used in their training and in clinical practice.

Data were described and analysed according to decade of graduation, implant treatment provision status, highest level of implant training and provision of restorative and/or surgical services among those with implant experience, to investigate trends in implant training attendance as the field of implantology has developed in Australia as well as subsequent service provision patterns. Graduation decade analysis pooled together all graduates from 1985 and before, accounting for the more widespread development of the field in the mid-1980s. Highest level of implant training for each respondent was determined by their reported completion of implant-related university qualifications, university-run CPD days, professional association/society programs, implant-company programs and/or work-based mentorship. If respondents had completed any formal non-specialist postgraduate university-based qualifications, their highest level of training was considered to be at the formal postgraduate

level. Respondents who had completed any CPD programs but no formal postgraduate qualifications were considered to have CPD as their highest level of implant training. The remainder who did not report any completion of formal postgraduate or CPD programs were placed in the "neither" or no-training category. 2016.

The statistical analysis (Pearson's Chi-squared tests to compare between categorical variables and independent sample t-tests to compare the means of two groups) was performed using SPSS software version 23.0 (SPSS, Chicago IL, USA) and significance set at $p<0.05$.

Results

Demographics

From the 405 responses received, most were registered as general dentists (74.8%, n=303). As there can be differences between different specialty types' involvement in implantology in clinical practice, and the responses from specialist groups were small in number, only the findings for the general dental practitioner (GDP) group are presented forthwith.

Over half of the respondents were male (54.1%, n=164) and most of the respondents did not own a practice, worked only in private practice or only in metropolitan areas (not all respondents provided their metropolitan or rural/regional location), and graduated from an Australian university (Table 3.1). Almost three-quarters of GDPs offered implant services to their patients (n=227, 74.9%) and these implant providers were significantly more likely to be male, practice owners or working only in the private sector (all $p<0.001$).

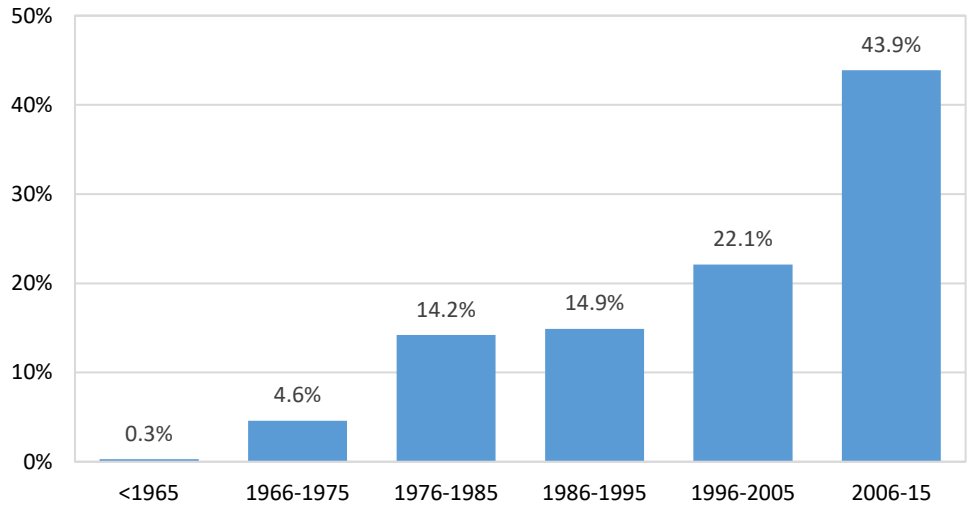
Table 3.1 Demographics of GDPs overall and by implant provision status

GDPs overall (n=303)	**Implant providers (n=227)**	**Non-providers (n=76)**	**p value**
Male (n=164)	86.6%	13.4%	**<0.001**
Female (n=139)	61.2%	38.8%	
Practice owner (n=120)	61.7%	38.3%	**<0.001**
Non-owner (n=183)	95.0%	5.0%	
Private practice only (n=253)	81.0%	19.0%	**<0.001**
Any public sector (n=50)	44.0%	56.0%	
Metropolitan practice only (n=214)	75.2%	24.8%	
Any rural/regional practice (n=68)	72.1%	27.9%	
Graduated from Australian university (n=255)	74.9%	25.1%	
Graduated from non-Australian university (n=48)	75.0%	25.0%	

p values <0.05 shown

Grouped by decade of graduation, the largest cohort of respondents graduated between 2006-15 (43.9%), followed by 1996-2005 (22.1%), with the smallest numbers graduating before 1976 (4.9%) (Figure 3.1). The mean year of graduation was 1998 and the median year 2002. GDPs who provide implant treatment had a significantly earlier average year of graduation (1997) than non-providers (2003) (p<0.001, 95% CI: 3.3-9.6 years earlier).

Figure 3.1 Year of graduation (by decade group) of GDP respondents (n=303)



Implant training after graduation

The types of implant training that GDPs had attended after graduation from their initial degree are shown in Table 3.2. Formal university postgraduate diploma/degree training was the highest level of implant training completed by 7.9% of GDPs, compared to CPD as the highest level for 73.3%, and 18.5% had attended neither (Table 3.3). Implant providers attended significantly more implant training at all levels and types than the GDPs not providing implants (non-providers), but 2.6% of implant providers had neither formal postgraduate nor CPD training (Table 3.3). Overall comparisons of GDPs by decade of graduation showed a significant difference overall for the highest level of training attended (p<0.001). Graduates from 2006-15 were most likely to have had no formal postgraduate or CPD implant training (28.6%). Graduates from 1986-2005 had the highest rates of formal postgraduate training (approximately 15%) and graduates from ≤1985 had the most CPD attendance as their highest level of training at 87.9% (Table 3.3). However, different graduation decade had no significant impact on the highest level of implant training among implant providers.

Table 3.2 GDPs' reported historical attendance at restorative and surgical implant training program types (multiple selections permitted), n=303

	Training program focus	
	Restorative	Surgical
Formal university postgraduate training	7.9%	6.6%
University-based CPD	36.0%	20.5%
Association/society CPD	58.7%	27.4%
Implant company CPD	60.7%	27.7%
Work-based mentorship	36.3%	13.5%
No programs cited	20.5%	53.8%

Table 3.3 GDPs' highest level of implant training attended

	Overall (n=303)	Implant provision		Decade of graduation				Providers with implant experience performing:	
		Implant providers (n=227)	Non-providers (n=76)	≤1985 graduates (n=58)	1986-1995 graduates (n=45)	1996-2005 graduates (n=67)	2006-2015 graduates (n=133)	Restoration only (n=139)	Surgery and restoration (n=73)
Formal postgraduate level	7.9%	10.6%	0.0%	1.7%	15.6%	14.9%	4.5%	2.9%	27.4%
CPD program level	73.6%	86.8%	34.2%	87.9%	68.9%	77.6%	66.9%	96.4%	71.2%
No formal postgraduate or CPD implant training	18.5%	2.6%	65.8%	10.3%	15.6%	7.5%	28.6%	0.7%	1.4%
p value		**<0.001**		**<0.001**				**<0.001**	

p values <0.05 shown

When comparing attendance at CPD provided by different organisations, programs run by implant companies (62.0%) and dental associations/societies (60.7%) were more frequently attended than those from universities (38.0%) (Table 3.4). Restoration-focused programs followed a very similar pattern to the overall, while surgical-focused programs were more evenly attended although university-based courses still had the lowest attendance (Table 3.2).

Dentists who had more experience with providing services and complex treatments reported higher rates of attendance at the various CPD types, but the longer time that older graduates had had to accumulate CPD must be considered and statistical analysis between groups was not performed. However, university CPD was the least attended within all decade groups, and the most recent graduates (2006-2015) reported a historical attendance of only 21.2%, less than half of their attendance at the other CPD program types, a greater difference than in the older graduate groups (Table 3.4). There were no significant differences between restorative only and surgical/restorative providers in terms of CPD program types attended.

Table 3.4 GDPs' reported historical attendance at CPD program types (multiple selections permitted)

CPD provider	Overall (n=303)	Implant provision		Decade of graduation				Providers with implant experience performing:	
		Implant providers (n=227)	Non-providers (n=76)	≤1985 (n=58)	1986-1995 (n=45)	1996-2005 (n=67)	2006-2015 (n=133)	Restoration only (n=139)	Surgery and restoration (n=73)
University	38.0%	48.0%	7.9%	60.3%	46.7%	46.3%	21.1%	47.5%	56.2%
Dental association or society	60.7%	75.8%	15.8%	84.5%	66.7%	71.6%	42.9%	74.8%	84.9%
Implant company	62.0%	77.1%	17.1%	77.6%	71.1%	71.6%	47.4%	77.0%	84.9%

Implant treatment provision

About three-quarters of GPDs (74.9%) offered implant services to their patients, including 213 (70.3%) who had begun and continue to do so (considered to have implant experience). GDPs were found to gradually begin performing implant treatment in the decade periods after they graduate (Table 3.5), with approximately 16% across the different graduation groups who never begin to do so. The most recent graduates appeared to be starting to perform implant treatments earlier with 54.1% doing so within the same decade period as their graduation.

Table 3.5 Comparison of GDPs' decade of graduation and decade of starting implant provision

Decade period of starting to perform implant treatment	GDPs overall (n=303)	Decade of graduation			
		≤1985 (n=58)	1986-1995 (n=45)	1996-2005 (n=67)	2006-2015 (n=133)
1985 and before	0.6%	3.4%			
1986-1995	8.3%	27.6%	20.0%		
1996-2005	16.5%	32.8%	31.1%	25.4%	
2006-2016	45.5%	20.7%	33.3%	58.2%	54.1%
Have not provided implant treatment	29.0%	15.5%	15.6%	16.4%	45.9%

Out of the entire GDP cohort (n=303), 78.5% treatment planned implants, 74.6% provided restorative treatment, 24.4% provided surgical treatment and 50.5% provided only restorative treatment. Of the 227 implant providers, 67.4% only restored implants, 0.4% only placed implants, and 32.2% performed both. Among GPDs with implant experience (n=213), those with formal postgraduate training (83.3%) were much more likely than those with CPD-level training (37.4%) to perform both surgical and restorative treatments ($p<0.001$).

Estimated annual case volume

Most of the GDPs with previous implant experience (n=213) estimated their annual implant case volume to be ≤20 cases (70.0%) while 8.4% estimated >50 cases (Table 3.6). Those with higher levels of implant training treated significantly more cases annually ($p<0.001$), and thus those who do both surgery and restoration also had a significantly greater caseload than those who restore only ($p<0.001$). GDPs in graduation decade groups before 2006 had similar case volumes,

with about 40% treating over 20 cases per year, while the most recent graduates (2006-15) were more likely (86.1%) to treat ≤20 cases per year (p=0.016).

Table 3.6 Estimated annual implant case volume reported by GDPs with implant experience

Estimated annual case volume	GDPs with implant experience (n=213)	Highest level of implant training			Decade of graduation				Providers with implant experience performing:	
		Postgraduate (n=24)	CPD training (n=187)	Neither (n=2)	≤1985 (n=49)	1986-1995 (n=38)	1996-2005 (n=54)	2006-15 (n=72)	Restoration only (n=139)	Surgery and restoration (n=73)
≤20	70.0%	45.8%	73.3%	50.0%	59.2%	65.8%	61.1%	86.1%	84.9%	41.1%
21-50	21.6%	16.7%	21.9%	50.0%	28.6%	28.9%	22.2%	12.5%	14.4%	35.6%
51-99	6.1%	25.0%	3.7%	0.0%	10.2%	2.6%	13.0%	0.0%	0%	17.8%
100+	2.3%	12.5%	1.1%	0.0%	2.0%	2.6%	3.7%	1.4%	0.7%	5.5%
p value		**<0.001**			**0.016**				**<0.001**	

p values <0.05 shown

Implant brands – training and usage

The most common implant brands used during training were also those preferred most commonly for patient treatment, with Astra Tech® (which merged with Dentsply Sirona® shortly after this survey was conducted), Straumann® and Nobel Biocare® predominating (Table 3.7). Among GPDs with implant experience (n=213), Straumann® was the most highly preferred brand (42.7%) although reported training history was highest from Nobel Biocare® among all GDPs as well as among implant providers only.

Table 3.7 Implant brands used by GDPs during training and in practice (multiple selections permitted)

	Brands used during training by GDPs overall (n=303)	Brands used during training by implant providers (n=227)	Brands preferred by GDPs with implant experience (n=213)
Biomet 3i®	10.6%	14.1%	3.3%
Astra Tech®	21.5%	27.8%	27.2%
MIS®	8.3%	10.6%	3.8%
Neoss®	7.3%	9.7%	8.0%
Nobel Biocare®	43.6%	56.4%	24.9%
Straumann®	33.7%	43.6%	42.7%
Other brands	15.5%	20.7%	12.2%

There were no significant differences in overall brand preferences between GDPs of different graduation decades. Straumann® was the most popular brand for all decade groups, but Nobel Biocare® was the second most popular for the ≤1985 graduates while Astra Tech® was the second most popular for all subsequent graduation cohorts.

Reported sources of implant oral hygiene instruction information

There were significant differences in the sources of information that GDPs cited for implant oral hygiene instructions (OHI), by decade of graduation (Table 3.8). More recent graduates recalled implant OHI information in their initial dental degrees (up to 66.2% in the most recent graduation decade) compared to fewer than five percent of those who graduated prior to 1996

(p<0.001). The most recent graduates were least likely to report learning implant OHI from journal articles (p=0.001). When comparing different CPD program types (cited by those who had ever attended each type), ≤1985 graduates recalled learning implant OHI from each program type at higher rates than other decade groups. Within the 2006-2015 graduate group, implant company CPD was reported as a learning source half as often (30.2%) as university-based CPD (64.3%), whereas the other graduation decade groups were more consistent. A small proportion of earlier graduates volunteered that they considered their clinical experience or knowledge of periodontal management to be applicable to implant OHI.

Non-providers who had attended implant-company CPD had a particularly low recall (15.4%) of learning implant OHI from these programs compared to implant providers (p=0.025), while no difference was found for the other CPD program types. Nearly one in five non-providers did not list any sources of implant OHI, compared to 2.6% of implant providers (p<0.001).

Table 3.8 Implant OHI information sources recalled by GDPs

	GDPs overall (n=303)	**Implant provision**			**Decade of graduation**				
		Implant providers (n=227)	Non-providers (n=76)	p value	≤1985 (n=58)	1986-1995 (n=45)	1996-2005 (n=67)	2006-2015 (n=133)	p value
Initial dental degree	38.0%	33.5%	51.3%	**0.006**	3.4%	4.4%	34.3%	66.2%	**<0.001**
Formal postgraduate implant training†	83.3% (24)	83.3% (24)	0% (0)	n/a	100.0% (1)	57.1% (7)	90.0% (10)	100.0% (6)	
University-based CPD†	58.3% (115)	57.8% (109)	66.7% (6)		77.1% (35)	33.3% (21)	48.4% (31)	64.3% (28)	**0.007**
Association/society CPD†	59.8% (184)	59.9% (172)	58.3% (12)		73.5% (49)	60.0% (30)	56.3% (48)	50.9% (57)	
Implant company CPD†	45.2% (188)	47.4% (175)	15.4% (13)	**0.025**	66.7% (45)	46.9% (32)	43.8% (48)	30.2% (63)	**0.003**
Hands-on course	6.9%	9.3%	0.0%	**0.006**	13.8%	8.9%	7.5%	3.0%	
Work-based mentorship	24.4%	44.0%	60.0%		15.5%	8.9%	31.3%	30.1%	**0.006**
Colleagues	35.0%	38.3%	25.0%	**0.035**	37.9%	28.9%	38.8%	33.8%	
Journal articles	36.6%	40.1%	26.3%	**0.031**	48.3%	51.1%	41.8%	24.1%	**0.001**
Textbooks	15.8%	14.1%	21.1%		13.8%	22.2%	22.4%	11.3%	
Experience or similar to periodontal management (volunteered answer)	1.0%	0.9%	1.3%		3.4%	2.2%	0.0%	0.0%	
No source cited	6.6%	2.6%	18.4%	**<0.001**	5.2%	8.9%	4.5%	7.5%	

p values <0.05 shown
† bracketed numbers attended this type of training in each column group, out of which the percentage citing it as a source was calculated

Discussion

This study found that among the GDPs who participated in the survey, higher levels of implant training after graduation from dental school were significantly correlated to implant treatment provision, greater complexity of such (i.e. performing surgical placement in addition to restoration) and higher estimated annual case volumes. This is consistent with previous research in Victoria (Cheung et al., 2016) where any training and higher levels of training were significantly correlated to willingness to treat more complex cases. No other studies are known

to have investigated the relationship between implant training level and treatment provision levels, and overall, few studies have surveyed dentists on their implant training (Gibson & Barclay 2006; Murray et al., 2016; Ng et al., 2011; Reid et al., 2005).

When comparing overall implant training attendance and implant service provision trends, GDPs in this study appeared to establish a knowledge base wider than the clinical treatments provided, i.e. not all of those who have attended training end up providing the services in clinical practice, most markedly at the surgical training level. The reasons influencing implementation in clinical practice subsequent to training warrant further investigation and may include the need for longer term learning, modular programs, practical experience, mentorship and clinical supervision, as suggested by participants in a study of university-based CPD where implant program attendees put their new skills into practice at a lower rate than rotary nickel-titanium endodontics program attendees (John & Parashos 2007).

Three-quarters of GDPs surveyed were implant providers, a greater proportion than 66.4% found in another recent Australia-wide survey (Guo et al., 2017), and 50.6% found in Victoria in 2008 (Cheung et al., 2016), perhaps reflecting the increasing popularity of implant provision among GDPs and/or increased patient awareness and demand over time. This trend has also been found in serial surveys of dentists in New Zealand (Murray et al., 2016; Reid et al., 2005) and Hong Kong (Ng et al., 2011).

Surgical implant placement was performed in this study by twice the proportion of GDPs reported in a 2006 USA random-sample survey (American Dental Association 2008). No other published proportions of the overall GDP workforce providing restorative and/or surgical implant services are available for comparison. Among implant-providing GDPs, the proportions in this study offering restorative and/or surgical services were similar to other recent surveys in Australia (Guo et al., 2017) and Hong Kong (Ng et al., 2011).

Six implant providers in this study (2.6%) did not report any attendance at implant training after graduation, while citing some sources of implant OHI information, but this finding was lower than the 12% found in the 2008 Hong Kong study who were self-taught from “books and manuals on implants” (Ng et al., 2011). The proportions of implant providers with formal postgraduate or CPD highest training levels in this study were otherwise similar to those in the Hong Kong study.

This study also found a similar caseload to that reported in Hong Kong, with the majority of implant providers treating ≤20 cases per year (Ng et al., 2011). If most dentists are performing implant treatment relatively infrequently, the rigor of training, appropriate case selection and

clinical supervision or mentorship need to be at a high level. Ongoing research should track the provision of implant treatments globally in terms of practitioner involvement and case volume, as the field of implantology and its education structure continue to evolve, which may provide information regarding outcomes and minimum training standards. A recent survey of 1015 implant-providing participants of an implantology Massive Open Online Course (MOOC) had respondents from 84 countries and is one of the first to provide a global perspective of implant providers (Dragan et al., 2019).

Graduation decade affected the level of implant training attended by respondents in this study, with recent graduates less likely to have attended any at all, similar to results found in New Zealand in 2004 (Reid et al., 2005) and 2014 (Murray et al., 2016) and the 2008 study in Victoria (Cheung et al., 2016). Recent graduates are most likely establishing their general skills before upskilling into implantology with restorative training first, reflected by their lower attendance at surgical programs. Graduates from 1986-2005 had the highest participation in formal postgraduate degrees in this study, having been at the stage of their careers to expand their skillset when these programs became available in Australia in the 2000s. Meanwhile, graduates from ≤1985 may have compensated for graduating before implants became available, with the highest reported rate of attendance at CPD training. Respondents were not asked specifically if they had received implant training in their initial dental degree, although this is unlikely for those who graduated prior to 2000.

Among implant providers in this study, the finding that decade of graduation did not affect the highest level of training suggests that younger dentists who took up implant training did so more quickly. In the future they may continue to do so and demonstrate higher overall levels of training than their more senior colleagues, just as they reported higher rates of implant treatment provision than their senior colleagues at the same career stage. Possible reasons for this finding may be the standardised inclusion of implant training in the initial dental degree, increasing availability of implant training programs of all types, increasing demand for implant treatment in the community and/or competitive pressure to offer a wider range of services. Basic implant training within the Australian initial dental degree programs since 2010 should include competency in some restorative procedures (Mattheos et al., 2010) and has likely allowed newly graduated dentists the confidence to provide simple implant treatments immediately or soon after graduation. Similarly, the MOOC participant survey identified a cluster of younger implant providers beginning to perform treatment within their first two years of practice, who had attended less formal postgraduate training than others (Dragan et al., 2019). At the other end of the spectrum, the possible reasons for 16% of GDP respondents in this survey

not providing implant treatments (excepting the most recent graduates) and whether this trend continues warrant further research.

Attendance at non-degree CPD provided by different organisations appears to have been rarely investigated in the literature. It must be acknowledged that industry support or sponsorship is intrinsic to implant training programs at all levels, and thus whether respondents considered the CPD-level programs they had attended to be organised by universities, professional associations/societies or implant companies themselves may have contained some overlap. Nevertheless, this study's findings were similar to findings in an American study of higher attendance at manufacturer-sponsored and privately-run courses compared to university-based courses (American Dental Association 2008), while studies in Hong Kong (Ng et al., 2011) and evaluating implant CPD in Europe (Ucer et al., 2014) did not compare attendance at different short course types. This study reported higher attendance rates at restorative and surgical CPD programs run by universities compared to the 2008 study in Victoria (Cheung et al., 2016), while implant company CPD attendance rates remained similar. While this comparison may represent the different sample groups or differences between Victoria and Australia as a whole, university-based CPD attendance may have increased from 2008 to 2016 and this trend should continue to be investigated. Dentists' motivations for attending a particular program might include availability, accessibility, cost and brand-related factors (e.g. where a practice already uses a certain brand of implant equipment).

CPD was the highest level of implant education attended by most implant providers in this study, yet it is classified as pre-clinical training for knowledge and understanding, lacking the structured curriculum, quality assurance and student assessment recommended for basic clinical competence levels (Ivanovski et al., 2010). Universities are recommended to play "a leading role" in implant education for GDPs (Mattheos et al., 2010) and "basic clinical education level" programs (Ivanovski et al., 2010) (which do not currently exist as a formal training and qualification pathway) have been proposed. As these programs are developed, greater understanding of why university-based CPD might be less frequently attended than other sources of CPD would be useful. The lack of university-led provision of education options at a level lower than formal postgraduate training was also similarly espoused in the recent study of global MOOC participants (Dragan et al., 2019).

This study is one of the first to investigate respondents' sources of implant OHI information and it is not surprising that the initial dental degree and work-based mentorship figured much more strongly for more recent graduating groups. Comparing the type of CPD provider, implant company CPD was the most popularly attended and yet was cited least as a source of OHI

information, particularly in the most recent graduation group, for whom university CPD was a much more frequent source. While a small percentage of GDPs overall (6.6%) did not cite any sources of implant OHI information, this proportion increased to almost one in five (18.4%) non-providers in this study, and indicates a need to better distribute information to those who have less interest in the field of implantology but who will still encounter implant-related disease in clinical practice.

It is interesting to note the varied sources of implant OHI information given the sparse literature and minimal clinical research available on the best evidence-based implant home hygiene techniques (Grusovin et al., 2010; Louropoulou et al., 2014) and lack of standard control protocols in peri-implant disease intervention research (Sanz & Chapple 2012). The recent Clinical Practice Guidelines from the American College of Prosthodontists (Bidra et al., 2016) did not make specific recommendations on hygiene technique and acknowledged that the guidelines are to be modified as higher quality evidence is established.

Nobel Biocare® and Straumann® are consistently found to be the most frequently used implants in recent surveys of dentists (Murray et al., 2016; Ng et al., 2011), a finding confirmed in the present study. Evaluation of brand loyalty in this study showed that GDPs could be moving away from Nobel Biocare® compared to its dominance in training usage and 2008 leading market position in the USA (approximately 28% market share according to Jüngling et al.), with a 25% leading market share claimed by Straumann® in 2018 (Institut Straumann AG 2019). In brands other than Nobel Biocare®, reported clinical usage more closely reflected training usage in this study. This likely reflects the emergence of industry competitors over time, including in their provision of training or affiliation with education systems e.g. the Straumann®/ITI education network.

The response rate in this study (2.1% of the registered GDP workforce in Australia in 2016) (AHPRA 2016) was lower than another country-wide survey of implant provision (7.6%) (Guo et al., 2017), both surveys being unable to access the national register to generate a randomly selected sample. Previous research has shown that web-based surveys of dentists receive lower response rates than do mailed surveys (Hardigan et al., 2012), and those of younger age or greater computer literacy may have been more likely to complete an online survey, leading to some selection bias. The demographics of the respondents in this study were nevertheless similar to the latest available proportions of employed dentist workforce in the country in 2013 (AIHW et al., 2016), with slightly more females and graduates from Australian universities in this cohort. As the study focused on the area of implantology, non-response bias may be present if those with a lower interest did not participate, and a survey also relies on participants' recall

and accuracy of self-reporting. The questionnaire did not survey the hours that GDPs worked (i.e. full- or part-time), which may affect their involvement in providing implants or more complex treatments. The results and trends reported in this study should be interpreted in light of these limitations but are in general agreement with initial global observations and other similar surveys.

Overall, the implant training preferences and provision of implant treatments by dentists in Australia should continue to be tracked as the field of implantology, its education structure, and understanding of long-term peri-implant pathology develop over time. Further research to investigate the preferences and training of different specialist disciplines would also provide an interesting comparison, particularly as implantology lacks an all-encompassing specialist discipline at this time.

Conclusions

This study highlighted the cumulative implantology training trends and current practice patterns of general dentists in Australia who responded to the survey, finding that dentists may be providing implant treatments increasingly earlier in their careers and respondents with more training were significantly more likely to perform more complex procedures. About 16% of GDPs surveyed are not involved in implant treatment once established in their careers. The rapid development of the field and standardised inclusion in initial degree programs in Australia since 2010 may be reflected in the differences in post-graduation implant training programs attended by respondents in varying stages of their careers. University-based CPD programs were attended at a low level by respondents compared to programs from dental associations or societies and implant companies. With the current CPD framework of non-compulsory, self-directed and non-standardised learning prior to providing implant treatment, challenges for the profession lie in ensuring that all are practising according to evidence-based standards, especially in the basic areas of prevention and patient education, including reaching dentists who are not interested in providing implant treatments themselves.

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Chapter 4: Dentists' implant maintenance preferences. Part I: home hygiene and oral hygiene instruction

A manuscript submitted to *Journal of Oral Implantology*.

Abstract

The aim of this study was to investigate the opinions and preferences of dentists in giving their patients oral hygiene instruction (OHI) specific to dental implants. An online survey was completed by 303 general dental practitioners (GDPs) registered in Australia, indicating their opinion of the correlation between patient home hygiene and peri-implant health, the specific techniques included in their implant OHI, their preferred timing, frequency and teaching methods. GDPs surveyed had high awareness of the importance of good implant hygiene. Brushing (86.5%), flossing (73.9%) and interdental brush (68.3%) were the most commonly advised techniques. Most GDPs gave OHI immediately after implant procedures were completed (77.3%) or at the next appointment for implants treatment planned by others (69.6%), although 18.2% never gave OHI in this situation. Of GDPs who gave any OHI, 57.4% repeated it routinely. About 80% of GDPs described or showed OHI to patients while only 36.3% asked the patient to demonstrate afterwards. Statistical analysis showed that higher levels of post-dental degree implant training and provision of implant treatment were significantly associated with higher provision of implant-specific OHI techniques and regular OHI repetition. GDPs with higher training and annual case volumes were more preventative in discussing OHI before implant treatment. Clinically, interdental cleaning should be emphasized and implant OHI reinforced and repeated long-term.

Introduction

The presence of plaque on the transmucosal surface of dental implants is the primary aetiological factor in the development of biological complications, i.e. peri-implant mucositis and peri-implantitis (Renvert et al., 2018; Zitzmann & Berglundh 2008), which can reduce implant success and survival. Poor overall oral hygiene has been strongly associated in clinical studies with greater peri-implant mucositis prevalence (Ferreira et al., 2006), peri-implant bone loss incidence (Lindquist et al., 1997) and peri-implantitis incidence (Costa et al., 2012; Ferreira et al., 2006). The prevalence of peri-implant mucositis and peri-implantitis is also greater where plaque is detected at the implant site (Canullo et al., 2016; Roos-Jansåker et al., 2006). In addition, the presence or absence of patient capability/accessibility to perform implant hygiene is highly predictive of the absence or presence of peri-implantitis, respectively (Serino & Ström 2009).

There is a lack of evidence for optimal self-performed implant hygiene (Grusovin et al., 2010; Louropoulou et al., 2014) with some mixed results in plaque and bleeding scores for powered toothbrushes compared to manual toothbrushes and a lack of standardisation or even the exclusion of interdental cleaning (and therefore plaque control at the implant site) in the few clinical studies available (Swierkot et al., 2013; Truhlar et al., 2000; Wolff et al., 1998). Flossing circumferentially around implants has been recommended previously in some literature reviews (Chen & Darby 2003; Kracher & Smith 2010) and in dental hygiene articles (Wingrove 2011) but floss remnants at exposed rough implant surfaces have more recently been found upon surgical exploration of refractive peri-implantitis cases (van Velzen et al., 2016). Published studies on the use of interdental brushes for implants (Chongcharoen et al., 2012) are limited, with little information on clinical parameters and peri-implant health or disease outcomes when used by patients. When subjects in published peri-implant research are described as receiving oral hygiene instructions (OHI), if at all, the OHI is usually not described in full.

The effective dissemination of information from published clinical research to evidence-based practice, to the reality of patient education in the clinical environment and subsequent implementation by individual patients is critical, but no investigations on these issues have been published to date. It is unclear what implant-specific OHI dentists in the general community are currently giving their patients, at what time/frequency and using which teaching methods, especially while the literature remains limited. The purpose of this study was to investigate the current opinions and preferences of dentists working in Australia when giving their patients implant-related oral hygiene information for at-home care, and factors affecting these preferences, especially implant dentistry training and education.

Methods

An online survey was conducted using SurveyMonkey™ (San Mateo, CA, USA) involving dentists registered in Australia. The survey was distributed electronically to the members of the seven Australian Dental Association state branches, the national professional association (members constitute approximately 70% of dentists registered in Australia), as well as the Australian Society of Periodontology (a non-profit society for dental practitioners) and the Royal Australasian College of Dental Surgeons (an internationally recognised provider of postgraduate dental qualifications and professional development). As an incentive, a prize draw was conducted. The research protocol for this study was granted ethics approval (Ethics ID 1443625) by the Health Sciences Human Ethics Sub-Committee of the University of Melbourne. Data were collected from March to September 2016.

A questionnaire (Appendix II) gathered information about dentists' opinions on the correlation between home hygiene and peri-implant health, the techniques that they recommend when giving implant-specific OHI, when they first give OHI for implants that they provide or treatment plan, when they first give OHI for implants that they did not treatment plan, their preferred OHI repetition frequency and their OHI communication methods (describing, showing the patient, asking the patient to demonstrate).

Data were examined by comparing whether or not dentists offered implant treatment to their patients, and their highest level of implant training attended after completion of their initial dental degree (formal postgraduate qualification, continuing professional development [CPD] or neither) to determine whether these factors influence their implant hygiene opinions and preferences. Among dentists with implant experience (i.e. had performed implant treatment previously), their self-reported annual implant case volume (separated into groups treating ≤20, 21-50, >50 cases per year) representing their current implant involvement and experience, and whether they perform restorative and/or surgical implant treatments were compared. Analysis was performed with the statistical software SPSS version 23.0 (SPSS, Chicago IL, USA) using Fisher exact tests to compare between categorical variables with significance set at $p<0.05$, and the findings were reviewed by an independent statistician.

Results

Responses were received from 303 general dentists. The demographic characteristics of the GDPs in this study are shown in Table 4.1, grouped according to whether they provide implant

treatments (74.9%) or not (25.1%). GDPs were considered to have implant experience if they had started to and continued to provide implant treatments (n=213).

Table 4.1 Demographics of GDP respondents by implant provision status

GDPs overall (n=303)	Implant providers (n=227)	Non-providers (n=76)	p value
Male (n=164)	86.6%	13.4%	**<0.001***
Female (n=139)	61.2%	38.8%	
Practice owner (n=120)	61.7%	38.3%	**<0.001***
Non-owner (n=183)	95.0%	5.0%	
Private practice only (n=253)	81.0%	19.0%	**<0.001***
Any work in public sector (n=50)	44.0%	56.0%	
Metropolitan practice only (n=214)	75.2%	24.8%	0.728
Any rural/regional practice (n=68)	72.1%	27.9%	
Graduated from Australian university (n=255)	74.9%	25.1%	1.000
Graduated from non-Australian university (n=48)	75.0%	25.0%	

*significant difference p<0.05

Most GDP respondents rated the correlation between implant home hygiene and the health of the peri-implant tissues to be strong or very strong (88.4%) and none considered it to be very weak (Table 4.2). No statistically significant were found between implant providers and non-providers or by comparing highest training level differences (all p>0.05), but all formal postgraduate-trained GDPs indicated a strong or very strong correlation.

Given the example of a single implant crown, the most common implant hygiene techniques that GDPs included in their instructions to their patients were brushing, flossing and interdental brush use (Table 4.3). Non-providers were significantly less likely to give brushing, flossing, circumferential flossing or oral irrigation OHI compared to implant providers. They were also significantly more likely to recommend none of the OHI techniques at all (11.8%, p<0.001).

The highest level of implant training also influenced the types of OHI given. Dentists with formal postgraduate or CPD training were more likely to advise brushing, flossing, circumferential flossing or oral irrigation, compared to dentists who had not undertaken any implant training. The latter group were also significantly more likely to recommend none of the technique options (p<0.001).

Table 4.2 The strength of correlation between implant home hygiene and peri-implant health, as reported by GDPs

	GDPs overall (n=303)	Implant provision		Highest level of implant training			Providers with implant experience (n=213) by annual case volume		
		Implant providers (n=227)	Non-providers (n=76)	Formal postgraduate (n=24)	CPD training (n=223)	Neither (n=56)	>50 (n=18)	21-50 (n=46)	0-20 (n=149)
Very strong	41.9%	43.2%	38.2%	45.8%	41.7%	41.1%	50.0%	47.8%	41.6%
Strong	46.5%	44.5%	52.6%	54.2%	44.4%	51.8%	38.9%	39.1%	45.6%
Neutral	10.2%	10.6%	9.2%	0.0%	12.1%	7.1%	11.1%	8.7%	11.4%
Weak or very weak	1.3%	1.8%	0.0%	0.0%	1.8%	0.0%	0.0%	4.3%	1.3%
p value		0.583		0.481			0.790		

Table 4.3 Post-restoration implant-specific OHI given by GDPs, for a single implant crown

	GDPs overall (n=303)	Implant provision			Highest level of implant training				Providers with implant experience (n=213) by annual case volume			
		Implant providers (n=227)	Non-providers (n=76)	p value	Formal postgraduate (n=24)	CPD training (n=223)	Neither (n=56)	p value	>50 (n=18)	21-50 (n=46)	0-20 (n=149)	p value
Brushing	86.5%	89.9%	76.3%	**0.006***	95.8%	87.9%	76.8%	**0.046***	88.9%	84.8%	91.9%	0.285
Flossing	73.9%	78.0%	61.8%	**0.007***	79.2%	76.7%	60.7%	**0.048***	66.7%	84.8%	78.5%	0.283
Superfloss™	41.9%	40.5%	46.1%	0.422	33.3%	40.4%	51.8%	0.205	33.3%	47.8%	37.6%	0.405
Interdental brush	68.3%	68.7%	67.1%	0.778	70.8%	69.1%	64.3%	0.759	77.8%	78.3%	66.4%	0.243
Circumferential flossing	41.3%	44.5%	31.6%	0.059	41.7%	45.3%	25.0%	**0.019***	27.8%	54.3%	43.0%	0.144
Oral irrigation	17.8%	20.7%	9.2%	**0.024***	37.5%	17.9%	8.9%	**0.012***	38.9%	23.9%	15.4%	**0.044***
Mouthwash	14.5%	15.9%	10.5%	0.347	12.5%	13.5%	19.6%	0.482	22.2%	17.4%	12.1%	0.314
Topical agent	1.0%	1.3%	0.0%	0.575	0.0%	1.3%	0.0%	1.000	5.6%	2.2%	0.7%	0.118
None of the above	3.0%	0.0%	11.8%	**<0.001***	0.0%	0.4%	14.3%	**<0.001***	0.0%	0.0%	0.0%	n/a

*significant difference p<0.05

Among GDPs with implant experience (n=213), those who treat >50 cases per year recommended circumferential flossing less than others (27.8%) and there were trends of greater mouthwash or oral irrigation recommendation with higher case volume. When comparing implant providers by whether they perform only restorative or surgical procedures as well, the group performing both procedures were significantly more likely to recommend the use of oral irrigation (p=0.002), mouthwash (p=0.019) and topical agents (p=0.040) than the group only restoring implants.

Where respondents plan or provide the patient's implant treatment (n=238), a majority reported first giving OHI immediately following procedures that they complete (77.3%) or at the next review/recall appointment (10.1%) (Table 4.4). Only one in ten (10.5%) first provided OHI before implant treatment started, although this was higher for formal postgraduate-trained GDPs and those with the highest estimated case volume. Two non-providers did not give OHI for implants that they treatment planned.

Comparing the highest level of implant training, those with CPD as their highest level of training had a lower rate of discussing implant OHI before treatment begins (7.8%) compared to 25-33% of those with formal postgraduate or no training. For dentists with implant experience, greater discussion of implant OHI before beginning treatment was associated with increasing annual case volume, up to one third of the highest volume practitioners, and provision of surgical treatments (19.2% vs 3.6% of those only restoring implants).

Where patients present with pre-existing implants that were not treatment planned by the respondent, 69.6% of all respondents reported first giving OHI at the next appointment or next recall while 12.2% first give OHI only in the presence of pathological signs or symptoms (Table 4.5). Nearly one in five (18.2%) reported not giving any OHI to these patients (including those who refer the patient to or leave it to other practitioners for OHI). There were 31.6% of non-providers in this group, compared with 13.7% of implant providers, showing significantly different preferences between these groups (p=0.003). Those with no training were almost twice as likely (28.6%) to give no OHI to these patients compared to 15-17% of those with CPD or formal postgraduate training, while those with formal postgraduate training were three times less likely to give OHI only in the presence of pathological signs or symptoms (4.2%), although this was not statistically significant (p>0.05).

Table 4.4 Timing of first OHI provision, for implant treatment provided or planned by respondent (n=238)

	GDPs overall (n=238)	**Implant provision**			**Highest level of implant training**				**Providers with implant experience (n=213) by annual case volume**			
		Implant providers (n=227)	Non-providers (n=11)	p value	Formal postgraduate (n=24)	CPD training (n=205)	Neither (n=9)	p value	>50 (n=18)	21-50 (n=46)	0-20 (n=149)	p value
Immediately after procedure	77.3%	80.2%	18.2%	**<0.001***	75.0%	79.0%	44.4%	**0.022***	66.7%	78.3%	85.9%	**0.034***
At first review or recall	10.1%	7.9%	54.5%		0.0%	10.7%	22.2%		0.0%	10.9%	6.7%	
Only if signs/symptoms	0.8%	0.9%	0.0%		0.0%	1.0%	0.0%		0.0%	0.0%	0.7%	
Before treatment begins (volunteered answer)	10.5%	10.6%	9.1%		25.0%	7.8%	33.3%		33.3%	10.9%	6.0%	
Do not give instructions	1.3%	0.4%	18.2%		0.0%	1.5%	0.0%		0.0%	0.0%	0.7%	

*significant difference p<0.05

Table 4.5 Timing of first OHI provision, for implants not treatment planned by respondent

	GDPs overall (n=303)	**Implant provision**			**Highest level of implant training**				**Providers with implant experience (n=213) by annual case volume**			
		Implant providers (n=227)	Non-providers (n=76)	p value	Formal postgraduate (n=24)	CPD training (n=223)	Neither (n=56)	p value	>50 (n=18)	21-50 (n=46)	0-20 (n=149)	p value
At next appointment or recall	69.6%	73.1%	59.2%	**0.003***	79.2%	71.3%	58.9%	0.168	77.8%	87.0%	69.8%	0.185
Only if signs/symptoms	12.2%	13.2%	9.2%		4.2%	13.0%	12.5%		11.1%	8.7%	14.1%	
None given	18.2%	13.7%	31.6%		16.7%	15.7%	28.6%		11.1%	4.3%	16.1%	

*significant difference p<0.05

Over half (57.4%) of the 289 GDPs who reported giving implant OHI then repeated OHI at every general/periodontal recall or implant review appointment, while 27.0% only did so only the presence of pathological signs or symptoms, including a high proportion of non-providers (41.9%) (Table 4.6). Overall, 42.6% of GDPs who reported giving implant OHI did not repeat it routinely, and implant providers and non-providers had significantly different preferences for repeating OHI ($p<0.001$). Higher levels of training were significantly correlated to a more preventive approach ($p=0.002$). All of the GDPs with formal postgraduate training, 98.2% of those with CPD training (219 of 223) and 82.1% with neither (46 of 54), reported giving any implant OHI at all. Formal postgraduate trained dentists were most likely to either repeat OHI at every review/recall (70.8%) while those with lower levels of training (up to 39.1% of GDPs with no training) and lower annual case volume were more likely to repeat OHI only in the presence of pathological signs or symptoms, although the latter did not reach significance in the overall comparison between groups ($p>0.05$).

Among GDPs with implant experience, those who perform restorative treatment only were more likely to repeat OHI only in the presence of signs or symptoms (28.1%) compared to those who perform surgical treatment as well (8.2%), with a significantly different overall distribution between these groups for this question ($p=0.002$).

When given a choice of descriptive, demonstration and patient demonstration methods used to give OHI to patients, about 80% of dentists chose describing or showing OHI, while only 36.3% asked their patients to demonstrate after instruction (Table 4.7). There were no differences in OHI instruction methods when comparing implant providers and non-providers or by highest level of implant training ($p>0.05$). Among those with implant experience, the highest volume group were significantly less likely to show their patients OHI compared to others ($p=0.003$), while the lowest volume group were least likely to ask their patients to demonstrate after instruction ($p=0.019$).

Table 4.6 Greatest preferred frequency of implant OHI repetition by providers of implant OHI (n=289)

	GDPs overall (n=289)	Implant provision			Highest level of implant training				Providers with implant experience (n=213) by annual case volume			
		Implant providers (n=227)	Non-providers (n=62)	p value	Formal postgraduate (n=24)	CPD training (n=219)	Neither (n=46)	p value	>50 (n=18)	21-50 (n=46)	0-20 (n=149)	p value
Repeat at every recall or review	57.4%	58.6%	53.2%	**<0.001***	70.8%	56.2%	56.5%	**0.002***	66.7%	67.4%	55.7%	0.062
Repeat only once at next recall or review	13.5%	16.7%	1.6%		20.8%	15.5%	0.0%		27.8%	15.2%	17.4%	
Repeat only if signs/symptoms present	27.0%	22.9%	41.9%		8.3%	26.5%	39.1%		0.0%	17.4%	25.5%	
Do not repeat	2.1%	1.8%	3.2%		0.0%	1.8%	4.3%		5.6%	0.0%	1.3%	

*significant difference p<0.05

Table 4.7 Methods of OHI instruction used by providers of implant OHI (n=289)

	GDPs overall (n=289)	Implant provision			Highest level of implant training				Providers with implant experience (n=213) by annual case volume			
		Implant providers (n=227)	Non-providers (n=76)	p value	Formal postgraduate (n=24)	CPD training (n=219)	Neither (n=46)	p value	>50 (n=18)	21-50 (n=46)	0-20 (n=149)	p value
Describe to the patient	76.5%	77.5%	72.6%	0.071	79.2%	78.1%	67.4%	0.065	66.7%	78.3%	79.2%	0.436
Show the patient	84.1%	84.1%	83.9%	0.255	83.3%	84.9%	80.4%	0.233	61.1%	95.7%	83.2%	**0.003***
Ask the patient to demonstrate after instruction	36.3%	36.6%	35.5%	1.000	41.7%	35.2%	39.1%	0.704	44.4%	52.2%	30.2%	**0.019***

*significant difference p<0.05

Discussion

The vast majority of dentists (88.4%) in this study considered the correlation between implant home hygiene and the condition of the peri-implant tissues to be strong or very strong, corresponding to the current evidence in the literature showing greater peri-implant pathology in patients with poor general oral hygiene (Costa et al., 2012; Ferreira et al., 2006; Lindquist et al., 1997) or plaque at the implant site (Canullo et al., 2016; Roos-Jansåker et al., 2006). However, translating this knowledge to teaching their patients to perform implant oral hygiene did not appear to be as straightforward.

The quantity and quality of evidence to support optimal self-performed oral hygiene methods (including interdental cleaning) in patients with implants to prevent peri-implant disease is limited. Professional and patient-performed "mechanical plaque control alone should be considered the standard of care" in managing mucositis and OHI should be individualised for each patient (Heitz-Mayfield & Salvi 2018; Salvi & Ramseier 2015), but patient-performed hygiene in studies' control groups have varied widely (Salvi & Ramseier 2015). Minimum implant oral hygiene measures for preserving peri-implant health as a standard control in clinical research (Sanz & Chapple 2012) and clinical trials with long-term follow-up are needed (Grusovin et al., 2010; Louropoulou et al., 2014). Otherwise it appears that oral hygiene methods in research are assumed from the periodontal literature. This may not be appropriate as peri-implant tissues demonstrate greater inflammation and recover more slowly than do gingivae/teeth subjected to experimental plaque accumulation (Salvi et al., 2012).

Hence it was not surprising to find a mixed pattern of implant OHI preferences among the dentists surveyed, who may be extrapolating from their own clinical experience or the periodontal literature. However, while more dentists with higher levels of training or who are implant providers gave any hygiene advice, it was not necessarily of better quality, e.g. they recommended oral irrigation more although its quality of evidence is limited, while interdental brushes (with promising results in an initial study by Chongcharoen et al., and considered the most efficacious interdental cleaning method in a review of the periodontal literature by Sälzer et al. in 2015) were recommended similarly by all analysis groups. Whether or not the provision of OHI by practitioners is significant in the primary prevention of peri-implant disease is not established though it is considered the standard of care (Jepsen et al., 2015). Nevertheless, the provision of any OHI may lead to the habitual use of more convenient hygiene methods, as was found with interdental brush use in an observational study of patients with full-arch implant-retained prostheses given personalised OHI, although the gingival condition did not improve (Kreve et al., 2016). It is therefore a concern that 11.8% of non-providers and 14.3% of GDPs

with no post-graduation implant training in this study do not give any implant-specific OHI, despite equally understanding the strong relationship between home hygiene and peri-implant health. These practitioners may be assuming others have responsibility for OHI or they may not want to contradict others with greater knowledge. Alternatively, implant training, personal involvement in treatment and the patient's prior investment may instil greater preventative motivation.

There is little to no literature on either OHI timing or its impact on implant oral hygiene performance or peri-implant outcomes. This study established baseline data on dentists' preferences for the first time that they give implant OHI, with the GDPs surveyed demonstrating a generally preventive approach, although this was stronger for implants that they plan or provide compared to pre-existing implants that they did not plan.

While only low numbers of non-providers reported treatment planning implants in this study, almost one-fifth of them never give any implant OHI to these patients. Pre-treatment discussion of additional hygiene needs should be considered part of informed consent by treatment planners, as demonstrated most strongly by the dentists with the highest annual case volume in this study (interestingly, CPD-trained GDPs in this study were least likely to discuss OHI before implant treatment, whereas GDPs with no training were perhaps more vigilant). Almost one-fifth of all GDPs in this study never give implant OHI to patients with pre-existing implants planned by other practitioners, including significantly more non-providers and GDPs with no implant training. These patterns could leave significant numbers of patients unaware of the care requirements.

The literature strongly recommends ongoing monitoring of oral hygiene around implants as part of regular maintenance (Renvert & Polyzois 2015). Repeated and individualised OHI is recommended as the key to periodontal disease prevention (Tonetti et al., 2015; Worthington et al., 2013) and although peri-implant recommendations are not available it is a concern that over 40% of GDPs in this study reported not repeating implant OHI routinely, with 27.0% only repeating it when signs or symptoms of pathology are present, including 41.9% of non-providers and 39.1% of GDPs with no training. As the signs and symptoms of pathology can be prevented by hygiene methods, a large group clearly did not maintain a precautionary approach. A more preventative attitude correlated strongly in this study to higher-level implant training.

Systematic reviews recommending OHI repetition in the periodontal literature (Tonetti et al., 2015; Worthington et al., 2013) do not, however, specify the effectiveness of various communication and teaching methods. In this study, showing the patient was the most popular method, in agreement with a study where intra-oral demonstration improved oral hygiene

indices in comparison to written information and explanation (Harnacke et al., 2012). Intra-oral camera usage improved outcomes again compared to demonstration (Willershausen et al., 1999) and is to be recommended for clinical use. An internal locus of control is important in effecting behavioural change related to oral hygiene (Galgut et al., 1987; Ower 2003), and asking the patient to demonstrate the technique may enhance this, with 36.3% of GDPs surveyed doing so; no published studies on this OHI method are available. Understanding of disease processes and personal benefit improved hygiene compliance while patient-centred goal-setting, planning and self-monitoring significantly improved clinical outcomes (Fjellström et al., 2010; Jonsson et al., 2006; Newton & Asimakopoulou 2015; Philippot et al., 2005; Renz & Newton 2009). These strategies should be included in implant OHI and in implant training programs, with implant-specific outcomes confirmed with further research.

The results of this study indicate the need to improve delivery of implant-specific oral hygiene promotion information to all dentists in Australia, particularly those who are not attending continuing education programs in implant dentistry or not providing implant treatment, whether due to a lack of interest in the area or otherwise. All GDPs are certain to encounter patients with implants and should be able to provide preventative advice and long-term implant maintenance, regardless of any perception of responsibility being held by other practitioners. As an example, informative newsletter literature or webinars could be developed by dental associations, to reach dentists who may not attend any implant training. Coverage of the current evidence should also be comprehensive within implant training programs of all levels, outlining limitations and the need to stay abreast of future developments. The challenges of the collaborative multi-practitioner nature of implant treatment and ongoing maintenance should be emphasized, with OHI responsibilities and specific techniques addressed in correspondence between practitioners. It is preferable that patients receive OHI and preventive advice from multiple practitioners rather than all of them each assuming that another is responsible.

As it stands, regardless of each practitioner's role or the size of the treatment team, implant OHI should be discussed with the patient during treatment planning, tailored to and demonstrated at completion of the hygiene-accessible prosthesis and reinforced regularly in an individualised recall program. Patients should be reminded that implants require particular care even when completely successful and asymptomatic. Compliance with recommended supportive periodontal maintenance frequency after specialist periodontitis treatment was significantly higher in patients with implants (Cardaropoli & Gaveglio 2012) and a similarly more preventive mindset may be found regarding hygiene compliance.

Data regarding self-reported preferences for OHI techniques, timing, frequency and methods of communication for overall oral hygiene (let alone involving implants) by dental practitioners is not known to have been previously surveyed or published and therefore this study's results cannot be compared with others. This study was limited by lack of access to a national register of dentists, and the response rate of 2.1% of the registered GDP workforce in Australia at the time (AHPRA 2016) was lower than 7.6% in a similar implant-related survey of Australian dentists (Guo et al., 2017). Mailed surveys of dentists receive better response rates than web-based surveys (26% vs 11%) (Hardigan et al., 2012) and randomly selected samples from national dentist registers resulted in response rates of 43-54% in other countries (Murray et al., 2016; Ng et al., 2011; Patel et al., 2010). Nevertheless, the demographic characteristics of the survey's respondents were generally similar to available statistics of employed dentists in Australia (including specialists) last reported in 2013 (AIHW et al., 2016), although the proportion of females and Australian university graduates were slightly higher in this study. Dentists with an interest in implant dentistry may have been more likely to complete this survey, and non-response bias cannot be excluded – effects found in the non-provider and no training groups might even be underestimated. The self-reporting nature of a survey may also have documented what the respondents believed to be ideal rather than truly representing their clinical practice.

Further research is warranted regarding dentists' OHI provision and preferences in other countries and to follow any changes resulting from the continued evolution of implant dentistry education and information distribution, parallel to the ongoing establishment of evidence for optimal implant hygiene practices and instruction methods.

Conclusion

The dentists surveyed in this study had good awareness of the correlation between implant hygiene and peri-implant health, and advised common hygiene techniques in a generally preventative fashion particularly for implants that they treatment planned. While implant providers and GDPs with higher levels of training were more involved in giving implant OHI, over 40% of respondents did not repeat OHI routinely. Greater promotion of implant OHI in the dental profession is indicated, particularly to reach GDPs with lower interest in implant dentistry, but also within all implant training programs. Clarity of correspondence in multi-practitioner management should also be emphasised. The establishment of a strong scientific basis for implant-specific oral hygiene, its delivery and frequency as well as research into clinical implementation by practitioners should be continued.

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Chapter 5: Dentists' implant maintenance preferences. Part II: diagnosis and treatment

A manuscript submitted to *Journal of Oral Implantology.*

Abstract

The aim of the present study was to investigate the diagnostic and treatment preferences of Australian dentists in professional implant maintenance. Three hundred and three general dental practitioners (GDPs) completed an online questionnaire, indicating their preferred implant diagnostic procedures and frequency, factors they consider in determining review periods, when they would review peri-implant pathology, their provision of peri-implant treatments and preferred instruments/techniques. During implant checks, over 90% of GDPs assessed oral hygiene and soft tissue appearance, 82.1% assessed pocket depths and 56.0% recession, while 10.7% only performed diagnostics after detecting clinical signs/symptoms. In determining review frequency, 91.4% considered oral hygiene, 79.4% periodontal/peri-implant history and 55.7% medical history. Supragingival/superficial prosthesis cleaning was performed by 77.9% of GDPs, 35.0% performed subgingival surface debridement, 41.9% treated peri-implant mucositis and 18.2% treated peri-implantitis. Around 15% did not treat nor refer peri-implant mucositis or peri-implantitis, including significantly more dentists who do not provide implant treatment and those with no implant training, while 19.1% did not use any implant-specific instruments/techniques in maintenance. GDPs with more implant training and treatment experience provided more complex maintenance procedures.

Introduction

Dental implants are a treatment modality for the replacement of missing or lost teeth, with success (Moraschini et al., 2015) and survival rates (Jung et al., 2012; Pjetursson et al., 2012b) above 90%, placed in the millions annually around the world (American Dental Association 2007). Systematic reviews also demonstrate significant rates of plaque-induced peri-implant pathology, namely peri-implant mucositis (weighted mean prevalence of 43-46.83% at a patient level) and peri-implantitis (weighted mean prevalence of 19.83-22% at a patient level) (Derks & Tomasi 2015; Lee et al., 2017), the latter of which is positively correlated to time in function (Derks & Tomasi 2015) and has an accelerating rate of progression (Derks et al., 2016b; Fransson et al., 2010). Meanwhile, healthy peri-implant status has rarely been reported (Derks & Tomasi 2015).

Strong evidence exists for some peri-implant disease risk factors including poor oral hygiene (Canullo et al., 2016; Costa et al., 2012; Ferreira et al., 2006; Lindquist et al., 1997; Roos-Jansåker et al., 2006a; Serino & Ström 2009) and periodontal disease history, in particular current periodontal disease activity (Canullo et al., 2016; Costa et al., 2012; Derks et al., 2016a; Ferreira et al., 2006; Marrone et al., 2013), the presence of residual deep periodontal pockets (Cho-Yan Lee et al., 2012; Pjetursson et al., 2012a) or the condition previously categorised as generalised aggressive periodontitis (Swierkot et al., 2012). Lack of adherence to a recommended regular supportive maintenance program is also associated with poorer outcomes (Costa et al., 2012; Hardt et al., 2002; Monje et al., 2016; Rinke et al., 2011; Roccuzzo et al., 2012; Roccuzzo et al., 2010). Tobacco smoking is a strong risk factor for implant failure (Anner et al., 2010; Bain & Moy 1993; DeLuca et al., 2006; Vervaeke et al., 2012; Wilson & Nunn 1999), which may be dosage dependent (Sanchez-Perez et al., 2007) and occur in the early or intermediate term rather than long-term (Moraschini & Barboza 2015). Diabetes mellitus (Monje et al., 2017) and other medical factors such as cardiovascular disease (Renvert et al., 2014), metabolic syndrome (Schwarz et al., 2015b) and bisphosphonate therapy (Chrcanovic et al., 2016) are still to be further investigated for associations to peri-implant disease.

With a reported rate of 33.6% of mechanical and/or biological complications in the first 5 years occurring in implant-supported fixed partial dentures reported in a systematic review (Pjetursson et al., 2012b), a lifelong professional recall and maintenance regimen has been strongly recommended (Bidra et al., 2016a; Pjetursson et al., 2012b; Wilson et al., 2014). Maintenance consists of clinical evaluation of the peri-implant tissues to diagnose peri-implant health, mucositis or peri-implantitis, subsequent management and ongoing prevention. Diagnostic procedures should include, at a minimum, visual inspection, pocket probing and assessment of bleeding on probing and radiographic bone level (Renvert et al., 2018). Whether

these procedures are performed by clinicians in the general community as recommended has not been studied. Evidence for the appropriate frequency of maintenance is limited (Bidra et al., 2016a) and while a minimum frequency has been recommended at, variably, 6 months (Bidra et al., 2016b) or yearly (Renvert et al., 2018), this uncertainty may affect current clinical practice.

Professional treatment protocols to prevent peri-implant mucositis have not been studied or standardised (Jepsen et al., 2015). Mechanical plaque control alone is the cornerstone of mucositis management (Salvi & Ramseier 2015), and professional removal using ultrasonic or hand instruments of various materials (Blasi et al., 2016; Heitz-Mayfield et al., 2011; Ji et al., 2014; Maximo et al., 2009; Porras et al., 2002; Riben-Grundstrom et al., 2015; Thöne-Mühling et al., 2010) and/or glycine powder air polishing (Blasi et al., 2016; Ji et al., 2014; Mussano et al., 2013; Riben-Grundstrom et al., 2015) has been studied. Non-surgical treatment alone is likely ineffective in treating peri-implantitis (Muthukuru et al., 2012; Renvert et al., 2008b; Romanos & Weitz 2012). Surgical treatment of peri-implantitis has encompassed a large variety of protocols and combinations of debridement instruments, decontamination solutions, antibiotics, resective or regenerative techniques (Chan et al., 2014; Heitz-Mayfield & Mombelli 2014; Mombelli et al., 2012; Renvert et al., 2012). The types of peri-implant conditions treated by dentists in the general community and their technique preferences are unknown and may vary widely given the lack of consensus.

The aims of this study were therefore to investigate the implant diagnostic procedures and frequency preferred by dentists in Australia, the maintenance types and treatment techniques they provide to manage biological complications, to assess possible influencing factors such as education sources and implant treatment experience, and to determine future directions for implant dentistry training and peri-implant research.

Methods

Using an online questionnaire (Appendix II) on SurveyMonkey™ (San Mateo, CA, USA), dentists were surveyed about their provision of implant diagnostic review procedures, their preferred frequency for implant review generally as well as in the presence of pathological signs and symptoms, and patient factors influencing their preferred review frequency. They also indicated their role in implant maintenance, their provision of types of professional implant maintenance treatments and the instruments or techniques used.

Dentists registered in Australia were eligible to participate in the survey, which was distributed electronically by the Australian Dental Association state branches, the Australian Society of

Periodontology and the Royal Australasian College of Dental Surgeons to their members, as access to the national register was unavailable. A prize draw was held to encourage participation. This study was approved by the Health Sciences Human Ethics Sub-Committee of the University of Melbourne (Ethics ID 1443625) and data collected between March and September 2016.

Data were described and comparisons made between implant providers and non-providers, the highest level of implant training dentists had attended after completing their undergraduate/graduate dental degree (formal postgraduate qualification, continuing professional development (CPD) or neither), their decade of graduation (≤1985, 1986-1995, 1996-2995, 2006-2015), whether they graduated from an Australian university or not and their location of practice (metropolitan areas only or any work in rural/regional areas). Dentists who had performed implant treatment previously were compared by their self-estimated annual implant case volume (<20, 21-50, >50 cases) and whether they provided restorative treatment only or also performed surgical implant placement. These factors were hypothesized to influence implant diagnostic review and professional maintenance preferences. Data were described and analysed using the statistical software SPSS version 23.0 (SPSS, Chicago IL, USA) to perform Fisher exact tests to compare between categorical variables ($p<0.05$). An independent statistical assessment of the findings was conducted.

Results

Three hundred and three Australian-registered general dentists participated in the survey. The gender, practice-ownership, practice sector and location, and country of graduation characteristics of the GDP group are shown in Table 5.1, compared to their implant treatment provision status.

Almost all GDPs (99.7%) believed GDPs have a role to play in implant maintenance, while 97.0% believed they themselves have a role in implant maintenance (Table 5.2). GDPs not providing implants and those with no implant training were significantly less likely to see themselves as having a role in implant maintenance.

Implant checks (i.e. implant-specific diagnostic procedures) were not performed by 4.0% of the respondents, including significantly more of the GDPs not providing implants (14.5%) and those with no implant training (17.9%) (Table 5.2, $p<0.001$). Of the 291 GDPs who performed implant diagnostics, 87.6% did so at every recall or implant review appointment, but 10.7% only did so if peri-implant signs/symptoms were present, including 16.9% of the GDPs not providing

implants. There were no significant differences in preferred frequency of implant diagnostics according to highest level of implant training or annual case volume (all p>0.05).

Table 5.1 Demographics of GDP respondents overall (n=303)

GDPs overall (n=303)	Implant providers (n=227)	Non-providers (n=76)	p value
Male (n=164)	86.6%	13.4%	**<0.001**
Female (n=139)	61.2%	38.8%	
Practice owner (n=120)	61.7%	38.3%	**<0.001**
Non-owner (n=183)	95.0%	5.0%	
Private practice only (n=253)	81.0%	19.0%	**<0.001**
Any work in public sector (n=50)	44.0%	56.0%	
Metropolitan practice only (n=214)	75.2%	24.8%	0.728
Any rural/regional practice (n=68)	72.1%	27.9%	
Dental degree from Australian university (n=255)	74.9%	25.1%	1.000
Dental degree from non-Australian university (n=48)	75.0%	25.0%	

*significant difference p<0.05

During a routine implant check, GDPs most commonly assessed oral hygiene around the implant (97.3%) and the visual appearance of soft tissues (94.5%), followed by bleeding on probing (88.7%) and pocket depth probing (82.1%) (Table 5.3). Recession measurement (56.0%) was performed least out of the available answer choices. Implant providers were significantly more likely to assess the soft tissues than non-providers (p=0.003). The highest level of implant training or annual case volume did not significantly affect the types of diagnostic procedures performed.

Radiographs to assess the bone level or bony defects around an implant may not be taken at every implant check, with 40.2% of GDPs who performed implant diagnostics taking “a routine radiograph of an established implant” every 24 months, 19.9% every 12 months and 32.6% doing so only in the presence of pathological signs or symptoms.

GDPs with formal postgraduate implant training (37.5% of 24) or the highest case volume of >50 implants per year (44.4% of 18) were twice as likely as their colleagues to take radiographs every 12 months, while those with no training (39.1%) or the lowest annual case volume (33.6% of 149) were about twice as likely as their formal postgraduate-trained (20.8%) or highest case volume colleagues (16.7%) to only take radiographs in the presence of signs/symptoms. However, no significant differences in overall preference distributions were found when comparing implant provision status, highest level of implant training or annual case volume (all p>0.05).

Table 5.2 GDPs' self-reported role in and clinical performance of implant diagnostics and maintenance

	GDPs overall (n=303)	**Implant provision**			**Highest level of implant training**			
		Implant providers (n=227)	Non-providers (n=76)	p value	Formal postgraduate (n=24)	CPD training (n=223)	Neither (n=56)	p value
GDPs who believe they have a role to play in implant maintenance	97.0%	99.6%	89.5%	**<0.001***	100.0%	98.7%	89.3%	**0.004***
GDPs who do not perform any implant-specific diagnostic procedures	4.0%	0.4%	14.5%	**<0.001***	0.0%	0.9%	17.9%	**<0.001***
GDPs who do not use any implant-specific maintenance instruments/techniques	19.1%	13.7%	35.5%	**<0.001***	8.3%	15.2%	39.3%	**<0.001***

*significant difference p<0.05

Table 5.3 Usage of implant-specific diagnostic procedures by GDPs who perform them (n=291)

	GDPs overall (n=291)	**Implant provision**			**Highest level of implant training**			
		Implant providers (n=226)	Non-providers (n=65)	p value	Formal postgraduate (n=24)	CPD training (n=221)	Neither (n=46)	p value
Oral hygiene assessment around implant	97.3%	97.8%	95.4%	0.383	100.0%	96.8%	100.0%	0.536
Soft tissue visual assessment	94.5%	96.9%	86.2%	**0.003***	100.0%	95.5%	89.1%	0.140
Pocket depth probing	82.1%	81.0%	86.2%	0.462	70.8%	82.8%	87.0%	0.276
Assessment of bleeding on probing	88.7%	88.5%	89.2%	1.000	83.3%	88.2%	95.7%	0.198
Assessment of suppuration	73.9%	72.6%	78.5%	0.423	70.8%	74.2%	76.1%	0.945
Recession measurement	56.0%	55.3%	58.5%	0.673	62.5%	54.8%	60.9%	0.655
Assessment of implant mobility	70.4%	71.2%	67.7%	0.644	70.8%	70.1%	71.7%	0.949

*significant difference p<0.05

When deciding on an appropriate implant check frequency, the patient's standard of oral hygiene was the most common factor (91.4%) considered by the GDPs who perform implant diagnostics (Table 5.4). This was followed by "previous periodontal or peri-implant history" (79.4%) while medical history was only considered by 55.7% of GDPs. No statistically significant differences were found between GDPs by highest level of implant training or implant provision status (all $p>0.05$). However, earlier graduation decade groups were less likely to consider previous periodontal/peri-implant history or the severity of the existing peri-implant condition compared to than more recent graduates (Table 5.4).

In the presence of signs or symptoms of a peri-implant condition, 55.7% of the GDPs who performed implant diagnostics preferred to repeat an implant check in 3 months or less, while 27.8% reviewed at 6 months and 8.6% would refer (Table 5.5). GDPs not providing implants were more likely to make a referral (15.4%) rather than nominate a preferred review period, compared to implant providers, with significantly different preferences overall ($p=0.005$). Almost 90% of formal postgraduate- or CPD-trained GDPs reviewed in 6 months or less compared to 63% of those with no training. CPD-level trained GDPs were much less likely (6.3%) to refer in the case of pathological signs/symptoms compared to the other groups (15-17%). Overall there was a significant difference in preference distribution according to highest implant training level ($p=0.004$).

In the provision of broad categories of implant maintenance and treatment of peri-implant pathology, 77.9% of all GDP respondents provided "supragingival/superficial implant prosthesis cleaning", 35.0% performed "subgingival debridement of implants/implant surface", 41.9% treated peri-implant mucositis and 18.2% treated peri-implantitis (Table 5.6). For the diagnosed conditions, 14.5% did not treat mucositis nor provide referral to another practitioner, and 16.5% did not treat peri-implantitis nor provide referral to another practitioner. GDPs not providing implants and those with lower implant training provided significantly less treatment than their counterparts, and were also more likely not to treat nor refer mucositis; 26.8% of those with no training did not treat nor refer peri-implantitis although it did not reach significance when compared with the other higher training groups. Significantly, GDPs who trained outside of Australia were twice as likely not to treat nor refer mucositis (25.0% vs 12.5% Australian graduates, $p=0.041$) and peri-implantitis (29.2% vs 14.1% Australian graduates, $p=0.018$). Among GDPs with implant experience, those who had higher annual case volumes or performed implant surgery in addition to restoration were much more likely to treat mucositis and peri-implantitis (both $p<0.001$) but there were no significant differences in these group comparisons for those who did not treat nor refer (all $p>0.05$).

Table 5.4 Factors which help GDPs who perform implant diagnostics (n=291) to decide on an implant check frequency

	GDPs overall (n=291)	Implant provision			Highest level of implant training				Decade of graduation				
		Implant providers (n=226)	Non-providers (n=65)	p value	Formal postgraduate (n=24)	CPD training (n=221)	Neither (n=46)	p value	≤1985 (n=58)	1986-1995 (n=45)	1996-2005 (n=67)	2006-2015 (n=133)	p value
Patient's standard of oral hygiene	91.4%	92.9%	86.2%	0.128	95.8%	92.8%	82.6%	0.064	93.0%	91.1%	90.9%	91.1%	0.971
Previous periodontal/peri-implant history	79.4%	81.9%	70.8%	0.057	70.8%	82.4%	69.6%	0.058	68.4%	73.3%	77.3%	87.8%	**0.011***
Medical history	55.7%	55.8%	55.4%	1.000	45.8%	57.9%	52.2%	0.439	48.9%	57.6%	56.9%	55.7%	0.798
Severity of existing peri-implant condition	72.5%	71.7%	75.4%	0.637	83.3%	71.0%	73.9%	0.491	63.2%	62.2%	81.8%	75.6%	**0.039***
Probing depths around the implant	65.3%	65.5%	64.6%	0.884	58.3%	67.4%	60.9%	0.485	59.6%	60.0%	63.6%	70.7%	0.373

*significant difference p<0.05

Table 5.5 Preferred implant review period in the presence of peri-implant signs or symptoms, by GDPs who perform implant diagnostics (n=291)

	GDPs overall (n=291)	Implant provision			Highest level of implant training			
		Implant providers (n=226)	Non-providers (n=65)	p value	Formal postgraduate (n=24)	CPD training (n=221)	Neither (n=46)	p value
Do not do implant check	1.4%	0.4%	4.6%	**0.005***	0.0%	0.5%	8.7%	**0.004***
3 months or less	55.7%	58.8%	44.6%		58.3%	57.5%	43.5%	
6 months	27.8%	28.3%	26.2%		20.8%	30.3%	19.6%	
12 months	4.8%	3.5%	9.2%		4.2%	3.2%	13.0%	
Varies depending on factors	1.7%	2.2%	0.0%		0.0%	2.3%	0.0%	
Would refer	8.6%	6.6%	15.4%		16.7%	6.3%	15.2%	

*significant difference p<0.05

Table 5.6 Types of peri-implant procedures and treatments provided by GDPs

	GDPs overall (n=303)	**Implant provision**			**Highest level of implant training**				**Providers with implant experience performing:**		
		Implant providers (n=227)	Non-providers (n=76)	p value	Formal postgraduate (n=24)	CPD training (n=223)	Neither (n=56)	p value	Restoration only (n=139)	Surgery and restoration (n=73)	p value
Supragingival/superficial implant prosthesis cleaning during recall/periodontal maintenance	77.9%	81.1%	68.4%	**0.026***	87.5%	79.4%	67.9%	0.095	80.6%	86.3%	0.345
Subgingival debridement of implants/implant surface during recall/periodontal maintenance	35.0%	41.0%	17.1%	**<0.001***	45.8%	39.0%	14.3%	**0.001***	41.7%	45.2%	0.663
Treatment of peri-implant mucositis	41.9%	48.9%	21.1%	**<0.001***	75.0%	45.7%	12.5%	**<0.001***	41.7%	69.9%	**<0.001***
Do not treat nor refer for peri-implant mucositis	14.5%	11.0%	25.0%	**0.004***	4.2%	12.1%	28.6%	**0.004***	11.5%	11.0%	1.000
Treatment of peri-implantitis	18.2%	23.3%	2.6%	**<0.001***	50.0%	18.4%	3.6%	**<0.001***	14.4%	45.2%	**<0.001***
Do not treat nor refer for peri-implantitis	16.5%	15.0%	21.1%	0.217	12.5%	14.3%	26.8%	0.088	15.1%	16.4%	0.843

*significant difference p<0.05

Among those GDPs who used any implant-specific instruments/techniques during professional maintenance or peri-implant treatment (n=245), flossing (76.3%) and rubber cup/brush with prophylaxis paste (73.9%) were the most popular (Table 5.7). Non-providers were significantly less likely to use adjunctive antimicrobials and surgical techniques than implant providers. GDPs working in rural/regional areas were significantly more likely to perform surgical debridement/recontouring (28.3%) than their metropolitan counterparts (11.0%) (p=0.004), the only significant difference between these two groups in this study. Australian graduates were more likely to use stainless steel ultrasonic scalers (40.7%, p=0.041) than dentists who graduated in other countries (22.2%), the only difference found between these two groups in this study.

By graduation decade, the most recent graduates (2006-15) used stainless steel ultrasonics more (49.0%) than their older colleagues (29-31%) (p=0.030) while more 1986-95 graduates (52.8%) used topical antimicrobials than the other decade groups (26-31%) (p=0.041).

Unsurprisingly, higher levels of implant training significantly correlated to greater use of surgical interventions and systemic antibiotics. Among dentists with implant experience, those performing surgical as well as restorative procedures used significantly more air-powder polishing (p<0.001), antimicrobials (p=0.029), local antibiotics (p=0.021) and systemic antibiotics (p<0.001), and performed more surgical treatments (p<0.001). These differences were largely found according to increasing annual case volume as well.

Implant-specific maintenance instruments/techniques were not used at all by 19.1% of the respondents, including significantly more of the GDPs not providing implants (35.5%) and those with less implant training (Table 5.2, all p<0.001). Among the 213 GDPs with implant experience, 15.4% of the 149 treating 0-20 cases per year did not use any implant-specific maintenance instruments/techniques compared to 2.2% of the 21-50 case group (n=46) and 5.6% of the >50 case group (n=18) (p=0.026).

Table 5.7 Usage of implant-specific maintenance instruments/techniques by GDPs who perform them (n=245)

	GDPs overall (n=245)	Implant provision			Highest level of implant training				Providers with implant experience performing:		
		Implant providers (n=196)	Non-providers (n=46)	p value	Formal postgraduate (n=22)	CPD training (n=189)	Neither (n=34)	p value	Restoration only (n=121)	Surgery and restoration (n=67)	p value
Floss	76.3%	75.5%	79.6%	0.707	81.8%	76.2%	73.5%	0.806	77.7%	73.1%	0.482
Rubber cup/brush with prophylaxis paste	73.9%	74.5%	71.4%	0.717	72.7%	74.6%	70.6%	0.844	77.7%	67.2%	0.122
Air-powder polishing/prophylaxis	9.8%	12.2%	0.0%	**0.006***	13.6%	10.6%	2.9%	0.329	5.8%	25.4%	**<0.001***
Stainless steel ultrasonic scaler	38.0%	39.3%	32.7%	0.416	31.8%	39.7%	32.4%	0.624	39.7%	37.3%	0.876
Plastic ultrasonic tips	26.5%	26.0%	28.6%	0.720	40.9%	25.9%	20.6%	0.234	22.3%	32.8%	0.122
Stainless steel curettes	15.5%	15.3%	16.3%	0.828	27.3%	13.8%	17.6%	0.206	13.2%	17.9%	0.399
Plastic/carbon curettes	43.3%	44.4%	38.8%	0.522	36.4%	47.6%	23.5%	**0.024***	43.0%	49.3%	0.446
Titanium curettes	12.7%	14.8%	4.1%	0.053	27.3%	12.2%	5.9%	0.074	12.4%	20.9%	0.142
Topical antimicrobials	32.2%	35.7%	18.4%	**0.026***	50.0%	34.4%	8.8%	**0.001***	31.4%	47.8%	**0.029***
Local antibiotics	9.8%	12.2%	0.0%	**0.006***	18.2%	10.1%	2.9%	0.156	8.3%	20.9%	**0.021***
Systemic antibiotics	18.4%	21.9%	4.1%	**0.003***	50.0%	17.5%	2.9%	**<0.001***	13.2%	40.3%	**<0.001***
Bone augmentation	6.1%	7.7%	0.0%	**0.046***	18.2%	5.8%	0.0%	**0.023***	0.8%	20.9%	**<0.001***
Open (surgical) debridement and/or recontouring	14.7%	17.9%	2.0%	**0.003***	50.0%	12.7%	2.9%	**<0.001***	3.3%	46.3%	**<0.001***

*significant difference p<0.05

Discussion

General dentists are mainly responsible for routine preventive dentistry in Australia, and respondents' perception of dental implant maintenance seems to be similar in this study. Compared to 66% in a small survey of dentists in the UK (Gibson & Barclay 2006), almost all GDPs in this study (97.0%) believe they have a role to play in implant maintenance, but this did not appear to translate completely into clinical practice.

Diagnostic tests are a critical part of ongoing monitoring, whereby peri-implant parameters are compared with baseline or previous records over time to detect any development of pathology. Of GDPs who perform implant checks in this study, 10.7% reported only doing so in the presence of pathological signs/symptoms rather than routinely. Almost all assessed local oral hygiene and soft tissue condition, as recommended in the literature (Renvert et al., 2018), but decreasing proportions performed pocket depth probing (82.1%), assessed suppuration (73.9%) and measured recession (56.0%); the latter should form part of probing depth assessment (Berglundh et al., 2018). It is a concern that at least one in five GDPs surveyed (on the above findings) may have a less than preventive approach, as clinical signs may only be detected upon performing diagnostic procedures, and changes in probing depth or radiographic bone levels may be the only sign of disease development or progression (Heitz-Mayfield 2008; Renvert et al., 2018).

The most recent peri-implant health and disease diagnostic criteria (Renvert et al., 2018) outlined that inflammatory changes should be present in addition to bleeding on probing to confirm a disease state. However, whether peri-implant disease can develop in the absence of signs (assessed only at the time of clinical examination) has not been established or excluded and requires further investigation, although considered to be rare in a recent review (Schwarz et al., 2018). In this study, GDPs not providing implants were particularly less likely to assess the soft tissues visually, whereupon even inflammatory changes present at the time of examination might be missed. Otherwise, no differences were found in implant check procedures and preferred frequency between GDPs in this study with different levels of training and treatment experience, indicating the need to promote a preventative attitude across the entire profession.

Radiographs assessing peri-implant bone levels should be taken when signs of clinical inflammation are detected, for comparison with baseline radiographs with the prosthesis in place (Renvert et al., 2018), ideally after remodelling (Sanz & Chapple 2012). Otherwise there are no standardised recommendations for radiograph frequency in the literature (Armitage & Xenoudi 2016), although previous recommendations for longitudinal clinical research (not

further elaborated upon in the literature) specified two-yearly reviews until 5 years and 5-yearly thereafter if bone levels are stable (Salvi & Lang 2004). It is not surprising to find a range of preferences in this study with 24-monthly and in the presence of pathological sign/symptoms the most popular, in general agreement with the available literature. Formal postgraduate-trained GDPs and those with the highest case volume may have demonstrated higher preference for 12-monthly radiographs if they were more concerned about the success of implants they had placed.

Consideration of patient-specific risk factors is critical in determining individualised review periods for each patient, as recommended (Armitage & Xenoudi 2016). While over 90% of GDPs surveyed considered the patient's oral hygiene, in agreement with the strong evidence for the role of poor plaque control in peri-implant mucositis (Heitz-Mayfield & Salvi 2018) and peri-implantitis (Schwarz et al., 2018), only 79.4% considered periodontal disease or peri-implant disease history, a concern given the strong evidence (Schwarz et al., 2018) for a link between periodontal disease history and peri-implantitis, specifically, currently active periodontitis (Canullo et al., 2016; Costa et al., 2012; Derks et al., 2016a; Marrone et al., 2013) or residual deep pockets (Cho-Yan Lee et al., 2012; Pjetursson et al., 2012a); peri-implantitis is also difficult to treat (Armitage & Xenoudi 2016) and known to recur after treatment (Esposito et al., 2012; Heitz-Mayfield & Mombelli 2014). Dentists who graduated earlier were less likely to take periodontal/peri-implant history into account in this study, perhaps reflecting the standardised recommended inclusion of implant dentistry in the Australian dental degree curriculum only in more recent years (Mattheos et al., 2010). Medical history was considered by only 55.7% of GDPs surveyed, a low figure given smoking (Rinke et al., 2011; Roos-Jansåker et al., 2006b) and poorer diabetes mellitus control (Monje et al., 2017; Tawil et al., 2008) have been significantly associated with peri-implant disease, although a recent review found that the evidence is not yet conclusive (Schwarz et al., 2018). Other possible associations between peri-implant disease and systemic conditions such as cardiovascular disease (Krennmair et al., 2016; Renvert et al., 2014), previous radiotherapy (Karbach et al., 2009) and increased age (Renvert et al., 2014) have also been deemed worthy of further investigation. Practitioners must stay abreast of continuing research on these common systemic factors.

Bone loss in peri-implantitis has been shown to vary between individuals, progress in a non-linear fashion and accelerate over time (Derks et al., 2016b; Fransson et al., 2010), while the speed and pattern of overall disease progression, the modifying impact of risk factors and how quickly treatments effects become apparent are not established in the literature. Given this uncertainty, it seems reasonable that over half of GDPs in this study would review a patient with peri-implant pathology within 3 months, similarly to the minimum recommended review period

after active periodontitis therapy (Sanz et al., 2015). Compared to higher training levels, GDPs with no training in this study were more likely to review at 12 months, which may be too long, while those with CPD training were least likely to refer to another practitioner compared to lower or higher training levels, perhaps demonstrating a lower concern for the potential severity of peri-implant disease. As 3 weeks has been shown to be an insufficient time for inflammatory markers to completely resolve after mucositis treatment (Heitz-Mayfield et al., 2011; Schwarz et al., 2015a), further research is needed to determine if there is an optimal time period for assessing disease resolution or progression and therefore ongoing management needs. The development of evidence correlating clinical parameter thresholds to efficacy of escalating treatment protocols, as was suggested in the Cumulative Interceptive Supportive Therapy protocol (Lang et al., 2000), would also provide practitioners with clearer clinical guidelines.

While surveys of periodontists in the USA (Papathanasiou et al., 2016), Australia and the UK (Mattheos et al., 2012) have outlined their preferences in armamentarium and surgical procedures, similar literature is not available on the relative provision of implant maintenance services by general dentists or their preferred instruments/techniques. As expected, GDPs with higher levels of training, implant providers and those performing surgical implant placement were highly significantly more likely to treat mucositis and implantitis in this study, while non-providers were also less likely to perform superficial or subgingival cleaning. Intriguingly, more GDPs in this study provided mucositis treatment (41.9%) than performed subgingival debridement (35.0%), raising the question of how they are doing the former without the latter, or whether using “subgingival debridement” rather than “submucosal” in the survey was confusing for respondents (it was chosen to minimise confusion for dentists with no implant training as “submucosal” has an alternative histological definition). A lack of standardised control procedures in the literature has meant that the efficacy of individual techniques is generally unknown, and there are as yet no standardised instrumentation protocols for practitioners in maintaining peri-implant health (Jepsen et al., 2015; Sanz & Chapple 2012), managing peri-implant mucositis (Schwarz et al., 2015a) or peri-implantitis (Romanos et al., 2015). It is therefore not surprising that GDPs had mixed preferences in this study, including in their use of some techniques shown to have disadvantages or detrimental effects. Metal instruments cause surface scratching (Agar et al., 1997; Baek et al., 2012; Mann et al., 2012; Matarasso et al., 1996; Mengel et al., 2004) and plastic curettes may be too large for effective use in the sulcus or implant threads (Maximo et al., 2009), but both were popular in this study. Conversely, there is some evidence for safe and effective use of air-powder prophylaxis (Mussano et al., 2013; Riben-Grundstrom et al., 2015) and plastic ultrasonics (Kawashima et al., 2007; Schmage et al., 2012), although recent *in vitro* research reported the possibility of residual

plastic debris (Bertoldi et al., 2017; Mann et al., 2012); these methods were preferred by a few GDPs. Perhaps the commercial promotion of plastic and titanium curettes anecdotally influenced their popularity among this study's respondents. Meanwhile, almost 40% of respondents may be assuming incorrectly that stainless steel ultrasonics can be used around implants as part of routine scaling and periodontal maintenance, including the most recent graduates who used stainless-steel ultrasonics more than their older colleagues, despite the inclusion of implant training in the dental curriculum in recent years. This highlights the need for specific teaching of evidence-based instrumentation in dental degree programs.

Topical antimicrobials do not appear to enhance mucositis management outcomes (Heitz-Mayfield et al., 2011; Porras et al., 2002; Thöne-Mühling et al., 2010) but were recommended in the recent AACP Clinical Practice Guidelines (Bidra et al., 2016b) and in this study were reportedly used widely, especially by those with more implant training. Local antibiotics appear to have some beneficial short-term effects in non-surgical peri-implantitis treatment (Buchter et al., 2004; Mombelli et al., 2001; Renvert et al., 2006; Renvert et al., 2008a), but their reported use in this study by some respondents is to be questioned since they are not available in Australia.

Systemic antibiotics are not recommended for mucositis treatment (Salvi & Ramseier 2015), and while they are commonly used in surgical peri-implantitis management research, the evidence for any particular regimen is not established (Javed et al., 2013). In this study, GDPs with more training or implant treatment experience were more likely to prescribe systemic antibiotics and perform surgical procedures, as expected, presumably in managing more complex peri-implant pathology. Rural/regional-based dentists surveyed were also more likely to report performing surgical peri-implant procedures, perhaps compensating for the low distribution of specialists outside of major cities (AIHW 2014).

It is a striking finding that 19.1% of GDPs in this study reported not using any implant-specific instruments/techniques for professional maintenance, including over a third of the GDPs not providing implants and almost 40% of those with no training. Additionally, when asked if they treat mucositis/peri-implantitis or refer to another practitioner, approximately 15% of GDPs did not choose either of these options, including up to 30% of those who did not attain their dental degree in Australia. These figures did not specify or exclude respondents who may not see any implant patients but they may indicate a less than pro-active attitude in managing peri-implant disease.

There are implications for implant dentistry education in Australia stemming from the results of this study. A more preventative approach should be promoted to all dentists, to compensate for

variable teaching from their initial dental degrees (depending on when/where attained), differing interest in implant training and lack of academic standardisation in CPD programs (Ivanovski et al., 2010), which was the most popular training type attended. For example, regular articles in dental association newsletters or easily accessible webinars could outline evidence-based and comprehensive diagnostic procedures, consideration of risk factors, plaque removal techniques, appropriate review periods and referral. The long-term responsibility of all general dentists to be proficient in peri-implant maintenance as part of dental disease prevention should be emphasized, regardless of their current contact with implant patients or their involvement in implant treatment. Given the evolving literature on disease process, speed of progression, standardised management and instrument protocols, practitioners must be encouraged to stay in touch with current research.

This research also highlights the challenges in translating evidence into clinical practice. Even with information available to practitioners in many forms and across many channels of communication, ensuring that dentists take up and implement this new knowledge is difficult.

One of the challenges in undertaking questionnaire-based research in Australia is lack of access to national dentist register to obtain an appropriate sample. Nonetheless, the characteristics of this study's respondents were similar to the latest available workforce reports (AIHW et al., 2016), albeit with a slightly higher proportions of females and Australian graduates. The sample size was smaller than studies in other countries using randomly selected samples from national dentist registers (Murray et al., 2016; Ng et al., 2011; Patel et al., 2010) and other recent surveys of Australian dentists (Guo et al., 2017). Dentists with lower interest in implant dentistry may be underrepresented if they were less likely to participate in the study, while the nature of the survey instrument also gathers participants' reported beliefs rather than strictly their clinical practices. The results of this survey are unable to be compared to others due to the absence of similar research into the clinical preferences of dentists working in the general community. It is hoped further investigations will continue to track clinical practice in Australia and globally, given the high numbers of implants being placed and the prevalence of peri-implant disease, as evidence for best practices continues to be developed and implant education also evolves.

Conclusion

This study established the implant diagnostic and maintenance practice patterns of a sample of general dentists in Australia, finding high awareness of the importance of oral hygiene and short-term review of peri-implant disease. Implant training and experience significantly increased

respondents' performance of diagnostic checks and more complex maintenance/treatment procedures. Over 10% of the respondents performing diagnostic procedures only did so when clinical signs/symptoms were present, while about 15% did not treat nor refer cases of peri-implant mucositis or peri-implantitis. Dentists must ensure a preventative attitude in performing peri-implant diagnostics, considering patient risk factors, making appropriate referrals and staying abreast of current evidence. Further research should continue to document and assess professional maintenance practices in the community as the quality of evidence in understanding peri-implant disease and its management develops.

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Chapter 6: Dental implant hygiene and maintenance – a survey of oral health practitioners in Australia

A manuscript submitted to *Journal of Dental Hygiene*.

Abstract

Purpose: The aims of this study were to investigate the implant-related training and clinical practices of oral health practitioners (OHPs – dental hygienists, dental therapists, oral health therapists) in Australia regarding implant oral hygiene instructions (OHI) and maintenance, and to understand their contributary role in providing peri-implant services.

Methods: A web-based survey collected data from members of the Dental Hygienists Association of Australia and the Australian Dental and Oral Health Therapists' Association.

Results: OHPs (n=154) considered implant home hygiene and peri-implant health to be very strongly associated. Their dental qualification (64.9%) and association-run continuing professional development (50.6%) were the most common sources of implant assessment/management information. Brushing (88.7%) and interdental brush (78.1%) were the most popular implant-specific OHI given. Almost all OHPs performed peri-implant diagnostics (85-100%), 94.0% performed supragingival cleaning, 67.5% subgingival cleaning, 55.0% treated peri-implant mucositis and 38.4% peri-implantitis. Floss (80.9%), prophylaxis (59.6%), plastic/carbon curettes (52.5%) and plastic-tipped ultrasonics (43.3%) were the instruments most commonly used during implant maintenance.

Conclusion: Oral health practitioners surveyed in Australia reported providing peri-implant services generally in agreement with the current literature. They expect to be highly involved in implant maintenance and provide the majority of preventive, periodontal and OHI services in their workplaces, with dentists/specialists more involved in managing peri-implant pathology.

Introduction

The prevention of peri-implant disease is of critical importance as dental implants gain in popularity and greater understanding of the rates of peri-implant disease is established. Recent meta-analyses found the weighted mean prevalence of mucositis at the patient level to be 43-46.8% and peri-implantitis to be 19.8-22% (Derks & Tomasi 2015; Lee et al., 2017). Peri-implantitis appears to have a non-linear and accelerating mode of progression (Derks et al., 2016; Fransson et al., 2010) and prevalence is correlated to higher number of years in function (Derks & Tomasi 2015). Regular ongoing review of implants is therefore widely recommended to detect peri-implant pathology (Bidra et al., 2016; Pjetursson et al., 2012; Wilson et al., 2014), with diagnostic tools and procedures firmly established in the literature (Heitz-Mayfield 2008; Renvert et al., 2018). These include visual assessment of inflammatory signs, pocket depth probing, suppuration and bleeding on probing assessment, and radiographic bone level evaluation. The performance of these procedures by dental practitioners in clinical practice has rarely been investigated, with one study of dental hygienists in the USA surveying their preferred clinical assessment techniques (Ward et al., 2012).

Professional and at-home plaque control are critical in managing peri-mucositis (Salvi & Ramseier 2015), which is a precursor to peri-implantitis (Heitz-Mayfield & Salvi 2018). The quantity and quality of literature to support patient-performed implant hygiene is poor, with no control protocol standardised within peri-implant management research to date. Professional treatment protocols for maintaining peri-implant health are lacking (Jepsen et al., 2015), and those for treating mucositis (Salvi & Ramseier 2015) and peri-implantitis (Romanos et al., 2015) are also not established. Studies vary widely in disease criteria (Heitz-Mayfield & Mombelli 2014) and control interventions and lack long-term follow-up (Grusovin et al., 2010; Muthukuru et al., 2012; Schwarz et al., 2015). Although interventions are often successful, lack of controls for entire treatment protocols as well as individual debridement, anti-infective, surgical, antibiotic procedures has been such that their true efficacy is unknown (Esposito et al., 2012; Grusovin et al., 2010). Standardised diagnostic and inclusion criteria for peri-implant epidemiological research have recently been proposed by Renvert et al. in 2018. Dental practitioners may thus vary widely on their preferred hygiene instructions and management protocols, and the severity of peri-implant conditions for which they are willing to provide treatment. There are only a few surveys in the literature documenting clinical practice preferences (of periodontists by Mattheos et al. in 2012 and Papathanasiou et al. in 2016, and of dental hygienists by Ward et al. in 2012), which may also depend on practitioners' implant-related training, when they graduated, their involvement with patients with implants and their own level of interest.

In Australia, oral health practitioners (OHPs) – dental hygienists, dental therapists and oral health therapists – made up 19.9% of registered practising dental practitioners in April 2018 (AHPRA 2018). A recent survey of Australian dentists found that 37.8% employ an OHP (Kempster et al., 2015). The services provided by OHPs in their clinical practice have been surveyed in the UK (Gibbons et al., 2000, 2001; Godson et al., 2009) and in Australia where they predominantly provide preventive services (Teusner et al., 2016). A study comparing private general dental practices which did and did not employ dental hygienists in Adelaide, South Australia found that those that did delegated many preventive and periodontal services to hygienists and had a significantly greater proportion of periodontal-focused services performed overall in the practice (Brown et al., 1994). However, none of the above studies differentiated between provision of periodontal vs peri-implant preventive and maintenance services, which may differ as the latter field is less established and has uncertain supporting literature as previously outlined. The study of dental hygienists in the USA (Ward et al., 2012) surveyed their implant-related training, peri-implant diagnostic and maintenance practices but the literature lacks other studies to which it can be compared.

This study therefore aimed to understand the role of OHPs in implant maintenance within the dental profession in Australia, by investigating their training, perspectives and clinical preferences in providing peri-implant oral hygiene, diagnostic and maintenance services, (and whether these differ from those of general dentists, similarly surveyed by this research group [Cheung et al., 2019]). Collaboration and the relative roles of different practitioner types in providing peri-implant compared to periodontal services in the practices in which OHPs work were surveyed, and implications for peri-implant/implant dentistry education and prospective research were determined.

Methods and materials

This study investigated the implant maintenance practices of oral health practitioners (OHPs) registered in Australia, which included dental hygienists, dental therapists and oral health therapists. In April 2018, 4467 OHPs were registered as practising with the Dental Board of Australia (AHPRA 2018).

After thoroughly considering the current literature on implant maintenance, and the clinical practice of maintenance in the Australian context, a survey was developed for this study in the Periodontics department of the Melbourne Dental School at The University of Melbourne (Appendix III) to gather initial data on trends in implant dentistry information sources and

treatment provision by OHPs in Australia. It was based on a similar web-based questionnaire (Appendix II) previously conducted of general dentists (Cheung et al., 2019) by the same research group, regarding their implant training, treatment provision, and peri-implant hygiene and maintenance preferences. The questions and validity of the survey were considered by the faculty involved in the study, and ethics clearance for this project's protocol was given by the Health Sciences Human Ethics Sub-Committee of The University of Melbourne (Ethics ID 1443625). For this study, 5 main question areas from the previous survey were replicated: respondents' demographics (gender, age, metropolitan or rural location and private or public sector of practice); their sources of implant-related assessment, maintenance and oral hygiene instruction (OHI) information; their opinion of the correlation between patient home hygiene and peri-implant health; their preferred implant-specific OHI, OHI frequency and communication methods, diagnostic procedures, instruments used in peri-implant maintenance; their provision of types of peri-implant treatment. In addition, this survey asked respondents to outline their structured working relationships and the roles of different practitioner types in providing preventative, periodontal and implant procedures in their main workplace.

The survey was hosted on Surveymonkey™ and was distributed by email to the members of the Dental Hygienists Association of Australia and the Australian Dental and Oral Health Therapists' Association, the national professional associations for OHPs in Australia. A reminder was sent 4 weeks afterwards and a prize draw was conducted to encourage participation rates. Data were collected from May to August 2018.

Data were described using SPSS statistical software version 23.0 (SPSS, Chicago IL, USA) and compared to findings from a similar survey of 303 general dentists in Australia (Cheung et al., 2019), with Chi-square tests performed to compare between categorical variables (significance set at 0.05).

Results

Demographics and roles in the practice

The survey was completed by 154 OHPs registered with the Dental Board of Australia. The large majority of respondents were female (92.9%) and had attained their dental qualification(s) from an Australian university (90.9%). Their mean age was 38.4 years (range 22-65) and mean year of qualification attainment was 2005 (range 1973-2017). The majority of respondents (55.8%) had graduated in the decade period prior to the survey (2008-2017), with 24.0% graduating between 1998-2007, 10.4% between 1988-1997, and 9.7% prior to 1987. Most OHPs (79.9%) worked only

in private practice and 59.1% worked only in metropolitan areas, with the remainder working at least some of the time in the public sector or rural/regional areas, respectively. Most OHPs worked at one (61.7%) or two (28.6%) practices, and a small number (2.6%) were dental practice owners. Table 6.1 shows the dentist/specialist types with whom OHPs had a structured working relationship, at the practice they designated to be their main workplace.

For the different possible levels of understanding, diagnosis and management of peri-implant conditions within a dental practitioner's scope of practice, over 80% of OHPs reported that understanding the pathological process (90.3%), peri-implant tissue assessment (81.2%) and maintenance of peri-implant health (85.1%) were in their scope of practice. About half considered treatment of peri-implant mucositis (50.0%) or peri-implantitis (50.6%) to be within their scope of practice.

Table 6.1 Structured relationship with dentist/specialist types reported by OHPs (n=154) at designated main workplace, multiple selections permitted.

General dentist	87.7%
Periodontist	20.1%
Orthodontist	13.0%
Prosthodontist	5.2%
Paediatric dentist	3.9%
Oral surgeon	2.6%
Endodontist	0.6%

The usual provision of services by different practitioner types as reported by OHPs in their main workplace is shown in Table 6.2. These results included only practices where patients with implants attended regularly (n=143, 83.1% general dental practices and 16.9% specialist practices). OHPs play a smaller role in diagnosing peri-implant status (<40%) compared to periodontal status (>70%). They perform the majority of maintenance for healthy peri-implant tissues in their workplaces, but dentists and specialists take increasing responsibility for peri-implant mucositis and peri-implantitis treatment, with a smaller but similar pattern in the provision of oral hygiene instruction to patients with these conditions.

Implant-related training

Just under two-thirds of respondents reported learning clinical procedures for implant assessment and management in their registrable dental qualification (64.9%) or continuing professional development (CPD) programs of any type (61.0%), while other common sources of training and information were colleagues, work-based mentorship and journal articles (Table 6.3). Only 14-17% of OHPs had attended CPD run by universities or implant companies compared to about half at dental association/society CPD. OHPs generally cited these sources to also have provided implant OHI information at similar rates, except for lower rates from university-based

CPD, implant-company CPD and textbooks (CPD sources of OHI were assessed as a percentage of reported attendees). Compared to general dental practitioners (GDPs) who were similarly surveyed, OHPs reported significantly higher learning of implant OHI from several sources (Table 6.3) and having any sources at all (p=0.001).

Table 6.2 Practitioner types providing services, as reported by OHPs where implant patients are seen at their main workplace (n=143)

		OHP alone	Dentist or dentist consulted by OHP	In-house specialist	External referral
Routine examination	Examination of new patient	9.1%	80.4%	9.1%	1.4%
	Examination of returning patient without implant(s)	21.0%	72.7%	4.9%	1.4%
	Examination of returning patient with implant(s)	16.8%	75.5%	6.3%	1.4%
Diagnosis	Diagnosis of periodontal disease	70.6%	18.2%	10.5%	0.7%
	Diagnosis of peri-implant health	38.5%	53.2%	8.4%	0.0%
	Diagnosis of peri-implant mucositis	29.4%	58.0%	10.5%	2.1%
	Diagnosis of peri-implantitis	23.8%	59.4%	11.2%	5.6%
Initial debridement, maintenance or treatment	No periodontal disease or implant	91.6%	5.6%	2.1%	0.7%
	Periodontal disease, no implant	91.6%	2.8%	4.2%	1.4%
	Peri-implant health	93.0%	4.9%	0.7%	1.4%
	Peri-implant mucositis	51.7%	20.3%	7.7%	20.3%
	Peri-implantitis	25.2%	25.2%	13.3%	36.4%
Provision of OHI	No periodontal disease or implant	97.2%	2.8%	0.0%	0.0%
	Periodontal disease, no implant	97.9%	2.1%	0.0%	0.0%
	Peri-implant health	97.2%	2.8%	0.0%	0.0%
	Peri-implant mucositis	83.9%	10.5%	1.4%	4.2%
	Peri-implantitis	77.6%	9.8%	3.5%	9.1%

Table 6.3 Sources of information for clinical implant assessment/management procedures and implant OHI, cited by OHPs (n=154), multiple selections permitted; implant OHI sources cited by GDPs and comparison between OHPs and GDPs

	OHPs' implant assessment and management sources	OHPs' implant OHI sources	GDPs' implant OHI sources (n=303)	p value
Registrable qualification	64.9%	63.6%	38.0%	**<0.001**
University-based CPD	16.9%	100.0% (26) †	58.3% (115) †	
Association/society CPD	50.6%	>100.0% (78) †	59.8% (184) †	**<0.001**
Implant-company CPD	14.3%	59.1% (22) †	45.2% (188) †	**0.015**
Hands-on course	13.0%	11.7%	6.9%	
Work-based mentorship	39.0%	36.4%	24.4%	**0.007**
Colleagues	48.1%	46.8%	35.0%	**0.015**
Journal articles	42.9%	36.4%	36.6%	
Textbooks	27.9%	15.6%	15.8%	
No source cited	0.6%	0%	6.6%	**0.001**

p values <0.05 shown

† bracketed numbers attended this type of CPD implant training, out of which the percentage citing it as a source of OHI was calculated

Implant home hygiene

Regarding the link between implant home hygiene and peri-implant health, 63.6% considered it to be “very strong”, 33.1% “strong”, 3.2% “neutral”, with none choosing “weak” or “very weak”. Almost all OHPs (98.1%) saw patients with implants as part of their clinical practice. The implant-specific oral hygiene instructions (OHI) that these OHPs most commonly gave for the example of a single implant crown were: brushing (88.7%), interdental brush (78.1%), flossing (66.2%) and circumferential flossing (62.3%) (Table 6.4). Compared to the GDPs who were similarly surveyed, OHPs were significantly more likely to recommend interdental brush (p=0.029), circumferential flossing (p<0.001) and oral irrigator (p<0.001). A small subgroup (3.3%) did not give any implant-specific OHI techniques, similarly to 3.0% of the GDP group.

Table 6.4 Post-restoration implant-specific oral hygiene instructions given, for the example of a single implant crown

	OHPs who see patients with implants (n=151)	**GDPs (n=303)**	**p value**
Brushing	88.7%	86.5%	
Flossing	66.2%	73.9%	
Superfloss™ (Oral-B®; Procter & Gamble Co., Cincinnati, OH, USA)	50.3%	41.9%	
Interdental brush	78.1%	68.3%	**0.029**
Circumferential flossing	62.3%	41.3%	**<0.001**
Oral irrigator	34.4%	17.8%	**<0.001**
Mouthwash	16.6%	14.5%	
Topical agent	2.6%	1.0%	
None of the above techniques	3.3%	3.0%	

p values <0.05 shown

While 75.2% of OHPs repeated OHI at every review or recall appointment, 21.4% repeated OHI only if signs/symptoms of peri-implant disease were present, significantly different overall from the preferences of the GDPs surveyed (p<0.001) particularly regarding regular repetition (Table 6.5). Out of the three suggested communication methods, OHPs were most likely to show their patients OHI (96.6%) and 49.0% asked the patient to demonstrate after instruction, both significantly more than GDPs surveyed (Table 6.5).

Table 6.5 OHI repetition and communication preferences

	OHPs who provide implant OHI (n=145)	GDPs who provide implant OHI (n=289)	p value
Greatest preferred frequency of implant OHI repetition			
Repeat at every recall or review	75.2%	57.4%	**<0.001**
Repeat only once at next recall or review	3.4%	13.5%	
Repeat only if signs/symptoms present	21.4%	27.0%	
Do not repeat	0%	2.1%	
OHI instruction method used			
Describe to the patient	73.8%	76.5%	
Show the patient	96.6%	84.1%	**<0.001**
Ask the patient to demonstrate after instruction	49.0%	36.3%	**0.011**

p values <0.05 shown

Professional maintenance

OHPs expected to be involved in peri-implant maintenance, with 99.4% of those who see patients with implants believing they have a role to play. The vast majority (96.7%) of OHPs who see implant patients also reported performing implant checks and diagnostic procedures. Over 95% of this group performed assessment of implant oral hygiene, soft tissues, pocket depths, bleeding on probing or suppuration with about 85% assessing recession or implant mobility (Table 6.6). Of the practitioners performing implant checks, all diagnostic procedures were performed at significantly higher rates by OHPs than GDPs, particularly those involving more than oral hygiene or visual soft tissue assessment.

Table 6.6 Implant-specific diagnostic procedures used by practitioners who perform implant checks

	OHPs (n=146)	GDPs (n=291)	p value
Oral hygiene assessment around implant	100.0%	97.3%	**0.043**
Soft tissue visual assessment	99.3%	94.5%	**0.014**
Pocket depth probing	96.6%	82.1%	**<0.001**
Assessment of bleeding on probing	97.3%	88.7%	**0.002**
Assessment of suppuration	95.2%	73.9%	**<0.001**
Recession measurement	85.6%	56.0%	**<0.001**
Assessment of implant mobility	84.9%	70.4%	**0.001**

p values <0.05 shown

Of the OHPs who see patients with implants (n=151), the proportions who provide supra- or subgingival implant cleaning during maintenance, treatment of peri-implant mucositis or peri-implantitis decreased with increasing complexity of the procedure types (Table 6.7). All procedure types were provided at significantly higher rates by OHPs than GDPs similarly surveyed. When asked if they would treat or refer mucositis, 10.6% did not choose either option, and 12.6% did not treat nor refer peri-implantitis, and these proportions were similar to the GDPs surveyed.

Table 6.7 Peri-implant procedures/treatment provided

	OHPs who see patients with implants (n=151)	GDPs (n=303)	p value
Supragingival/superficial implant prosthesis cleaning during recall/periodontal maintenance	94.0%	77.9%	**<0.001**
Subgingival debridement of implants/implant surface during recall/periodontal maintenance	67.5%	35.0%	**<0.001**
Treatment of peri-implant mucositis	55.0%	41.9%	**0.009**
Do not treat nor refer for peri-implant mucositis	10.6%	14.5%	
Treatment of peri-implantitis	38.4%	18.2%	**<0.001**
Do not treat nor refer for peri-implantitis	12.6%	16.5%	

p values <0.05 shown

A small proportion (6.6%) of OHPs who see implant patients did not use any implant-specific instruments or techniques in professional maintenance, and this was significantly lower than 19.1% of the 303 GDPs surveyed (p<0.001). Among the OHPs who did (n=141), flossing was the most popular (80.9%), followed by rubber cup/brush prophylaxis (59.6%) and plastic/carbon curettes (52.5%) (Table 6.8). Plastic ultrasonic scaler tips (43.3%) were more than twice as popular as stainless-steel ultrasonics (19.9%). GDPs surveyed were more likely to use rubber cup prophylaxis (p=0.004) and stainless-steel ultrasonics (p<0.001), while OHPs were significantly more likely to use air-powder polishing, plastic ultrasonics and titanium curettes (p≤0.001).

Table 6.8 Instruments/techniques used in professional maintenance, by percentage of practitioners using them

	OHPs (n=141)	GDPs (n=245)	p value
Floss	80.9%	76.3%	
Rubber cup/brush with prophylaxis paste	59.6%	73.9%	**0.004**
Air powder polishing/prophylaxis	29.8%	9.8%	**<0.001**
Stainless steel ultrasonic scaler	19.9%	38.0%	**<0.001**
Plastic ultrasonic tips	43.3%	26.5%	**0.001**
Stainless steel curettes	16.3%	15.5%	
Plastic/carbon curettes	52.5%	43.3%	
Titanium curettes	29.8%	12.7%	**<0.001**
Topical antimicrobials	39.7%	32.2%	
Interdental brush (volunteered answer)	2.1%		
Superfloss™ (volunteered answer)	1.4%		

p values <0.05 shown

Discussion

Oral health practitioners in Australia who participated in this study demonstrated a very preventative attitude regarding dental implants. The provision by OHPs of diagnostic and maintenance procedures and OHI in different patient scenarios relative to the general dentists

and specialists with whom they work have rarely been investigated in the literature. The provision of OHI (>97%) and periodontal debridement (>91%) by OHPs in this study was comparable to or higher than that found in a subset of hygienists working with GDPs (91.2% providing OHI, 72.5% performing subgingival scaling and root planing), in a survey of periodontal service provision by GDPs in Victoria, Australia (Darby et al., 2005). This study provides initial insight into provision of implant-specific diagnosis, peri-implant maintenance and OHI by different practitioner types in the practices employing OHPs. As expected, there is greater involvement of dentists and specialists and more external referral reported with increasing severity of peri-implant pathology.

Dental practitioners provide services according to their scope of practice and the relatively recent addition of implant dentistry to dental practice means that the education sources may be widely variable, such as the dental qualifications, dental association/society CPD and the work environment most commonly reported in this study, particularly for older practitioners updating their knowledge of their own volition. This may explain the discrepancies found between what OHPs considered to be within their scope of practice, and the slightly higher proportions who then reported providing these services (i.e. 85.1% indicating peri-implant health maintenance and 50.0% indicating peri-implant mucositis treatment were in their scope of practice, and these procedures being performed by 94.0% and 55.0% respectively). OHPs' reported implant learning from dental qualifications and CPD courses (61-65%) in this study was slightly higher than 51-52% reported in a survey of dental hygienists in the USA (Ward et al., 2012), which did not differentiate between the CPD provider types. An interesting finding in this study was the much lower attendance reported at university-based and implant-company CPD compared to dental association CPD. This may represent different availability or accessibility of programs from the expected providers of continuing professional education, and echoes similar lower attendance at university-based programs by the GDPs previously surveyed (Cheung et al., 2019). There are associated implications for the ongoing development of implant education in Australia and perhaps more courses need to be made available to OHPs.

Implant OHI inclusion in implant training was more highly reported by OHPs surveyed in this study, compared to the GDPs previously surveyed (Cheung et al., 2019), in almost all categories. This may reflect the preventative focus of OHPs from education through to clinical practice, as expected, which by comparison may indicate the need for greater preventative emphasis or cohesion in the implant education system available to GDPs. Differences between implant OHI sources cited by OHPs and GDPs may also be due to the later mean graduation year – 2005 for OHPs compared to 1998 for GDPs (Cheung et al., 2019) – and team environment in which OHPs work, encouraging work-based mentorship and learning.

Patient-performed implant hygiene forms a critical part of mechanical plaque control, considered the standard of care for mucositis management together with professional plaque control (Heitz-Mayfield & Salvi 2018; Salvi & Ramseier 2015). OHPs in this study demonstrated a strong understanding of the close link between implant home hygiene and peri-implant health. However, there is no evidence-based patient-performed protocol related to preventative efficacy (Grusovin et al., 2010; Louropoulou et al., 2014) nor an established standard hygiene control for clinical research (Sanz & Chapple 2012). Dental practitioners may therefore be inferring their implant OHI preferences from the periodontal literature or their clinical experience. In this study, interdental brush was the most commonly recommended interdental cleaning method, in agreement with the current periodontal literature deeming it the most efficacious interdental cleaning method (Sälzer et al., 2015), although evidence for peri-implant efficacy is limited (Chongcharoen et al., 2012). While flossing and circumferential flossing were next most frequently recommended, flossing has recently been identified as a possible peri-implantitis risk factor in implants with exposed rough implant surfaces due to the retention of floss fibres (van Velzen et al., 2016). The higher recommendation of circumferential flossing and oral irrigator by OHPs compared to GDPs may be due to promotion of these techniques in the hygienist-focused literature (Wingrove 2011).

Almost all OHPs showed their patients the hygiene technique when giving OHI, significantly more than the GDPs surveyed, and more in agreement with the limited literature on OHI communication efficacy, where intra-oral demonstration was more effective than written or verbal explanation (Harnacke et al., 2012). OHP respondents were also more likely than GDPs to ask their patients to demonstrate the technique, which could contribute to a high internal locus of control important in changing oral hygiene behaviour (Galgut et al., 1987; Ower 2003). Further research is needed to establish its efficacy in OHI communication. Additionally, although the OHPs surveyed were generally more preventative in repeating OHI at every recall/review appointment compared to surveyed GDPs, about a quarter of both groups only repeated OHI when signs/symptoms were present. Repetition of individualised OHI is strongly recommended in the prevention of periodontal disease (Tonetti et al., 2015; Worthington et al., 2013), and all practitioners should reinforce pre-emptive OHI over the long-term especially when peri-implant disease can be difficult to treat when it occurs (Romanos et al., 2015).

The diagnostic procedures for peri-implant monitoring are well-established in the literature (Heitz-Mayfield 2008; Renvert et al., 2018) and OHPs in this study performed them at high rates around or above 90%. These findings were generally similar to the dental hygienists in the USA study (Ward et al., 2012), except for the lower performance of probing and bleeding on probing assessment (around 70%) in that study. The provision of different peri-implant treatments by

practitioners has rarely been investigated in the literature. OHPs in this survey provided similar levels of supragingival cleaning (94.0%) but less subgingival debridement (67.5% vs around 80%) compared to the dental hygienists in the USA (Ward et al., 2012). Similar proportions of OHPs and GDPs surveyed (10-17%) reported not treating nor referring cases of peri-implant mucositis or peri-implantitis, and given the potential severity and difficult management of the latter condition (Armitage & Xenoudi 2016; Heitz-Mayfield & Mombelli 2014), timely coordinated management by all practitioners should be reinforced. Overall, OHPs surveyed provided comprehensive implant diagnostics and all types of peri-implant maintenance at significantly higher rates and were more likely to use any implant-specific instruments/techniques than the GDPs similarly surveyed. Provision of peri-implant diagnosis, maintenance and pathology treatment in a general dental practice may therefore vary widely depending on whether OHPs are employed, and this study's findings may reflect a greater focus on preventative care by OHPs, as is expected of their role in clinical practice. Further research is needed to investigate why GDPs do not have an equally preventative and implant-specific attitude in providing implant maintenance, particularly as they should all be able to manage patients with implants and most do not employ OHPs in Australia (Kempster et al., 2015).

There are no standard evidence-based protocols for the treatment of peri-implantitis (Romanos et al., 2015) or peri-implant mucositis (Schwarz et al., 2015), nor the maintenance of peri-implant health (Jepsen et al., 2015; Sanz & Chapple 2012). Dental practitioners' preferred use of maintenance instruments and techniques given the uncertainty in the literature has rarely been investigated: periodontists have been surveyed in the UK, Australia (Mattheos et al., 2012) and the USA (Papathanasiou et al., 2016), and dental hygienists in the USA (Ward et al., 2012). Compared to the latter survey, the OHPs in this study used stainless steel curettes and ultrasonic tips (16-20% vs 6-8%), plastic ultrasonic tips (43.3% vs 12%), prophylaxis paste (59.6% vs 38%) and air powder polishing (29.8% vs 19%) at higher rates, and plastic curettes (52.5% vs 89%) at lower rates. In this study, higher usage of air-powder polishing and plastic ultrasonic tips and lower usage of stainless-steel ultrasonics by OHPs compared to GDPs is in closer agreement with the available literature supporting the efficacy of and minimal damage from air powder polishing (Mussano et al., 2013; Riben-Grundstrom et al., 2015; Schmage et al., 2014) and plastic ultrasonics (Kawashima et al., 2007; Schmage et al., 2014), although some recent *in vitro* studies have shown plastic debris remaining after plastic ultrasonic use (Bertoldi et al., 2017; Mann et al., 2012). However, OHPs reported higher titanium curette usage which, while not exempt (Matarasso et al., 1996; Mengel et al., 2004) from metal instruments causing surface scratching *in vitro* (Agar et al., 1997; Baek et al., 2012; Mann et al., 2012; Matarasso et al., 1996; Mengel et al., 2004), may do so at lower levels (Bertoldi et al., 2017). Plastic curettes were also popular

amongst OHPs in this study, although they may be too large (Maximo et al., 2009) or ineffective at cleaning (Schmage et al., 2014). Antimicrobial use was similar in this survey (around 40%) to the hygienists in the USA (Ward et al., 2012), but while chlorhexidine was recommended in the recent American College of Prosthodontists' Clinical Practice Guidelines (Bidra et al., 2016), its adjunctive use in clinical trials has not resulted in better treatment outcomes (Heitz-Mayfield et al., 2011; Porras et al., 2002; Thöne-Mühling et al., 2010). Current evidence-based maintenance methods should be comprehensively covered in implant dentistry education, especially for GDPs.

The sample size in this study was smaller than the 1083 respondents in a repeatedly mailed survey to the same hygienist and therapist association member lists in 2013 (Teusner et al., 2016), with web surveys of dentists shown to have lower response rates (11%) than mailed surveys (26%) (Hardigan et al., 2012). At an effective representation rate of 3.5% of the registered OHPs in Australia at the time (AHPRA 2018), this study was similar to other recent web-based surveys of Australian dental practitioners (Bailey et al., 2016; Cheung et al., 2019; Guo et al., 2017). Overall, the demographics of the surveyed group were similar to the most recently available dental labour force report in Australia in 2012 (AIHW 2014). The respondents may have self-selected based on greater interest in implant dentistry (non-response bias) and self-reported answers may not be completely reflective of clinical practice. The full-time or part-time workload of respondents was not asked and may affect their involvement in implant maintenance. Although a pilot test was not conducted, the survey instrument was intended to gather initial data on implant maintenance trends in the OHP population, and this study provides previously un-documented insight into the training, role and attitudes of OHPs in implant maintenance in Australia, and may indicate future directions for research and investigation.

Variability in the availability of implant CPD programs for OHPs and the influence of collaboration with dentists/specialists in clinical practice could be further investigated. Practitioners should be encouraged to stay abreast of the current literature as evidence for implant home hygiene, OHI communication and implant maintenance protocols continues to develop, and further research to track practitioner preferences and clinical roles could assess treatment efficacy and education structures.

Conclusion

In this study, oral health practitioners surveyed in Australia showed a preventative approach to implant-specific patient-performed hygiene and understanding of thorough peri-implant

diagnosis and maintenance. They reported evidence-based preferences in clinical practice and play a large role in periodontal disease management, maintaining peri-implant health and giving OHI (both peri-implant and periodontal) in their workplaces, where the involvement of dentists and specialists was higher for patients with more severe peri-implant pathology.

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Chapter 7: Dental implant maintenance teaching in Australia – a survey of education providers

A manuscript submitted to *European Journal of Dental Education*.

Abstract

Introduction: Implant treatments and peri-implant maintenance continue apace while the evidence for implant maintenance and home hygiene continues to be developed. Information sources for dental practitioners and patients in peri-implant health maintenance and disease management are generally not known. The implant maintenance topics, convenors and presenters, and delivery methods within implant dentistry teaching are rarely reported.

Materials and methods: An online survey was distributed to 56 convenors of implant dentistry and maintenance education programs in Australia, garnering responses from 24 individuals which outlined 43 different education programs.

Results: Lectures were the main delivery method for implant maintenance information across the different course types. Peri-implant diagnostics were generally taught according to current literature recommendations, but coverage varied in topics where the evidence is yet to be established (e.g. home hygiene, professional maintenance and implant review). Some educators reported awareness of limitations in their programs.

Conclusion: Implant dentistry education programs in Australia vary widely in teaching implant maintenance. The structure of implant dentistry teaching at the continuing professional development level requires further development.

Introduction

Peri-implant diseases affect significant proportions of patients with dental implants, with weighted mean prevalence of 43-63.4% for peri-implant mucositis and 18.8-22% for peri-implantitis at the patient level reported in recent meta-analyses (Atieh et al., 2013; Derks & Tomasi 2015; Lee et al., 2017). The 2017 World Workshop established the most recent diagnostic criteria for peri-implant health, mucositis and peri-implantitis by consensus (Berglundh et al., 2018; Renvert et al., 2018), as research continues into the peri-implant disease process, which is not completely understood (Derks et al., 2016b; Fransson et al., 2010). While some guidelines have been developed for peri-implant maintenance, such as those by the American College of Prosthodontists (Bidra et al., 2016), the quality and quantity of evidence is acknowledged to be limited. Clinical evidence is still lacking for optimal patient-performed implant home hygiene (Grusovin et al., 2010; Louropoulou et al., 2014), the professional maintenance of peri-implant health (Jepsen et al., 2015) – the prevalence of which has rarely been documented in clinical studies (Derks et al., 2016a) – as well as the effective management of mucositis (Grusovin et al., 2010; Romanos et al., 2015; Schwarz et al., 2015) and peri-implantitis (Esposito et al., 2012; Heitz-Mayfield & Mombelli 2014; Romanos et al., 2015).

While the scientific evidence for implant maintenance continues to evolve, patients continue to receive implant treatments in the millions annually (American Dental Association 2007) and practitioners must provide preventive services; surveys of practitioners' clinical preferences in implant maintenance and patient home habits have begun to report on current clinical practice (Chapter 4; Chapter 5; Chapter 6; Ward et al., 2012). A cross-sectional survey of 51 patients in private practice in Australia showed that lack of interproximal cleaning at home was significantly associated with greater peri-implant disease prevalence, but the patients also reported generally poor recall of any implant hygiene instructions received from their treating dentists (Chapter 2). Meanwhile, surveys of general dentists and oral health practitioners in Australia showed that the latter group demonstrated a greater preventative focus in managing implant patients (Chapter 4; Chapter 6) and that for 73.6% of GDPs surveyed, continuing professional development (CPD) was their highest level of implant training (Cheung et al., 2019). The information sources for practitioners in clinical practice and patient home habits are unclear, given the mixed evidence available, and many types of implant dentistry training programs are available.

Dental practitioners in Australia must have adequate training supporting their scope of clinical practice (AHPRA 2014). In implant dentistry, dental graduates in Australia are suggested to be able to demonstrate competence in restoring non-aesthetic single crowns and implant-retained

removable mandibular prostheses, maintaining peri-implant health, diagnosing peri-implant pathology, and treating peri-implant mucositis, as per curriculum consensus across Australian universities since 2010 (Mattheos et al., 2010). This constitutes only part of the wider range of skills and treatments that can be provided. Dentists who graduated prior to 2010 as well as graduates from non-Australian universities are likely to have received highly variable coverage of implant dentistry and implant maintenance in their initial degrees. Dental hygiene/dental therapy/oral health therapy graduates (oral health practitioners – OHPs) may also have received varying levels of information especially with changes in the programs offered by universities over the past 20 years. Further learning can be sought by practitioners at different levels: specialist qualification, non-specialist postgraduate diploma, or non-award CPD from various sources (such as universities, dental associations, dental societies, privately-run institutes and implant companies). These non-award programs are not currently required to be accredited or to meet any competency standards such as those suggested upon graduation, although it has been recommended in Australia (Ivanovski et al., 2010) and in Europe (Mattheos et al., 2014). In Australia, it is currently at each practitioner's discretion as to whether their training is sufficient for them to include implant treatments within their scope of practice. Furthermore, the coverage of implant maintenance in education programs and whether practitioners' scopes of practice are adequately updated to include implant maintenance is not known. Some surveys of implant dentistry teaching have been performed in Europe (Afsharzand et al., 2005; De Bruyn et al., 2009; Koole et al., 2014; Ucer et al., 2014; Vasak et al., 2007), the United Kingdom (Blum et al., 2008) and North America (Kihara et al., 2017; Petropoulos et al., 2006), primarily of university-run programs, but the coverage of implant maintenance has rarely been reported upon.

This survey thus aimed to describe the current status of implant maintenance teaching in Australia and to investigate the coverage of maintenance topics included currently and within the last 5 years in the implant dentistry-related education programs available in Australia.

Materials and methods

This study received ethics approval from the Health Sciences Human Ethics Sub-Committee of the University of Melbourne (Ethics ID 1443625). An online survey (Appendix IV) hosted on Surveymonkey™ (San Mateo, CA, USA) was electronically distributed to persons known to be involved in implant dentistry/maintenance teaching in Australia via their publicly-available email addresses. They included:

1. periodontal and implant dentistry department convenors for undergraduate/graduate dentistry, oral health therapy and dental hygiene degrees
2. convenors of postgraduate implant dentistry diplomas (GradDip) and Doctor of Clinical Dentistry periodontology specialisation programs (DCD)
3. convenors of implant-focused CPD organised by universities, Australian Dental Association state branches, the Australian Society of Implant Dentistry, Australian Osseointegration Society state branches, private institutes which advertised publicly via ADA newsletters, implant companies and dental equipment companies

They were asked to outline the organisations for which they developed implant education programs within the last 5 years, and their intended audiences or the course type of which each program was a part. For each audience/course type, they outlined the program length, main teaching topics, the position/role/background of the person determining and/or delivering the content and the coverage of factors affecting peri-implant pathology. They were also asked to indicate whether specific content regarding implant home-care oral hygiene instructions, peri-implant diagnostic procedures, maintenance and treatment procedures were covered and how this information was delivered. Comments regarding implant maintenance teaching were welcomed. One reminder email was sent 4 weeks after the initial invitation to participate. Data were collected from May to July 2018.

Data were described in overall trends as well as by comparing the six different intended audiences/course types for which the programs were intended (henceforth referred to as different course types): undergraduate/graduate dental degrees, undergraduate hygiene/oral health therapy degrees, GradDip, DCD, CPD for dentists, CPD for OHPs.

Results

From the 56 individuals contacted for this survey, 24 responses were received (42.8% response rate). Of the 19 who were based in a university setting, 6 respondents were involved in convening programs for multiple course types (up to 4). The non-university responses were received from convenors of programs organised by professional associations (n=2), implant companies (n=2) and dental equipment companies (n=1), which were also intended for multiple course types. In total, 43 programs across the six course types were reported upon by the respondents, comprising 10 programs targeted towards undergraduate/graduate dental students, 8 for undergraduate OHP students, 6 for GradDip students, 7 for DCD students, 10 for dentists attending CPD programs, and 2 for OHPs attending CPD programs.

Implant maintenance content in all formal university qualification types and university-based CPD was usually determined by university heads of department or program convenors and delivered by specialists (mostly periodontists and some prosthodontists). One university-based CPD program also reported working with the syllabus from the International Team for Implantology (an internationally-recognised implant dentistry global education provider, with a relationship to the Straumann® implant company). Where commercial companies were involved, including in programs for undergraduate/graduate dental students, content was generally determined by the company representatives together with the convenors/presenters. This also applied in dental association or commercial company CPD programs, where implant maintenance content was delivered by whoever was presenting the program (periodontist, prosthodontist, oral surgeon, or experienced general dentist).

Lectures were the most common method of implant maintenance content delivery, used in 57.1-100% of programs in the various course types (Table 7.1). Journal articles were most common in GradDip and DCD programs (>70%), with some usage (40%) in teaching dental students and dentists attending CPD. CPD programs lacked any supervised practice or student observation. Among the formal university qualifications, supervised practice occurred in about one-third of undergraduate and GradDip programs and 57.1% of DCD programs that respondents reported upon, while observing/assisting patient treatment was rarely included except for dental students (40%) and GradDip programs where 50% involved private clinic-based mentoring.

Table 7.1 Implant maintenance content delivery methods in programs, by course type

	Undergraduate /graduate dental degree (n=10)	**Undergraduate hygiene/oral health therapy degree (n=8)**	**GradDip (n=6)**	**DCD (n=7)**	**CPD for dentists (n=10)**	**CPD for OHPs (n=2)**
Lectures	100.0%	75.0%	66.7%	57.1%	100.0%	100.0%
Journal article recommendations	40.0%	25.0%	83.3%	71.4%	40.0%	0.0%
Textbook recommendations	20.0%	37.5%	33.3%	28.6%	30.0%	0.0%
Hands-on workshop e.g. models, pig jaws	30.0%	12.5%	16.7%	28.6%	30.0%	0.0%
Supervised patient treatment	30.0%	37.5%	33.3%	57.1%	0.0%	0.0%
Observing/assisting patient treatment	40.0%	12.5%	16.7%	14.3%	0.0%	0.0%
Private clinic-based mentorship program	10.0%	0.0%	50.0%	0.0%	0.0%	0.0%
None	0.0%	0.0%	16.7%	14.3%	0.0%	0.0%

After brushing, flossing and interdental brush use were the most recommended implant oral hygiene techniques, covered by ≥50% of programs in all course types (Table 7.2). Superfloss™ and circumferential flossing were taught more to dental and GradDip students (≥60%) and less

in the other course types (≤30%), while mouthwash was more commonly taught to dental and OHP students (50%) than in the other course types (≤33.3%). Oral irrigation was taught in 20-33.3% of the various formal university qualifications. About 30% of GradDip and DCD programs did not cover any specific implant oral hygiene techniques.

Table 7.2 Implant-specific oral hygiene instructions included in programs, by course type

	Undergraduate /graduate dental degree (n=10)	Undergraduate hygiene/oral health therapy degree (n=8)	GradDip (n=6)	DCD (n=7)	CPD for dentists (n=10)	CPD for OHPs (n=2)
Regular brushing	100.0%	75.0%	66.7%	57.1%	70.0%	50.0%
Regular interdental flossing	90.0%	50.0%	66.7%	57.1%	60.0%	50.0%
Superfloss™ or equivalent (floss with stiff threader)	70.0%	37.5%	66.7%	14.3%	30.0%	0.0%
Interdental brushes	100.0%	50.0%	66.7%	57.1%	80.0%	50.0%
Circumferential flossing (floss looped around crown and 'see-saw' motion)	60.0%	0.0%	66.7%	14.3%	30.0%	0.0%
Oral irrigation (e.g. Waterpik)	20.0%	25.0%	33.3%	28.6%	20.0%	0.0%
Mouthwash	50.0%	50.0%	33.3%	0.0%	20.0%	0.0%
None	0.0%	0.0%	33.3%	28.6%	10.0%	0.0%

In general, peri-implant diagnostic procedures (oral hygiene, soft tissue condition, pocket depth, bleeding on probing, suppuration, recession, radiographic, implant mobility assessments) were well covered by all course types (Table 7.3), but recession and implant mobility were covered by fewer programs and particularly fewer CPD programs.

Teaching of specific maintenance instruments or procedures varied considerably. Floss, plastic/carbon curettes and titanium curettes were most commonly taught, covered by more than half the programs in almost all course types (Table 7.4). Air powder and rubber cup polishing were taught next most commonly, in 30-60% of formal university qualifications and 30-50% of CPD programs. Plastic ultrasonics were covered in 50% of GradDip and CPD programs, about 40% of initial dental and OHP degrees and only 14.3% of DCD degrees. Topical antimicrobials were taught in 50% of initial dental and OHP degrees and OHP CPD programs but less so elsewhere. There was little coverage of systemic antibiotics except in DCD (42.9%) and CPD (50-60%) programs. Local antibiotics were very rarely taught in general, and stainless-steel curettes were taught in 50% of the GradDip programs.

Table 7.3 Implant diagnosis procedures included in programs, by course type

	Undergraduate /graduate dental degree (n=10)	Undergraduate hygiene/oral health therapy degree (n=8)	GradDip (n=6)	DCD (n=7)	CPD for dentists (n=10)	CPD for OHPs (n=2)
Oral hygiene assessment around implant i.e. presence of plaque or calculus	100.0%	75.0%	66.7%	57.1%	90.0%	100.0%
Soft tissue visual appearance assessment e.g. inflammation, keratinised mucosa	90.0%	75.0%	66.7%	71.4%	100.0%	100.0%
Pocket depth probing	100.0%	75.0%	83.3%	57.1%	100.0%	100.0%
Assessment of bleeding on probing	100.0%	75.0%	83.3%	71.4%	100.0%	100.0%
Assessment of suppuration	100.0%	75.0%	83.3%	71.4%	100.0%	100.0%
Recession measurement	50.0%	62.5%	66.7%	57.1%	70.0%	50.0%
Radiograph to check bone level/bone defects	90.0%	75.0%	66.7%	57.1%	90.0%	100.0%
Assessment of implant mobility	80.0%	62.5%	66.7%	57.1%	50.0%	50.0%
None	0.0%	0.0%	16.7%	14.3%	0.0%	0.0%

Table 7.4 Professional maintenance instruments/techniques included in programs, by course type

	Undergraduate /graduate dental degree (n=10)	Undergraduate hygiene/oral health therapy degree (n=8)	GradDip (n=6)	DCD (n=7)	CPD for dentists (n=10)	CPD for OHPs (n=2)
Floss	90.0%	75.0%	66.7%	57.1%	50.0%	50.0%
Rubber cup/brush with prophylaxis paste	60.0%	50.0%	50.0%	42.9%	30.0%	50.0%
Air powder polishing/prophylaxis	60.0%	50.0%	33.3%	28.6%	40.0%	0.0%
Stainless steel ultrasonic scaler	20.0%	12.5%	16.7%	0.0%	0.0%	0.0%
Plastic ultrasonic tips	40.0%	37.5%	50.0%	14.3%	50.0%	50.0%
Stainless steel curettes	10.0%	12.5%	50.0%	14.3%	20.0%	0.0%
Plastic/carbon curettes	60.0%	62.5%	50.0%	57.1%	50.0%	100.0%
Titanium curettes	70.0%	75.0%	50.0%	42.9%	70.0%	50.0%
Topical antimicrobials	50.0%	50.0%	16.7%	14.3%	30.0%	50.0%
Local antibiotics	10.0%	0.0%	16.7%	14.3%	20.0%	50.0%
Systemic antibiotics	30.0%	12.5%	16.7%	42.9%	60.0%	50.0%
Bone augmentation	50.0%	12.5%	33.3%	57.1%	70.0%	50.0%
Open (surgical) debridement and/or recontouring	60.0%	12.5%	50.0%	57.1%	70.0%	50.0%
None	10.0%	0.0%	16.7%	14.3%	10.0%	0.0%

Within all the implant education program types (i.e. not just those with an implant maintenance focus), respondents reported a generally high coverage of peri-implant pathology risk factor topics (Table 7.5). Of other factors which can impact peri-implant health and diagnosis, crown retention system, frequency of implant review and frequency of routine radiograph were frequently covered. Splinted or separate crowns were covered least of all, mentioned in half of the GradDip programs but seldom in the other course types.

Respondents were asked for additional comments regarding implant maintenance teaching, and it was acknowledged as an area that was "identified as requiring updating" within one oral health therapy degree, and "underrated and too-often overlooked" in one dental degree, while another dental degree program reported including a one week block devoted to implant complications with peri-implantitis as a core topic. A convenor of professional association lecture evenings reported a greater focus on professional maintenance and treatment rather than home care.

Table 7.5 Risk factors and other preferences affecting peri-implant health findings included in programs, by course type

	Undergraduate /graduate dental degree (n=10)	Undergraduate hygiene/oral health therapy degree (n=8)	GradDip (n=6)	DCD (n=7)	CPD for dentists (n=10)	CPD for OHPs (n=2)
Peri-implant disease risk factors:						
The patient's standard of oral hygiene	100.0%	87.5%	83.3%	57.1%	70.0%	100.0%
Previous periodontal/peri-implant history	100.0%	87.5%	83.3%	71.4%	90.0%	100.0%
Medical history	100.0%	75.0%	66.7%	71.4%	90.0%	100.0%
Severity of existing peri-implant condition	100.0%	75.0%	83.3%	57.1%	80.0%	100.0%
Probing depths around the implant	100.0%	75.0%	83.3%	57.1%	90.0%	100.0%
None of the above	0.0%	0.0%	16.7%	14.3%	10.0%	0.0%
Other prosthodontic and maintenance preferences:						
Implant crown retention system	90.0%	37.5%	66.7%	71.4%	80.0%	100.0%
Splinting or separating two adjacent implants	20.0%	0.0%	50.0%	28.6%	20.0%	0.0%
Frequency of implant review	80.0%	50.0%	66.7%	71.4%	70.0%	50.0%
Frequency of routine radiography	70.0%	62.5%	66.7%	57.1%	80.0%	100.0%
None of the above	0.0%	12.5%	16.7%	28.6%	10.0%	0.0%

Discussion

Several surveys of implant education, primarily in Europe and North America, have been conducted in the last two decades, including European consensus workshops in 2009 (Mattheos et al., 2009) and 2014 (Mattheos et al., 2014). Most of these studies surveyed opinion and/or faculty leaders on the teaching of implant dentistry in undergraduate/predoctoral degree programs (Afsharzand et al., 2005; Blum et al., 2008; De Bruyn et al., 2009; Kihara et al., 2017; Koole et al., 2014; Petropoulos et al., 2006), generally reporting on the topic areas included, expected competencies or clinical requirements, specialty departments/faculty involved and challenges/limitations. A few surveys reported on implant dentistry inclusion in postgraduate specialty programs (De Bruyn et al., 2009; Koole et al., 2014) and implant-focused CPD programs (Ucer et al., 2014; Vasak et al., 2007), the latter also exploring the need and/or desire for accreditation and standardisation, as recommended in Workshop consensus statements in Europe (Mattheos et al., 2009; Mattheos et al., 2014) and similarly in Australia (Mattheos et al., 2010). Only two of the above surveys briefly reported on the inclusion of implant maintenance or recall in the predoctoral curriculum (Blum et al., 2008; Kihara et al., 2017). This study aimed to investigate this area in more detail, as it has not been reported upon previously, and focused on the content developers, presenters, delivery methods and inclusion of specific implant maintenance topics.

While the previous studies of implant education in universities have reported on the involvement of various specialty departments, including specifying the departments teaching implant prosthodontics or surgery (Petropoulos et al., 2006), this study presents the involvement of different disciplines in teaching implant maintenance. From this study, implant maintenance teaching in formal university qualifications and university-based CPD programs in Australia appears to have very strong involvement of dental specialists and periodontists in particular. Comparatively, the backgrounds of content developers and presenters of other CPD-providing organisations were more varied and included commercial company representatives, and this does not appear to have been reported upon elsewhere.

Lectures appeared to be the primary method of implant maintenance information delivery in this study, apart from the greater direct contact with the literature reported in formal postgraduate qualifications (GradDip and DCD). Greater exposure to the current literature for dental/OHP students and CPD attendees could enhance understanding of the importance of implant maintenance and its current limitations. This information could be provided using online teaching formats (which were reported by Ucer et al. [2014] to be surprisingly uncommon), such as online courses, webinars or informative bulletins. Further, the inclusion of more clinical

teaching or observation of implant maintenance procedures (and not just implant placement and restoration) may be of value across all course types, and particularly in the CPD sector which reported none in this survey. The finding of 30-40% of dental degree programs offering clinical practice or observation of implant maintenance in this study was similar to the limited literature available, where in a survey of 13 UK dental schools, four (30.8%) offered hands-on experience and seven (53.8%) provided observation in "restorative or maintenance stages" (Blum et al., 2008), while 36.2% of 47 North American dental schools included maintenance/recall in their clinical requirements (Kihara et al., 2017). Otherwise, the modes of delivery of implant maintenance information have rarely been reported previously in the literature.

Regarding the implant maintenance content reported by educators in this study, comparison is made below to current recommendations from the literature. The mixed quality of current evidence in the topic areas of home oral hygiene and professional maintenance are reflected in this study's findings.

The quantity and quality of evidence for implant-specific oral hygiene for performance by patients at home is low (Esposito et al., 2012; Grusovin et al., 2010; Louropoulou et al., 2014). It is not surprising therefore that the educators surveyed appeared to be taking their cues from the periodontal literature, particularly emphasizing interproximal cleaning, with the high recommendation of interdental brushes in line with the conclusions of systematic reviews (Sälzer et al., 2015; Slot et al., 2008), while the quality of evidence for flossing efficacy is widely acknowledged to be weak (Sälzer et al., 2015; Sambunjak et al., 2011). Patient-performed interdental brush efficacy around implants remains to be quantified in clinical research, with one study of patients with full arch implant-supported restorations finding that interdental brush use increased most after OHI was given, but that overall cleaning ability remained poor (Kreve et al., 2016). The adjunctive use of mouthwash is likely to be another recommendation appropriated from the periodontal literature, and chlorhexidine gluconate is included as "the oral topical agent of choice" for implants in the Clinical Practice Guidelines from the American College of Prosthodontists (Bidra et al., 2016), but the limited evidence for its use in implant home plaque control (Felo et al., 1997; Truhlar et al., 2000) is mixed and it did not improve outcomes when included as part of peri-implant mucositis treatment (Porras et al., 2002; Thöne-Mühling et al., 2010).

Implant diagnostics are strongly established in the literature, with the latest recommendations by consensus (Renvert et al., 2018) building upon previous reviews and recommendations (American Academy of Periodontology 2013; Heitz-Mayfield 2008). The educators surveyed in this study reported generally high adherence to current recommendations and this should

continue as the literature evolves. One interesting finding in this study was the lower coverage of recession measurement, as it can be easily performed during pocket probing. The development of recession is a possible sign of peri-implantitis (Berglundh et al., 2018) and assessment is an essential part of pocket depth probing and bone level assessment, as the mucosal margin is the reference point itself. As with the other diagnostic procedures, changes over time may represent the development of pathology (Heitz-Mayfield & Salvi 2018), and from the patient's perspective, recession may cause aesthetic concerns. This survey's findings appear consistent with recent surveys of the clinical preferences of dental practitioners in Australia, where 56.0% of GDPs surveyed and 85.6% of OHPs surveyed measured recession, at lower rates than the other diagnostic procedures (Chapter 5; Chapter 6). The development of a standardised reference point e.g. measuring the height distance from the contact point area or cemento-enamel junction of an adjacent tooth could be considered in future diagnostic recommendations.

There are no evidence-based standardised instrumentation protocols for implant maintenance, whether in maintaining health (Jepsen et al., 2015) or treating peri-implant mucositis (Schwarz et al., 2015) and peri-implantitis (Romanos et al., 2015), and this was reflected in the mixed teaching of maintenance instruments/techniques found in this study. While there was understanding from most educators in this study that stainless steel instruments are less appropriate, having been shown to cause significant surface scratching (Agar et al., 1997; Baek et al., 2012; Mann et al., 2012; Matarasso et al., 1996; Mengel et al., 2004), curettes of different materials have theoretical advantages but unproven efficacy. Limited evidence has shown that titanium curettes also cause scratching (Matarasso et al., 1996; Mengel et al., 2004), although perhaps to a lesser extent (Bertoldi et al., 2017), and plastic curettes may be ineffective at removing plaque (Schmage et al., 2014) as they may be too large (Maximo et al., 2009). Their popularity in the education programs described in this study is therefore not strongly supported by the literature. In contrast, there are some studies supporting the cleaning efficacy and lack of damage caused by plastic ultrasonics (Kawashima et al., 2007; Schmage et al., 2012) and air powder polishing (Mussano et al., 2013; Riben-Grundstrom et al., 2015), yet their coverage in education programs in this study was slightly lower than that of the plastic and titanium curettes. In recent surveys comparing current preferences of GDPs and OHPs for these four instrument options, plastic curettes were most popular (used by 43-53%), followed by plastic ultrasonics (26-44%), with titanium curettes (12-30%) and air powder polishing (9-30%) used at much lower levels (Chapter 5; Chapter 6). Interestingly in this study, plastic ultrasonics were rarely taught in DCD programs. Whether this finding reflects teaching by specialists who have habitually used other instruments or found them to be more effective is unknown and may warrant further investigation. Rubber cup polishing appeared to be more popular among

practitioners (60-74%) than educators in this survey, and its use in the literature is not widely described, other than being suggested as a possible method for maintaining peri-implant health (Armitage & Xenoudi 2016). Flossing was both most commonly taught by the educators surveyed and used in practice by the practitioners surveyed (Chapter 5; Chapter 6) but it is not usually mentioned as a professional maintenance method in the treatment literature. Systemic antibiotics have no proven protocol but are commonly used (Claffey et al., 2008; Javed et al., 2013) due to the difficulty of treating peri-implantitis, and correspondingly, some DCD students in this study were taught about them; their higher inclusion in CPD programs may be a concern (if included as part of the theory of peri-implantitis treatment, as there was no supervised clinical teaching or clinical observation). Overall, further research into efficacious peri-implant maintenance armamentarium should continue, and educators should ensure their programs reflect the latest evidence.

Some risk factors for peri-implant disease are well-established in the literature, such as poor oral hygiene (Costa et al., 2012; Ferreira et al., 2006; Roos-Jansåker et al., 2006; Serino & Ström 2009), poor compliance to regular supportive maintenance (Costa et al., 2012; Rinke et al., 2011; Roccuzzo et al., 2010), active periodontal disease or residual pockets (Canullo et al., 2016; Cho-Yan Lee et al., 2012; Pjetursson et al., 2012), extent of peri-implantitis (Lee et al., 2017), and systemic factors such as smoking (Rinke et al., 2011; Roos-Jansåker et al., 2006). The influence of some factors such as keratinised mucosal margin and occlusal overload are less conclusive in the literature (Heitz-Mayfield & Salvi 2018; Schwarz et al., 2018), and still others which may impact upon peri-implant disease require further investigation (e.g. smoking, diabetes mellitus, metabolic diseases). Coverage of these factors within the overall topic areas of oral hygiene, periodontal/peri-implant history and medical history was encouragingly high overall in this study, although slightly lower in the DCD programs, perhaps due to a more self-directed learning structure.

Prosthetic factors are also known to impact peri-implant disease, such as the greater incidence of biological complications where implants have been cemented rather than screw-retained (Jung et al., 2012; Sailer et al., 2012; Wittneben et al., 2014), and inflammation and disease related to cement retention (Korsch et al., 2014; Linkevicius et al., 2013; Wilson 2009). However, the impact of other prosthetic factors such as prosthesis design, embrasure shape, or splinting of adjacent implants upon peri-implant disease have not been established, and clinical guidelines are lacking, although the importance of cleaning accessibility in prosthesis design has been established (Derks et al., 2016a; Heitz-Mayfield & Salvi 2018; Renvert & Polyzois 2015; Serino & Ström 2009). For example, adjacent implants restored with splinted or separate crowns have both shown negligible crestal bone loss after 5-10 years in a few studies (Blanes et al., 2007;

Naert et al., 2002; Vigolo & Zaccaria 2010), but separate crowns were preferred by patients in a recent split-mouth prospective study (Clelland et al., 2016). The literature continues to develop from previous concerns about occlusal overloading in the 1990s (Quirynen et al., 1992), now considered to have no evidence as a peri-implantitis risk factor (Schwarz et al., 2018), and splinted crowns being described as "current practice" in a 2008 review article (Gross 2008), compared to ongoing recommendations of oral hygiene to be a primary consideration (Goldberg et al., 2001; Grossmann et al., 2005; Weigl 2003). In this study, splinted or separate crowns for adjacent implants were covered by 20-50% of programs for dental students/dentists in the various course types. Educators must ensure that current literature regarding all aspects of these types of prosthetic decisions are included in education programs, so that implant maintenance factors are considered within the current paradigm of restoration-driven implant dentistry.

There is little evidence for the frequency of implant review in the literature, other than a 6-monthly recommendation in recent American College of Prosthodontists Clinical Guidelines (Bidra et al., 2016). Radiographic assessment "to discriminate between health and disease states" (Renvert et al., 2018) is recommended in the case of pathological signs (American Academy of Periodontology 2013) and otherwise lacks a routine recommended frequency, e.g. every 2 years, although the possibility of bone loss in the absence of detected signs/symptoms (for which diagnostic criteria does not yet exist) is acknowledged in a recent review (Schwarz et al., 2018), and was found in a recent clinical study of patients in the general community (Chapter 2). The mixed coverage of implant review and radiograph frequency in this study may reflect the ongoing uncertainty in the literature.

The inclusion of implant maintenance information appropriate for each education program type and level of implant service provision (including no provision) should be mandatory given the prevalence of peri-implant diseases (Atieh et al., 2013; Derks & Tomasi 2015; Lee et al., 2017), and the acknowledgement by some educators in this study of the inadequacy of their current content. The implant maintenance knowledge and competency requirements for graduating dentists in Australia since 2010 (Mattheos et al., 2010) is an existing suggested standard which could be considered a baseline level of competency for all dentists, but there are no current requirements for CPD implant training programs to deliver this content. While this survey was limited to the size of the implant education sector in Australia and received only small numbers of responses from non-university sources, the findings support suggestions from Australian and European reviews of CPD for accredited and assessment-based implant dentistry training at the CPD level (Mattheos et al., 2009; Mattheos et al., 2014; Mattheos et al., 2010). Possible delivery formats could include a university-led Graduate Certificate award program to be considered a

minimum clinical competency training level (Ivanovski et al., 2010), or a structured modular format suiting a learner-directed personal development plan (Mattheos et al., 2014). While implant maintenance has been recommended to be covered in undergraduate and specialist training (Mattheos et al., 2014), its inclusion in CPD training and attempts to reach dentists who have little interest in providing implant treatments nor attending implant training should not be neglected. A recent survey of 303 Australian general dentists found that CPD was the highest level of implant training attended by 73.6% of respondents, 18.5% had not attended any formal postgraduate nor CPD implant training and approximately 15% were not involved in providing implant treatments when established in their careers (Cheung et al., 2019). The latter low-interest group may also be of significant size in other countries; these dentists will nevertheless have contact with patients with implants and should have basic clinical competencies in diagnostics and maintenance. Profession-wide distribution of implant maintenance information should therefore be considered in planning implant dentistry teaching, such as with the online teaching formats suggested previously (online courses, webinars or informative bulletins).

While this study was limited in scale due to the small size of the implant dentistry education sector in Australia and the challenges of maximising a response rate with a voluntarily submitted online survey, it provides initial insight into the current position of implant maintenance within implant dentistry teaching as a whole, and improvements needed as reported by respondents. Teaching in non-university environments in particularly varies widely even among the small number who responded and there may be some non-response bias, where implant maintenance may have been of lesser interest to those who did not complete the survey. As is known and was confirmed in this study, there was significant overlap whereby a single respondent may coordinate training programs for several different audience groups and course types. Developments in this sector should be followed as the importance of implant maintenance continues to be established, as it directs the evolving knowledge and clinical practice of dental practitioners.

Conclusion

This study established an initial understanding of current implant maintenance teaching in Australia at several levels, from undergraduate degrees and CPD to postgraduate diplomas and specialisation. Respondents acknowledged a need for increased and updated inclusion in their programs. The mixed preferences of educators in teaching implant home hygiene and professional maintenance in this study likely reflects the limited evidence available, but

diagnostic methods are strongly established and should continue to be comprehensively covered. Comprehensive and contemporaneous inclusion of implant maintenance within implant dentistry teaching as a whole is of paramount importance in the guidance of dental professionals.

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Chapter 8: Discussion

Information flow from the literature to educators to practitioners

The 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions culminated in the recent updated classification for periodontitis (Papapanou et al., 2018) and a new classification for peri-implant diseases (Renvert et al., 2018). However, while the subsequent management of diagnosed periodontal diseases has evidence-based management protocols known profession-wide, peri-implant diseases do not. Standardised diagnostic criteria form the first step in streamlining the quality of research into peri-implant disease management, but in the meantime this thesis shows that there is great variability in clinical practice and an even more confused picture for patients.

All dental practitioners learn the preventative foundation for maintaining the natural dentition, and the same should apply for acquired artificial dentition, particularly when implants mimic natural structures more closely than any other previous reconstructive treatment options yet are significantly different. Implant maintenance should be integrated into the entire process of pre-operative discussion, treatment planning, surgical and restorative treatment, not just considered the post-treatment phase. It should be taught as such, both to those learning practical implant provision skills and those who are not. The existing education system and CPD programs in Australia by which OHPs have been able to learn implant maintenance appears to be effective, with OHPs reporting high levels of evidence-based practice (Chapter 6). The challenge for the education sector lies in information delivery to general dentists to ensure more uniform knowledge levels and appropriate practice standards, with a distinction between the education pathways for dentists who want to provide implant treatments, and programs for those who do not. All dentists should either have at least the same preventative skills and priorities as OHPs or current graduation-level competencies. Alternatively, specific referral guidelines by which to operate could be developed. The feasibility of possible forms of information delivery to dentists who would not otherwise attend implant dentistry education, such as a mandatory update program related to scope of practice, remain to be seen, with internet-based teaching formats such as webinars, online courses or emailed newsletters updates a possibility.

There are strong indications from the OHP, GDP and educator surveys conducted that universities should strive to increase the attendance at their CPD-level programs. GDPs reported much higher historical accumulated attendance at dental association or implant company CPD compared to university-based CPD programs (Cheung et al., 2019), while OHPs reported highest

attendance at dental association CPD and low attendance at university-based or implant-company CPD (Chapter 6). From the perspective of implant maintenance content, university-based CPD more universally involved professors or heads of department determining content and periodontists teaching it (Chapter 7), and was recalled just as frequently as a source of implant OHI information by GDPs despite their lower historical attendance (Cheung et al., 2019).

Nevertheless, non-award CPD programs are considered pre-clinical education and do not confer adequate competencies for clinical practice among general dentists (Ivanovski et al., 2010). While a Graduate Certificate level of basic clinical competency has been suggested below the more advanced Graduate Diploma level (Ivanovski et al., 2010), these programs are not currently available and thus dentists practising at this level are mostly attending non-award CPD programs at their own discretion in order to do so. Only one-tenth of the GDPs surveyed offering implant services to their patients had attended formal postgraduate training in implants (Cheung et al., 2019). The role of universities in providing Graduate Certificate training programs would therefore be critical in standardising the minimum level clinical competencies, including in implant maintenance. Alternatives could include the equivalent student-directed completion of core requirements, from, for example, programs offered by different universities, or a formalised accreditation process for programs from different education providers to be included within such a system. Mentorship and/or a program of supervised clinical practice would be essential (Donos et al., 2009; Mattheos et al., 2010).

In general, educators' intended content appeared to be reliably accepted and deployed in the knowledge and preferences of GDPs and OHPs surveyed (Chapters 4-6). Clinical techniques for diagnostics, and especially OHI and maintenance should be specified in training programs and not just assumed, and practical clinical exposure to implant maintenance could be considered. A particular finding in comparing the educator and practitioner surveys was a lower teaching and performance of recession measurement compared to other diagnostic procedures, which were otherwise consistently and commonly taught. OHPs performed almost all diagnostic procedures at higher rates than GDPs but similarly assessed recession less commonly (Chapter 6). As suggested in Chapter 7, the development of a protocol to establish consistent reference points would be useful in standardising clinical practice for recession assessment.

Another finding of interest in comparing the dentist survey and educator survey was that plastic ultrasonic tips, which have promising evidence for effective and safe implant cleaning, were rarely taught in DCD programs, at lower rates than in the other course types. In the dentist survey, in results not reported in Chapters 3-5, periodontists (n=44) reported the highest usage of stainless-steel ultrasonics (59.1%) and curettes (52.3%) amongst GDP and specialist groups,

and similar usage of plastic ultrasonic tips (27.3%) to GDPs (26.5%). Whether these findings represent teaching by specialists who prefer stainless-steel instruments, as reported previously (Mattheos et al., 2012), or whether those with more experience find them to be more effective, is unknown and may warrant further investigation.

Given the limitations of current evidence for the disease process, OHI, maintenance procedures and frequency of maintenance, the need to stay abreast of the current research and evolving literature should be emphasized in education programs at all levels. Teaching by periodontists who would have more clinical experience in the area, as appears to be more frequently the case in university-based qualification and CPD programs, could be of benefit.

Information flow from dental practitioners to patients

One of the clear findings from the patient survey (Chapter 2) was that although plaque/calculus presence and lack of interproximal oral hygiene were significantly associated with peri-implant disease, patients had mixed or poor recall of previous implant OHI received from their practitioners, either immediately after implant treatment was completed (53.8% of implants), or at any time subsequently (57.7% of implants). This is in contrast to the finding in the GDP survey (Chapter 4) where 87.4% of treatment-planning respondents reported giving OHI immediately after treatment completion or at the next recall/review, and 69.6% of respondents gave OHI at the next appointment for implants they had not planned. However, repetition of OHI by GDPs was poor, with only 57.4% of those who give OHI doing so regularly, and perhaps this explains the similar rate of OHI recall by patients. More of the OHPs surveyed repeated implant OHI regularly (75.2%), but large proportions of both groups (21.4% of OHPs, 27.0% of GDPs) only repeated it in the presence of peri-implant signs/symptoms, which is not a sufficiently preventative approach. While OHI methods overall require further research and investigation, there is room for improvement in the long-term pre-emptive reiteration of implant OHI to patients, and this should be emphasized at the implant education level as well.

In comparing the implant OHI preferred by practitioners and the hygiene techniques patients reported performing at home, flossing recommendation and performance was similar at around 70%, but the recommendation of interdental brushes (around 70%) and circumferential flossing (41-63%) was higher than patient performance (45% and 24.4% at implant level respectively). The converse pattern was found for mouthwash, which was only recommended by about 15% of practitioners yet utilised for 39.7% of implants (35.3% of patients), and lacks evidence for peri-implant maintenance efficacy in the literature (Felo et al., 1997; Thöne-Mühling et al., 2010;

Truhlar et al., 2000). These findings are in general agreement with the observation in one clinical study (Pjetursson et al., 2005) that patient hygiene habits do not appear to change significantly after implant treatment, as interdental brushes have been available only in recent years and circumferential flossing is a technique specific to implants. Nevertheless, one encouraging finding in the patient survey was that interdental brush usage was higher around more recently placed implants. The challenge of achieving behavioural change through OHI communication methods still stands.

The patient survey was conducted in private general dental practices which did not employ OHPs. As OHPs reported a generally higher preventative focus when surveyed, patients with implants who attend practices which do employ OHPs may have different home hygiene habits, recall of OHI received and/or peri-implant outcomes, which could be an area of further research.

Overall, from a preventive perspective, the role of education of general dentists in particular is of great importance and potential in facilitating greater long-term success of dental implant treatment. The finding in the patient survey that implants provided by general dentists were reported to have a significantly higher likelihood of a previous soft-tissue complication was in agreement with the Swedish implant registry study where implant prostheses provided by general dentists were more likely to have moderate/severe peri-implantitis (Derks et al., 2016). In response, Tarnow (2016) commented on the need to ensure adequate training of general dentists in implant restoration, from the dental school level. Predisposition to peri-implantitis due to prosthetic design-related factors has also been identified as a main possible subtype of disease development and risk profiling (Canullo et al., 2016). The results of this thesis emphasize the need to also improve information distribution to general dentists who are already working in the community. GDPs who reported higher case volumes were more preventative in providing pre-treatment OHI (Chapter 4) and implant maintenance generally (Chapter 5). The impact of implant case volume on implant restoration quality was beyond the scope of the research conducted (and is not known to have been reported on in the literature) but might have a similar effect. Although implant maintenance was the focus of this thesis, the above findings and literature and the fact that most implant-providing dentists surveyed treat small numbers of implant cases annually (Cheung et al., 2019) should therefore be carefully considered in planning restoration-focused implant education programs as well.

Additional results

Gender differences among dentists

The respondents in the dentist survey had a slightly higher representation of females (45.9%) than the most recent data for the Australian dental workforce (38.0% of employed dentists, including specialists) (AIHW et al., 2016), and the female GDPs surveyed had a mean graduation year of 2003 compared to 1996 for male GDPs (p<0.001, CI:4.8-10.1 years earlier). Attendance at implant training after graduation was significantly different between genders overall and at the CPD level, with male GDPs having attended all types of restorative and surgical CPD training at significantly higher rates, and 26.6% of female GDPs having attended no CPD or postgraduate training, compared to 11.6% of male GDPs (p=0.004 for distribution of highest level of implant training attended). However, attendance at postgraduate implant training was similar between genders. Sources of implant OHI information were generally similar between genders when accounting for graduation year and attendance at courses, except that female GDPs reported their colleagues as a source of information significantly more often (42.4% vs 28.7% males, p=0.012).

Both female and male GDP groups surveyed have been increasingly starting to provide implant treatment within the first years of their careers, evident when comparing graduation decade groups. Men have done so at higher rates than women in all graduation decade groups, reaching significance in all except for the most recent 2006-2015 cohort. While about 50% of female and male GDPs restored implants, male GDPs were more likely to perform surgical placement (35.4% vs 10.8% of female GDPs), and female GDPs were more likely not to provide any implant treatment (38.8% vs 13.4% males), a significantly different distribution of implant treatment provision overall (p<0.001). Among GDPs with implant experience, male GDPs also estimated their annual case volume (41.2% doing >20 cases) to be significantly higher (p<0.001) than female GDPs (89.6% doing 0-20 cases).

In implant home hygiene preferences, no significant differences in OHI techniques, timing of OHI provision or OHI communication methods were found between genders. Except where female GDPs were more likely to perform pocket depth probing (p=0.038), there were no significant differences between genders in the performance of implant diagnostics, the frequency of radiographic review, the risk factors considered in determining recall frequency, or preferred review period in the case of pathology.

Superficial implant cleaning and peri-implant mucositis treatment were provided equally by the gender groups, while subgingival debridement (p=0.032) and peri-implantitis treatment

(p=0.002) were provided at higher rates by male GDPs, likely reflecting their greater provision of implants, greater surgical experience and overall implant experience by time. There were no differences by gender when comparing the 19.1% of GDPs who did not use any implant-specific maintenance instruments or techniques, and among those who did, there were few differences by gender in the instruments/techniques used (except for greater use of local and systemic antibiotics by male GDPs, despite a lack of evidence to support their use).

Overall, female GDPs were younger and reported lower implant training and lower implant provision, yet no significant differences were found compared to their male colleagues in their understanding of correlation between OH and peri-implant health, their OHI preferences, diagnostic preferences, provision of implant maintenance treatment overall, and preferred maintenance armamentarium. Implant training and experience therefore showed no correlation to a preventative approach and provision of implant maintenance services, by this comparison. Reasons for these findings require further investigation and could include the more recent average graduation of female GDPs in this study, female GDPs having a more preventative approach overall, and/or the inadequacy of implant maintenance teaching within implant training programs particularly at the most popular CPD level.

There are also implications for implant education as a result – further investigation is needed into why female GDPs are attending CPD programs at lower rates and providing less implant treatments. Other avenues of research might include whether they are more risk averse in providing complex treatments, or whether they prefer to have attained more qualifications before proceeding, similarly to job-application trends identified in the business world (Barsh & Yee 2011; Mohr 2014). The study did not ask GDPs about their workload (full- or part-time) and their number of work locations, factors which could influence willingness to invest in or commit to offering more complex dental services and which might disproportionately affect female GDPs.

Prosthetic preferences and future direction

Dentists were surveyed about some implant restoration preferences which could impact on peri-implant outcomes, not previously reported in the manuscript chapters included in this thesis. Among GDPs with implant experience, almost all (93.4%) preferred direct screw access retention of prostheses rather than cementation (0.9%) or cross-pin (2.3%), and 83.6% preferred separate single crowns when restoring adjacent implants in optimum conditions while 14.6% preferred to splint the crowns together. These findings are in agreement with the current literature on the impact of retention method on biological outcomes (Jung et al., 2012; Korsch et al., 2014; Sailer et al., 2012; Wilson 2009), hygiene accessibility (Derks et al., 2016; Heitz-Mayfield & Salvi 2018;

Serino & Ström 2009) and the similar long-term clinical outcomes in splinted and non-splinted adjacent implants (Blanes et al., 2007; Naert et al., 2002; Vigolo & Zaccaria 2010) despite previous concerns (Quirynen et al., 1992) and subsequent variable research findings in occlusal overloading (Duyck & Vandamme 2014). The strong preference for screw retention is also in agreement with its apparent increasing popularity among practitioners, as documented in serial systematic reviews (Jung et al., 2008; Jung et al., 2012) and previous surveys of Australian dentists and specialists (Cheung et al., 2016; Guo 2015; Sambrook et al., 2012; Wang et al., 2016b). Future research could elaborate on some differences in these studies between surveyed preferences and recorded clinical usage, especially among general practitioners. Clinicians' preferences for splinted vs separate single crowns have not been previously documented in the literature and similar research should be conducted in other populations; meanwhile, patients have been reported to prefer the non-splinted restorations (Clelland et al., 2016) and these findings should be confirmed. Interestingly, although the number of implant-providing prosthodontists in this survey was small (n=19), they preferred splinting more (36.8%) than GDPs and periodontists (about 14%), possibly reflecting a more load-focused approach.

Areas of further research

Following on from the results of this thesis, research should continue in several key areas:

- The continued establishment of evidence-based implant home hygiene protocols, professional implant maintenance protocols and armamentarium, ideally in studies with standardised controls, for the maintenance of peri-implant health as well as the management of disease;
- Continued development of effective OHI communication strategies;
- Peri-implant outcomes at the community level, expanding upon the results of the Swedish implant registry study (Derks et al., 2015), this thesis and other surveys of patient-reported outcomes;
- Clinician preferences, provided services and volume of implant treatment provision in the community, including understanding the comparative scale of implant provision in general dental and specialist practice (such as with the analysis of insurance information in the USA [American Dental Association 2007]) and the role OHPs can play in implant maintenance;
- Development and monitoring of implant dentistry education systems and programs.

Reviewing the literature has brought up several areas requiring further research and investigation:

- The peri-implant disease process, onset, disease activity process from mucositis to peri-implantitis and the speed of progression are not yet understood. Whether progressive peri-implant bone loss can occur in the absence of inflammation (at the time of examination or otherwise) is unclear (Schwarz et al 2018), and better understanding could improve recommendations for review and radiographic monitoring.
- Risk factors for peri-implant disease, where the evidence is currently inconclusive or limited (Schwarz et al., 2018), such as iatrogenic factors (cement type and excess, titanium granules, implant positioning) and systemic factors (genetics, smoking, diabetes mellitus, cardiovascular and other metabolic conditions);
- Clinical research is needed into patient-performed interproximal cleaning, especially in interdental brush use around implants, including whether brush shape matters, such as with a narrow-waisted brush (Chongcharoen et al., 2012).
- Implant-retained prosthesis design guidelines are yet to be developed and whether embrasure shape or volume affect hygiene efficacy and clinical outcomes is unknown. Interdental cleaning and accessibility should also be considered in the context of non-anatomical embrasure shapes, prosthesis design, the loosening of implant-tooth interproximal contacts over time and associated food impaction (Byun et al., 2015; Koori et al., 2010; Wang et al., 2016a; Wong et al., 2015).
- The development of ultrasonic scaler tips in materials that are effective and non-damaging, such as copper alloy (Baek et al., 2012), and do not leave residual fragments should continue.
- Similarly, periodontal probes of different materials could be assessed and developed with the aim of better negotiation around implant-retained prosthesis contours e.g. plastic or flexible probes. Increases in probing depths over time (Renvert et al., 2018) may be sufficient for diagnosis when consistently performed with currently-available instruments. Probing after prosthesis removal is strongly correlated to bone loss measurements whereas probing without prosthesis removal is not (Serino et al., 2013), but feasibility in day-to-day clinical practice is questionable. If bone loss is considered to occur circumferentially (Schwarz et al., 2018), an alternate approach may be to record and present the deepest ideally angled pocket depth per implant, as in the patient survey results (Chapter 2), and not just mean probing depth as is most common in the literature, even in a study which presented probing depths at different positions (Serino et al., 2013).

- Surveys of better quality to track the rate of performance of oral hygiene habits in the general community would provide evidence for general dental health promotion as well as baseline data, so that comparisons could be made for research into oral hygiene interventions specific to particular conditions. These kinds of baseline data are needed especially if clinical research is to better represent dental practice in the community and not just convenient university or specialist practice study populations.

Possible strategies to facilitate communication between practitioners and in determining disease risk:

- The limitations in the current methods of keeping dental records and implant baseline parameters should be addressed as they are essential in long-term diagnostic review. There may be lack of access or communication challenges where records and radiographs might be kept by various dental practitioners, such as if a patient were to relocate or change dentists over time. Solutions may include a proposed global digital implant registry (Klinge et al., 2018) or digital dental health records linked to the patient's government records. As with other digital health records, online security will be an ongoing concern. Alternatively, patients may have to play a larger role in keeping their own implant records and understanding this necessity.
- Periodontal maintenance generally refers to supportive therapy following treatment of periodontal disease in a lifelong periodontitis patient. There is room for confusion in the terminology of implant maintenance, as it refers to both the maintenance of peri-implant health as well as the treatment of peri-implant disease and subsequent post-recovery maintenance. Different terms to describe whether a site has a history of peri-implant disease would be helpful. Periodontitis classification includes the category of the successfully treated periodontitis patient with a reduced periodontium (Chapple et al., 2018), but there is no analogous terminology nor documented understanding of stable peri-implantitis tissues after treatment. Whether the risk of recurring disease should be considered at the patient or implant level is also yet to be determined. A starting point is the composite criterion for successful peri-implantitis treatment (implant survival, probing depth <5mm, no BOP or suppuration, absence of further bone loss) suggested by Heitz-Mayfield and Mombelli (2014), which may require updates corresponding to the new peri-implant disease classification. The current knowledge of disease progression is also insufficient to adequately define a recurrence of inflammation as mucositis in an otherwise stable site, or recurrent peri-implantitis, and whether it might be analogous to the differentiation between gingival inflammation in

a stable periodontitis patient with probing depths ≤3mm, and recurrent periodontitis (Chapple et al., 2018). Clearer or more comprehensive terminology would facilitate better communication between practitioners and more appropriate management.

- The development of a comprehensive predictive model of peri-implant disease risk could help to streamline the implant treatment planning process according to the risk profile of each patient and each implant site, such as in the prosthetic-, plaque- and surgical-related risk profiles developed by Canullo et al. (2016) through data-mining. This would aim to minimise disease risk, simplify individualised maintenance and management in the event of disease occurrence and improve peri-implantitis treatment outcomes by addressing the relevant causative factors. Whether the relative importance of peri-implant disease risk factors can be compiled into a tool such as the periodontal risk assessment functional diagram (Lang & Tonetti 2003) or PreViser® analytical software (www.previser.com) remains to be seen.

Concluding remarks

Through the literature reviewed and the findings of the surveys conducted, this thesis has identified areas where immediate real-life and clinical improvements can be made in managing dental implants after treatment is completed, at every level of information development, transfer, receipt and subsequent integration into daily clinical practice and home care, as well as areas of further research. Based on the thesis' findings, the clinical practice of implant maintenance and home hygiene can be enhanced immediately within the boundaries of current evidence, whereby it is hoped that implant success, patient experience and peri-implant outcomes will improve. Advances in scientific understanding will also continue into the future. The challenges that are unique to the field of implant dentistry have been made clear in this thesis' series of surveys, i.e. the relative youth of the field and need to further understand the peri-implant disease process; the complex task for implant dentistry educators to train practitioners with different backgrounds and goals in a new and emerging discipline; and the multidisciplinary and multi-practitioner nature of implant treatment provision. Dental implants have been a paradigm-changing treatment modality, and the profession should continue to strive for best evidence-based practice standards, to optimise treatment success and patient quality of life in the long-term.

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Appendix I: Patient survey instrument

The questionnaire and examination record form used in Chapter 2 is presented here.

Patient Questionnaire – implant maintenance:

1. Name: _____

2. Gender: M/F

3. What is your date of birth? _____

4. What is your medical history:
- Medical conditions (in particular diabetes, osteoporosis, arthritis/dexterity issues)
  _____
- Medications -
  _____
- If you smoke, on average how many per day _____

5. What is your dental history:
a) how extensive would you rate your treatment history?
○ minimal
○ average
○ extensive
b) what dental treatment or conditions have you had apart from implants? (select all that apply)
☐ fillings
☐ root canal
☐ gum disease
☐ cracks (fractured teeth)
☐ jaw joint/ temporomandibular joint problems
☐ tooth grinding/clenching
☐ crowns/bridges
☐ removable partial dentures
☐ cosmetic treatment e.g. veneers, tooth whitening
☐ orthodontic braces
☐ other _____
c) if you have missing/lost teeth what was the cause of your teeth being extracted?
_____

6. Do you attend the dentist:
○ on a regular basis
○ only when you have a problem

7. How frequently do you have a check up? _____

8. Do you have any gum disease? Y/N
Or family history of it? Y/N

9. What do you use to clean your teeth and implants, and how often? (select all that apply and indicate frequency for those selected)
☐ Brushing _____
☐ Regular interdental flossing _____
☐ Interdental brush e.g. Pikster _____
☐ Superfloss _____
☐ Loop flossing around implant _____
☐ Mouthwash _____
☐ Irrigation device (e.g. Waterpik or AirFlosser) _____
☐ Other (specify) _____ _____

10. What was the main reason for the loss of the tooth which was replaced by an implant?
- o Decay
- o Gum disease
- o Cracked or fractured tooth
- o Failed root canal
- o Failed crown or bridge
- o Naturally missing or never had a tooth
- o Other (specify) _____

11. Who was your implant treatment performed by?
- o your general dentist
- o another general dentist with special implant interest
- o referred to specialist for surgery and returned to your general dentist for implant crown
- o referred to specialist(s) for surgery and implant crown
- o other (specify) _____

12. What year was your implant treatment completed? _____

13. Were there any complications during or immediately after treatment?
- o Yes (specify what and when) _____
- o No

14. When implant treatment was completed were you given any specific instructions on how to clean the implant at home?
- o Yes; instructions given by: _____
  Please outline the instructions: _____
- o No, just to continue with oral hygiene as normal

15. Has anyone else has given you instructions on how to clean the implant at home and what were they?
- o Yes; instructions given by: _____
  Please outline the instructions: _____
- o No

16. After the treatment was completed did you return for a review appointment or any followup treatment?
- o Yes (specify when) _____
- o No

17. Do you have appointments to specifically check or clean/maintain the implant?
- o Yes; appointments with: _____
  Please outline how often: _____
- o No

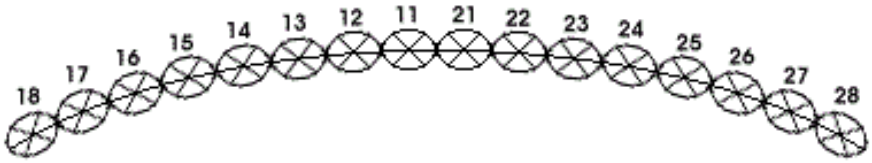
18. Is your implant checked and treatment performed/arranged during your routine dental checkups?
- o Yes
- o No

19. Have you had any significant problems with the implant (inside the bone), implant crown or gums around the implant requiring further treatment?
- o Yes (specify problem and when it occurred) _____
- o No

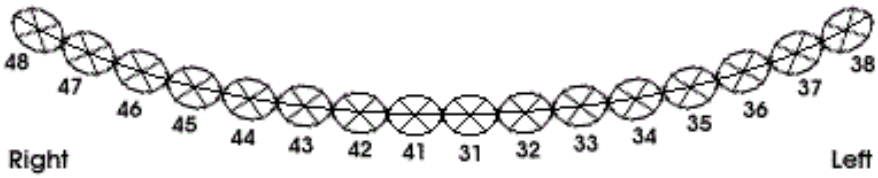
Patient Examination:

General dental condition:

1. Dental condition:
☐ absent teeth _____
☐ % of teeth restored _____
☐ RCT _____
☐ previous/current periodontal condition _____
☐ cosmetic work _____
☐ fixed prostheses _____
☐ removable prostheses _____
2. Any current pathology: _____
3. Periodontal status CPITN: ☐☐☐
☐☐☐
4. O'Leary plaque index: (ask not to brush just before appointment)



$$\frac{\text{Total Number Tooth Parts With Plaque}}{\text{6 x Number of Teeth Present}} \times 100 = _____\%$$



Implant condition:

1. Tooth position: _____
2. Any described symptoms _____
3. Presence of pain generally: Y/N
4. Mobility of crown: Y/N
5. Retention system: screw-retained/cemented
6. Circumferential probing depths: MB___B___DB___ML___L___DL___
7. Soft tissue margin position _____
8. Soft tissue visual condition: e.g. healthy/inflamed; keratinised/non-keratinised collar _____
9. Presence of bleeding on probing: Y/N
10. Presence of pus: Y/N
11. Presence of plaque/calculus: Y/N Mombelli index: 0/1/2/3
12. Any threads probeable: Y/N
13. Any threads visible: Y/N
14. Radiograph: where is bone level in relation to threads _____
15. Implant system _____
16. Any bony defects _____
17. Any defects between crown and fixture _____
18. Local factors affecting cleansability e.g. ridge lap crown, overcontoured crown, long tight contact points, splinted crowns _____
19. How do you clean the implant? _____
20. Do you have any pain/discomfort when cleaning the implant? Y/N

Appendix II: Dentist questionnaire

The questionnaire used in Chapters 3-5 is presented here.

Notes:

1. Multiple choice answer choices preceded by a circular checkmark indicate where one selection only is allowed as the answer. Square checkmarks denote that multiple selections are allowed, and this is also indicated in the question.
2. Some questions were skipped over using the “Skip logic” function on the Surveymonkey™ website, depending on the answers chosen by respondents. These are indicated below by description within square brackets.

Please complete the survey as accurately as possible. The survey requires approximately 20 minutes to complete.

On submission of the completed survey you can enter into a prize draw to win one of three $100 cash debit cards.

*All questions to be answered

General Information

1. What is your gender?
- M
- F

2. What is your year of birth? _____

3. Where and when did you complete your basic registrable dental degree?
Qualification: _____ Institution: _____ Year: _____

4. What are you registered with AHPRA as?
- General dentist
- Prosthodontist
- Periodontist
- Oral surgeon
- Oral and maxillofacial surgeon
- Orthodontist
- Endodontist
- Paedodontist
- Other _____

5. If you have specialist qualifications, where and when did you complete your specialist training?
Qualification: _____ Institution: _____ Year: _____

6. If you have non-specialist postgraduate (university/fellowship) qualifications, where and when did you complete them?
Qualification: _____ Institution: _____ Year: _____

7. Do you (select all that apply):
- ☐ Own your own private practice
- ☐ Work as an associate/contractor in private practice
- ☐ Work in public dentistry
- ☐ Work in a metropolitan area
- ☐ Work in a rural/regional area

Implant Training and General Preferences

8. If you provide implant treatment what year did you begin to do so? (indicate if N/A) _____

9. What postgraduate training have you completed in implant restoration (select all that apply):
Implant Restoration
- ☐ University degree/diploma
- ☐ University run CPD days
- ☐ Professional association/society course series
- ☐ Professional association/society CPD days
- ☐ Implant company course series
- ☐ Implant company mentorship program
- ☐ Implant company CPD days
- ☐ Work-based mentorship
- ☐ Other (please specify) _____
- ☐ None

10. What postgraduate training have you completed in implant surgery (select all that apply):
☐ University degree/diploma
☐ University run CPD days
☐ Professional association/society course series
☐ Professional association/society CPD days
☐ Implant company course series
☐ Implant company mentorship program
☐ Implant company CPD days
☐ Supervised implant surgery
☐ Observation and assisting implant surgery
☐ Work-based mentorship
☐ Other (please specify) _____
☐ None

11. Do you (select one):
o Only restore implants
o Only perform implant surgery
o Both restore and place implants
o Neither

12. How many implants do you restore/place per year:
o 0-20
o 21-50
o 51-99
o >100

13. Do you use/prefer/ask for particular implant systems/brands:
o Yes (please specify) _____
o No

14. What implant systems/brands did you primarily use during your training?
o list as many as applicable _____
o N/A

15. Do you use/prefer/ask for a particular fixture to abutment connection?
o Yes, external hex
o Yes, internal
o No

16. Do you use/prefer/ask for a particular implant crown to fixture connection?
o Yes, direct screw access
o Yes, cemented
o Yes, cross pin
o No

17. When restoring two adjacent implants e.g. 14/15 given optimum conditions do you prefer to:
o Splint the crowns together
o Place separate single crowns
o I am not involved in implant treatment

Implant Maintenance and Hygiene Instruction

18. Do you believe you have a role to play in the maintenance of implants?
o Yes
o No

19. Do you believe general dentists have a role to play in the maintenance of implants?
o Yes
o No

20. If you surgically place and/or restore implants do you give your patients specific post-restoration implant maintenance instructions i.e. for long term regular implant hygiene performed by the patient at home?
- o Yes
- o No
- o I do not place/restore implants

21. When is the FIRST time you give a patient specific post-restoration implant maintenance instructions, for an implant placed/restored/treatment planned by you?
- o Immediately following implant procedures that I complete
- o At the first review following implant restoration (please specify preferred time period in next question) [if this answer chosen, participant will be directed to Q22; all other answers will skip to Q23.]
- o At the first general/periodontal recall following implant restoration
- o Only if signs/symptoms of peri-implant condition present
- o Other (please specify) _____
- o I do not give instructions
- o I do not place/restore/treatment plan implants

22. If you answered 'At the first review following implant restoration' in Q21, please specify preferred time period of review: _____

23. If you do not give specific post-restoration implant maintenance instructions, why not?
- o I do not believe implant-specific maintenance instructions are necessary
- o I do not place/restore/treatment plan implants
- o I specifically refer the patient back to their implant dentist or periodontist (if applicable) for instructions
- o I ask the patient to ask their implant dentist or periodontist (if applicable) for instructions
- o I leave it to the implant surgeon
- o I leave it to the restoring dentist/specialist
- o I leave it to the patient's general dentist
- o I leave it to the patient's periodontist (if applicable)
- o I leave it to the hygienist
- o I ask my hygienist to do it
- o Other (please specify) _____
- o I give instructions

24. If you see a returning patient of yours with an implant NOT placed/restored/treatment planned by you, do you give specific post-restoration implant maintenance instructions?
- o Yes, at their first appointment with me at which they have the implant
- o Yes, at their next general/periodontal recall appointment with me
- o Yes, only if there is peri-implant pathology present
- o No, I specifically refer them back to their implant dentist or periodontist (if applicable) for instructions
- o No, I ask the patient to ask their implant dentist or periodontist (if applicable) for instructions
- o No, I leave it for their implant dentist or periodontist (if applicable)
- o Other (please specify) _____

25. When do you REPEAT specific post-restoration implant maintenance instructions? (please select the greatest frequency that applies to you)
- o I first gave instructions immediately after treatment completion, and repeat ONLY at the next implant review or general/periodontal recall following this
- o At every implant-specific review (please specify preferred frequency in next question) [if this answer chosen, participant will be directed to Q26; all other answers will skip to Q27]
- o At every general/periodontal recall
- o Only if signs/symptoms of peri-implant condition present
- o Other (please specify) _____
- o I do not give instructions.

26. If you answered that you REPEAT specific post-restoration implant maintenance instructions 'At every implant-specific review' in the previous question, please specify preferred frequency: _____

Implant Hygiene Instructions

27. What specific post-restoration implant maintenance home care instructions do you usually give for a single implant crown? (select all that apply)

☐ Regular brushing
☐ Regular interdental flossing
☐ 'Superfloss' or equivalent (floss with stiff threader)
☐ Interdental brushes
☐ Circumferential flossing (floss looped around crown and 'see-saw' motion)
☐ Oral irrigation (e.g. Waterpik)
☐ Mouthwash
☐ Other (please specify) _____
☐ None

28. How do you give specific post-restoration implant maintenance home care instructions? (select all that apply)

☐ Describe procedures to the patient
☐ Show procedures to the patient
☐ Ask the patient to show you after instruction
☐ I do not give instructions

29. Where did you learn specific post-restoration implant maintenance home care instructions? (select all that apply)

☐ Undergraduate dental degree
☐ Postgraduate university degree/diploma
☐ University run CPD
☐ Professional association/society courses or CPD
☐ Implant company courses or CPD
☐ Hands on live patient courses
☐ Work-based mentorship
☐ Colleagues
☐ Journal articles
☐ Textbooks
☐ None
☐ Other (please specify) _____

Implant Review

30. What do you perform during a routine implant check i.e. implant-specific diagnostic procedures? (select all that apply)

☐ Oral hygiene assessment around implant i.e. presence of plaque or calculus
☐ Soft tissue visual appearance assessment e.g. inflammation, keratinised mucosa
☐ Pocket depth probing
☐ Assessment of bleeding on probing
☐ Assessment of suppuration
☐ Recession measurement
☐ Radiograph to check bone level/bone defects
☐ Assessment of implant mobility
☐ I do not perform implant checks

31. When do you perform an implant check i.e. implant-specific diagnostic procedures? (please select the greatest frequency that applies to you)

o Only at a specific implant review appointment following treatment completion (please specify preferred time period in next question) [if this answer chosen, participant will be directed to Q32; then will skip to Q34]
o At regular specific implant review appointments (please specify preferred frequency in next question) [if this answer chosen, participant will be skip to Q33 then continue to Q34]
o At every general/periodontal recall [will skip to Q34]
o Only if signs/symptoms of peri-implant condition present [will skip to Q34]
o I do not perform implant checks [will skip to Q34]
o Other (please specify) _____ [will skip to Q34]

32. If you answered that you perform an implant check 'Only at a specific implant review appointment following treatment completion' in the previous question, please specify preferred time period: _____

33. If you answered you perform an implant check 'At regular specific implant review appointments' in the previous question, please specify preferred frequency: _____

34. What factors help you decide on a specific implant check frequency? (select all that apply)
☐ The patient's standard of oral hygiene
☐ Previous periodontal/peri-implant history
☐ Medical history
☐ Severity of existing peri-implant condition
☐ Probing depths around the implant
☐ I do not perform implant checks
☐ Other (please specify) _____

35. How often do you prefer to take a routine radiograph of an established implant?
○ 6 months
○ 12 months
○ 24 months
○ Only if signs/symptoms of peri-implant condition present
○ I do not take any radiographs of established implants
○ other (please specify) _____

36. How often do you prefer to repeat an implant check if signs/symptoms of a peri-implant condition are present?
○ 3 months
○ 6 months
○ 12 months
○ I do not perform any implant checks
○ Other (please specify) _____

37. In your experience, what is the strength of correlation between the quality of implant home hygiene and peri-implant health?
○ Very strong
○ Strong
○ Neutral
○ Weak
○ Very weak

Maintenance Procedures

38. Do you perform supragingival/superficial implant prosthesis cleaning during recall/periodontal maintenance?
○ Yes
○ No
○ No, but I refer the patient to their general dentist
○ No, but I refer the patient to their hygienist
○ No, but I refer the patient to their periodontist

39. Do you perform subgingival debridement of implants/implant surface during recall/periodontal maintenance?
○ Yes
○ No
○ No, but I refer the patient to their general dentist
○ No, but I refer the patient to their hygienist
○ No, but I refer the patient to their periodontist

40. Do you perform treatment of peri-implant mucositis?
○ Yes
○ No
○ No, but I refer the patient to their general dentist
○ No, but I refer the patient to their hygienist
○ No, but I refer the patient to their periodontist

41. Do you perform treatment of peri-implantitis?
○ Yes
○ No
○ No, but I refer the patient to their general dentist
○ No, but I refer the patient to their hygienist
○ No, but I refer the patient to their periodontist

42. If you answered 'Yes' to any of Questions 33-36, what instruments/techniques do you use? (select all that apply)

☐ Floss	☐ Stainless steel curettes	☐ Systemic antibiotics
☐ Rubber cup/brush with prophylaxis paste	☐ Plastic/carbon curettes	☐ Bone augmentation
☐ Air powder polishing/prophylaxis	☐ Titanium curettes	☐ Open (surgical) debridement and/or recontouring
☐ Stainless steel ultrasonic scaler	☐ Topical antimicrobials	☐ Other (please specify) _____
☐ Plastic ultrasonic tips	☐ Local antibiotics	☐ I do not treat peri-implant conditions

Thank you for participating in the survey. Your answers will be submitted when you click 'Done' at the bottom of this page.

If you would like to enter the prize draw to win one of three $100 cash debit cards, please enter your email address below, which will only be used for the purposes of the draw.

_____

Appendix III: Oral health practitioner questionnaire

The questionnaire used in Chapter 6 is presented here.

Notes:

1. Multiple choice answer choices preceded by a circular checkmark indicate where one selection only is allowed as the answer. Square checkmarks denote that multiple selections are allowed, and this is also indicated in the question.
2. Some questions were skipped over using the “Skip logic” function on the Surveymonkey™ website, depending on the answers chosen by respondents. These are indicated below by description within square brackets.
3. Some questions had multiple choice answers for each sub-question, described in square brackets.

Please complete the survey as accurately as possible. The survey requires approximately 20 minutes to complete.

On submission of the completed survey you can enter into a prize draw to win one of three $100 cash debit cards.

A. General Information

1. What is your gender?
- F
- M

2. What is your year of birth? _____

3. Where and when did you complete your registrable hygiene or oral health therapist qualification?
Qualification: _____ Institution: _____ Year: _____

4. If you have additional dental-related qualifications, what are they, where and when did you complete them? (please list all in respective order if applicable)
Qualification: _____ Institution: _____ Year: _____

5. What are you registered with AHPRA as? (select all that apply)
- ☐ Dental hygienist
- ☐ Dental therapist
- ☐ Oral health therapist
- ☐ Other (please specify) _____

6. How many different practice locations do you work at? _____

7. Do you currently work in a (select all that apply):
- ☐ metropolitan area
- ☐ rural/regional area

8. Do you (select all that apply):
- ☐ Work in private practice
- ☐ Work in public dentistry
- ☐ Own a private dental practice
- ☐ Other (please specify) _____

B. Implant Training

9. Does your scope of practice or training include any of the following aspects regarding peri-implant conditions? (select all that apply):
- ☐ Understanding the pathological process
- ☐ Performing assessment of peri-implant tissues
- ☐ Clinical procedures to maintain peri-implant health
- ☐ Clinical treatment of peri-implant mucositis
- ☐ Clinical treatment of peri-implantitis

10. Where have you learned any clinical procedures for peri-implant assessment and management that you know? (select all that apply):
- ☐ Undergraduate oral health degree/diploma (i.e. for registration)
- ☐ Postgraduate university degree/diploma
- ☐ University run CPD
- ☐ Professional association or society CPD
- ☐ Implant company CPD
- ☐ Hands on courses
- ☐ Work-based mentorship
- ☐ Colleagues
- ☐ Journal articles
- ☐ Textbooks
- ☐ None
- ☐ Other (please specify) _____

C. Work Arrangements

Please answer the questions in this section with regard to one main practice location only.

11. What type of practice is this work location (whether private or public)?
- ○ General dental practice
- ○ Specialist practice
- ○ Other (please specify) _____

12. With what types of practitioners do you have a structured professional relationship with at this work location? (select all that apply)
- ☐ General dentist
- ☐ Periodontist
- ☐ Orthodontist
- ☐ Prosthodontist
- ☐ Paediatric dentist
- ☐ Other (please specify) _____

13. What are the main types of services that you provide at this work location? (select all that apply)
- ☐ Diagnostic
- ☐ Treatment planning
- ☐ Preventive
- ☐ Restorative
- ☐ Periodontal
- ☐ Orthodontic
- ☐ Other (please specify or describe in further detail) _____

14. Do patients receive any periodontal and/or implant assessment at this work location?
- ○ Yes
- ○ No [skip to Q22]

Please answer the questions in this section with regard to one main practice location only, choosing from the dropdown menu.

15. In your practice, who USUALLY performs a routine dental examination for:
- a. A new patient Select an answer: [multiple choice answers in dropdown menu, identical for each part of Q15-21: hygienist/oral health therapist, dentist, in-house specialist, external referral is made, other (please describe below) _____]
- b. A returning patient without any dental implants Select an answer: [multiple choice answers in dropdown menu]
- c. A returning patient with dental implant(s) Select an answer: [multiple choice answers in dropdown menu]

16. In your practice, who USUALLY has responsibility for determining a diagnosis of:
- a. Periodontal disease Select an answer: [multiple choice answers in dropdown menu]
- b. implant health Select an answer: [multiple choice answers in dropdown menu]
- c. peri-implant mucositis Select an answer: [multiple choice answers in dropdown menu]
- d. peri-implantitis Select an answer: [multiple choice answers in dropdown menu]

17. In your practice, who USUALLY performs the following procedures for a patient with no periodontal disease or implants:
- a. Initial debridement Select an answer: [multiple choice answers in dropdown menu]
- b. Oral hygiene instruction (OHI) Select an answer: [multiple choice answers in dropdown menu]
- c. determining the time before next recall Select an answer: [multiple choice answers in dropdown menu]

18. In your practice, who USUALLY performs the following procedures for a patient with periodontal disease, who has no implants
- a. Initial debridement Select an answer: [multiple choice answers in dropdown menu]
- b. OHI Select an answer: [multiple choice answers in dropdown menu]
- c. determining the time before next recall Select an answer: [multiple choice answers in dropdown menu]

19. In your practice, who USUALLY performs the following procedures for a patient with a healthy implant
- a. Initial debridement Select an answer: [multiple choice answers in dropdown menu]
- b. Implant maintenance and cleaning Select an answer: [multiple choice answers in dropdown menu]
- c. OHI Select an answer: [multiple choice answers in dropdown menu]
- d. determining the time before next recall Select an answer: [multiple choice answers in dropdown menu]

20. In your practice, who USUALLY performs the following procedures for a patient with peri-implant mucositis
a. Initial debridement Select an answer: [multiple choice answers in dropdown menu]
b. Peri-implant mucositis treatment Select an answer: [multiple choice answers in dropdown menu]
c. OHI Select an answer: [multiple choice answers in dropdown menu]
d. determining the time before next recall Select an answer: [multiple choice answers in dropdown menu]

21. In your practice, who USUALLY performs the following procedures for a patient with peri-implantitis
a. Initial debridement Select an answer: [multiple choice answers in dropdown menu]
b. Peri-implantitis treatment Select an answer: [multiple choice answers in dropdown menu]
c. OHI Select an answer: [multiple choice answers in dropdown menu]
d. determining the time before next recall Select an answer: [multiple choice answers in dropdown menu]

22. Who in the practice USUALLY arranges any external referrals that a patient requires? (select all that apply)
☐ I arrange this directly, if I know it is not managed within the practice
☐ I liaise with dentist/specialist and they make the referral
☐ Other (please specify) _____

D. <u>Implant Review</u>

23. Do you believe you have a role to play in the maintenance of dental implants?
○ Yes
○ No

24. What do you perform during a routine implant assessment i.e. implant-specific diagnostic procedures? (select all that apply)
☐ Oral hygiene assessment around implant i.e. presence of plaque or calculus
☐ Soft tissue visual appearance assessment e.g. inflammation, keratinised mucosa
☐ Pocket depth probing
☐ Assessment of bleeding on probing
☐ Assessment of suppuration
☐ Recession measurement
☐ Radiograph to check bone level/bone defects
☐ Assessment of implant mobility
☐ I do not perform any peri-implant diagnostic procedures (only select if you have not made any other selections above) [only this option skips to Q29]

25. When do you perform an implant check i.e. implant-specific diagnostic procedures? (please select the GREATEST FREQUENCY that applies to you)
○ At their first appointment with me at which they have the implant
○ At regular specific implant review appointments
○ At every general/periodontal recall
○ Only if signs/symptoms of peri-implant condition present
○ Other (please specify) _____

26. What factors help you decide on a specific implant check frequency? (select all that apply)
☐ The patient's standard of oral hygiene
☐ Previous periodontal/peri-implant disease history
☐ Medical history
☐ Severity of existing peri-implant condition
☐ Probing depths around the implant
☐ I consult with the patient's dentist/specialist
☐ Other (please specify) _____

27. How often do you prefer to take a routine radiograph of an established implant?
○ 6 months
○ 12 months
○ 24 months
○ Only if signs/symptoms of peri-implant condition present
○ I consult with the patient's dentist/specialist
○ I do not take any radiographs of established implants
○ I refer the patient to see their dentist/specialist
○ Other (please specify) _____

28. How often do you prefer to repeat an implant check if signs/symptoms of a peri-implant condition are present?
- o 3 months
- o 6 months
- o 12 months
- o I consult with the patient's dentist/specialist
- o I refer the patient to their dentist/specialist in the case of any pathology
- o Other (please specify) _____

29. In your experience, what is the strength of correlation between the quality of implant home hygiene and peri-implant health?
- o Very strong
- o Strong
- o Neutral
- o Weak
- o Very weak

E. **Implant Hygiene Instructions**

30. Do you give implant-specific oral hygiene instructions to any patients with dental implants?
- o Yes – [skip to Q32]
- o No – [continue to next Q31 'If you do not give any OHI', then skip to Q36 'where have you learned']

31. If you do not give any implant-specific OHI to patients, why not? – [all answers skip to Q36]
- o I do not see any patients with implants
- o I do not believe implant-specific instructions are necessary
- o I refer or ask the patient to ask their implant dentist, general dentist or periodontist
- o I leave it to the patient's implant dentist, general dentist or periodontist
- o I directly ask the patient's dentist/specialist in the practice to give them implant OHI
- o Other (please specify) _____

32. When is the FIRST time you give a patient oral hygiene instructions specifically for their implants?
- o At their first appointment with me at which they have the implant
- o At the first general/periodontal recall at which they have an implant (e.g. if they have a new implant)
- o Only if signs/symptoms of peri-implant condition present
- o Other (please specify) _____

33. When do you REPEAT specific OHI for implants? (please select the GREATEST FREQUENCY that applies to you)
- o Only once at the next recall appointment after implant OHI was first given
- o At every implant-specific review appointment
- o At every general/periodontal recall
- o Only if signs/symptoms of peri-implant condition present
- o Other (please specify) _____

34. What specific implant maintenance home care instructions do you usually give for a single implant crown? (select all that apply)
- ☐ Regular brushing
- ☐ Regular interdental flossing
- ☐ 'Superfloss' or equivalent (floss with stiff threader)
- ☐ Interdental brushes
- ☐ Circumferential flossing (floss looped around crown and 'see-saw' motion pulling ends back and forth)
- ☐ Oral irrigation (e.g. Waterpik)
- ☐ Mouthwash
- ☐ Other (please specify) _____

35. How do you give patients specific implant maintenance home care instructions? (select all that apply)
- ☐ Describe procedures to the patient
- ☐ Show procedures to the patient
- ☐ Ask the patient to show you after instruction

36. Where did you learn home care instructions specific to implants? (select all that apply)
☐ Undergraduate oral health degree/diploma (i.e. for registration)
☐ Postgraduate university degree/diploma
☐ University run CPD days
☐ Professional association or society CPD
☐ Implant company CPD days
☐ Hands on courses
☐ Work-based mentorship
☐ Colleagues
☐ Journal articles
☐ Textbooks
☐ None
☐ Other (please specify) _____

F. Maintenance Procedures

37. If you have provided any treatment of peri-implant tissues, what year did you begin to do so?
○ Have not provided any peri-implant treatment
○ [dropdown year selection]

38. Do you perform supragingival/superficial implant prosthesis cleaning during recall/periodontal maintenance?
○ Yes
○ No
○ No, but I refer the patient to their general dentist
○ No, but I refer the patient to their periodontist

39. Do you perform subgingival debridement of implants/implant surface during recall/periodontal maintenance?
○ Yes
○ No
○ No, but I refer the patient to their general dentist
○ No, but I refer the patient to their periodontist

40. Do you perform treatment of peri-implant mucositis?
○ Yes
○ No
○ No, but I refer the patient to their general dentist
○ No, but I refer the patient to their periodontist

41. Do you perform treatment of peri-implantitis?
○ Yes
○ No
○ No, but I refer the patient to their general dentist
○ No, but I refer the patient to their periodontist

42. If you answered 'Yes' to any of the previous 4 questions, what instruments/techniques do you use? (select all that apply)
☐ Floss
☐ Rubber cup/brush with prophylaxis paste
☐ Air powder polishing/prophylaxis
☐ Stainless steel ultrasonic scaler
☐ Plastic ultrasonic tips
☐ Other (please specify) _____
☐ Stainless steel curettes
☐ Plastic/carbon curettes
☐ Titanium curettes
☐ Topical antimicrobials
☐ I do not treat peri-implant conditions

Thank you for participating in the survey. Your answers will be submitted when you click 'Done' at the bottom of this page. If you would like to enter the prize draw to win one of three $100 cash debit cards, please enter your email address below, which will only be used for the purposes of the draw. _____

Appendix IV: Educator questionnaire

The questionnaire used in Chapter 7 is presented here.

Notes:

1. Multiple choice answer choices preceded by a circular checkmark indicate where one selection only is allowed as the answer. Square checkmarks denote that multiple selections are allowed, and this is also indicated in the question.
2. Some questions were skipped over using the “Skip logic” function on the Surveymonkey™ website, depending on the answers chosen by respondents. These are indicated below by description within square brackets.

1. What is the type of organisation where you are involved in developing or overseeing the implant education program(s)?
   - University
   - TAFE
   - Professional association
   - Private education institute or company
   - Implant company
   - Dental equipment company
   - Other (please specify) _____

2. At what level(s) do you provide implant education? (select all that apply)
   - ☐ Undergraduate/graduate dental students
   - ☐ Undergraduate oral health therapy students
   - ☐ Undergraduate hygiene students
   - ☐ Graduate implant diploma/non-specialist postgraduate degree students
   - ☐ Doctor of Clinical Dentistry students
   - ☐ Continuing professional development for dentists
   - ☐ Continuing professional development for hygienists/oral health therapists
   - ☐ Other (please specify) _____

3. a. As previously asked, do you provide implant education for undergraduate/graduate dental students? [repeats Q2 but is used as a skip logic mechanism with SurveyMonkey to allow a set of answers of Q4-10 for each education level]
   - Yes
   - No [skip to Q3b, after Q10]

Please complete the following questions for the education level selected in your previous answer (undergraduate/graduate dental students)

4. What are the types and topics of your implant education program(s)? (select all that apply)

   A. Program length
   - ☐ As part of university degree/diploma syllabus
   - ☐ CPD course series e.g. multiple multi-day programs
   - ☐ Intensive CPD program e.g. one week
   - ☐ Multi-day conference
   - ☐ CPD days (1-2 day program)
   - ☐ Lecture evenings
   - ☐ Other (please specify) _____

   B. Main program topic:
   - ☐ Implant restoration
   - ☐ Implant surgery
   - ☐ Peri-implant maintenance
   - ☐ Periodontal maintenance
   - ☐ Other (please specify) _____

5. Who decides on the implant maintenance content in your education program(s)? Please describe their position or role:_____

6. What is the dental background of the person who delivers the implant maintenance component in your education program(s)? Please describe:_____

7. Which of the following implant maintenance and home care techniques are or have been covered in your education program(s), within the last 5 years? (select all that apply)
    A. Oral hygiene instructions for implant home care:
        ☐ Regular brushing
        ☐ Regular interdental flossing
        ☐ 'Superfloss' or equivalent (floss with stiff threader)
        ☐ Interdental brushes
        ☐ Circumferential flossing (floss looped around crown and 'see-saw' motion)
        ☐ Oral irrigation (e.g. Waterpik)
        ☐ Mouthwash
        ☐ None
        ☐ Other (please specify) _____
    B. Peri-implant diagnostic procedures:
        ☐ Oral hygiene assessment around implant i.e. presence of plaque or calculus
        ☐ Soft tissue visual appearance assessment e.g. inflammation, keratinised mucosa
        ☐ Pocket depth probing
        ☐ Assessment of bleeding on probing
        ☐ Assessment of suppuration
        ☐ Recession measurement
        ☐ Radiograph to check bone level/bone defects
        ☐ Assessment of implant mobility
        ☐ None
        ☐ Other (please specify) _____
    C. Peri-implant maintenance and treatment procedures:

☐ Floss	☐ Stainless steel curettes	☐ Systemic antibiotics
☐ Rubber cup/brush with prophylaxis paste	☐ Plastic/carbon curettes	☐ Bone augmentation
☐ Air powder polishing/prophylaxis	☐ Titanium curettes	☐ Open (surgical) debridement and/or recontouring
☐ Stainless steel ultrasonic scaler	☐ Topical antimicrobials	☐ Other (please specify) _____
☐ Plastic ultrasonic tips	☐ Local antibiotics	☐ None

8. Regarding ONLY the implant diagnosis, maintenance and home care information above, how is it delivered in your education program(s)? (select all that apply)
    ☐ Lectures
    ☐ Journal article recommendations
    ☐ Textbook recommendations
    ☐ Hands-on workshop e.g. models, pig jaws
    ☐ Supervised patient treatment
    ☐ Students observe and assist patient treatment
    ☐ Private clinic-based mentorship program
    ☐ None
    ☐ Other (please specify) _____

9. Which of the following topics that impact upon peri-implant health are or have been covered in your education program(s), within the last 5 years? (select all that apply)
    A. Risk factors:
        ☐ The patient's standard of oral hygiene
        ☐ Previous periodontal/peri-implant history
        ☐ Medical history
        ☐ Severity of existing peri-implant condition
        ☐ Probing depths around the implant
        ☐ None of the above
        ☐ Other (please specify) _____

B. Other factors:
   - ☐ Implant crown retention system
   - ☐ Splinting or separating two adjacent implants
   - ☐ Frequency of implant review
   - ☐ Frequency of routine radiography
   - ☐ None of the above

10. Do you have any additional comments about implant maintenance within your program(s) at this education level? _____ [proceed to the next question in the list of Q3b-h, as applicable]

3b. As previously asked, do you provide implant education for undergraduate oral health therapy students?

- o Yes [proceed through Qs 4-10 regarding this group]
- o No [skip to Q3c]

Please complete the following questions for the education level selected in your previous answer (undergraduate oral health therapy students)

3c. As previously asked, do you provide implant education for undergraduate hygiene students?

- o Yes [proceed through Qs 4-10 regarding this group]
- o No [skip to Q3d]

Please complete the following questions for the education level selected in your previous answer (undergraduate hygiene students)

3d. As previously asked, do you provide implant education for graduate implant diploma/non-specialist postgraduate degree students?

- o Yes [proceed through Qs 4-10 regarding this group]
- o No [skip to Q3e]

Please complete the following questions for the education level selected in your previous answer (graduate implant diploma/non-specialist postgraduate degree students)

3e. As previously asked, do you provide implant education for Doctor of Clinical Dentistry students?

- o Yes [proceed through Qs 4-10 regarding this group]
- o No [skip to Q3f]

Please complete the following questions for the education level selected in your previous answer (Doctor of Clinical Dentistry students)

3f. As previously asked, do you provide implant education for continuing professional development programs for dentists?

- o Yes [proceed through Qs 4-10 regarding this group]
- o No [skip to Q3g]

Please complete the following questions for the education level selected in your previous answer (continuing professional development programs for dentists)

3g. As previously asked, do you provide implant education for continuing professional development for hygienists/oral health therapists?

- Yes [proceed through Qs 4-10 regarding this group]
- No [skip to Q3h]

Please complete the following questions for the education level selected in your previous answer (continuing professional development for hygienists/oral health therapists)

3h. As previously asked, do you provide implant education for any other dental practitioner or student groups that have not already been described?

- Yes (please specify) _____ [proceed through Qs 4-10 regarding this group]
- No

Please complete the following questions for the education level selected in your previous answer

Thank you for participating in the survey; your contribution is greatly appreciated. Your answers will be submitted when you click 'Done' at the bottom of this page.