Screening for Type 2 Diabetes Mellitus initiated through the dental setting: a cost-effectiveness analysis

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I. Abstract

Background. Diabetes Mellitus (DM) is the fastest growing chronic condition in Australia. Approximately, 30% of DM in Australia is undiagnosed. Early identification may delay or prevent the onset of DM with minimal complication.

In the Western Pacific (WP) region, Australia has the highest per capita spending on DM. With the rising cost of healthcare, increasing emphasis is being made to ensure that health interventions are not only practical but also cost-effective that can save resources which otherwise may have to be spent on complication and hospital admission.

By stretching the number of contact points between health care providers and individuals seeking care, there is plenty of opportunity for early identification of asymptomatic individuals with Type 2 Diabetes Mellitus (T2DM). With this link between DM and periodontal disease, dentists may have an unrealized opportunity to identify risk groups and refer them to physicians for further care. For any screening activity in the dental setting, the participation of Oral Health Professionals (OHP) is important. Little is known as to how well oral health professionals incorporate into practice on the evidence supporting the link between DM and periodontal disease. Besides that, no previous studies have reported the cost-effectiveness of opportunistic screening using a diabetes risk assessment tool in the dental setting.

As such, the aim of the thesis is twofold. To explore the Victorian oral health professionals (OHP) knowledge, attitude and practice (KAP) around DM and to evaluate the overall economic justification of screening for diabetes and pre-diabetes in the dental setting.

Methods. A cross-sectional survey of Victorian OHP was conducted. The questionnaire consisted of sociodemographic, practice characteristics and diabetes-related KAP. Descriptive statistics with frequencies and percentages were used to summarize the variables. A Mann-Whitney and Kruskal-Wallis test was performed to determine differences in OHP response to the KAP questions.

The screening model consists of a decision tree and a disease progression Markov model to identify the risk of T2DM over a ten-year period. Literature data were used for the risk
categorisation and disease transition for health states. The cost-effectiveness of screening was compared to “no screening” option. A hypothetical population of 40 to 74-year-old Victorian dental patients with no previous history of DM were screened with the Australian type 2 Diabetes Risk Assessment Tool (AUSDRISK). Those identified as high-risk follow-up with the physician for screen diagnosis using Fasting Plasma Glucose (FPG). Based on the previous finding from two-step screening in the dental setting the model made an assumption that 21.5% of the dental patient identified as high risk follow up with the physician. The cost-effectiveness was analysed from a societal perspective. The main outcome measure includes cost per case detected as undiagnosed T2DM, new cases of T2DM. A univariate sensitivity analysis was performed to determine the effect of different physician follow-up rate from the dental setting to identify undiagnosed T2DM.

**Results.** The survey analysis included 197 OHP. General and specialist dentist constitute 65% and 11% of the response and the remainder were dental hygienist and therapist. Around 86% of the OHP showed adequate knowledge of DM. Further 93% and 81% of the OHP expressed positive attitude and practice behaviour towards T2DM screening and management. For OHP to perform chair-side screening for DM, 58% felt it was essential, and 70% felt it was appropriate. More female (67%) and public sector OHP (79%) felt it is important to conduct chair-side screening for T2DM. The majority (65.4%) of the OHP agreed on consent as the most important and insurance coverage as the least important (43%) consideration for T2DM screening.

Under model assumption, the number of dental patients identified as undiagnosed T2DM and pre-diabetes were 4,108 (0.3%) and 10,072 (0.8%). The cost incurred for one new case of undiagnosed T2DM and pre-diabetes were $15,508 and $6,325. The Number Needed to Screen (NNS) to identify one new case of undiagnosed T2DM and pre-diabetes were 288 and 117. Among those followed up with the physician, at the end of five years, 81.5% had Normal Glucose Tolerance (NGT), 8.1% had Impaired Fasting Glucose (IFG), 6.9% had T2DM, and the all-cause mortality was 3.5%. At the end of the ten-year period, 10% had T2DM. The overall and disease-free survival was 92.8% and 82.8%.

**Discussion.** Majority of OHPs had adequate knowledge and a positive attitude towards T2DM screening in the dental setting. The survey identified “patient willingness” as the most
important consideration among the OHPs for implementing T2DM screening in the dental setting.

The screening model identified several methodological challenges due to incongruent data and unsuitable comparator. Despite that, opportunistic screening with AUSDRISK was found to be neither clinically effective nor cost-effective compared to screening in the medical setting. High screening cost, poor predictive ability of AUSDRISK, low prevalence of the disease, unnecessary physician referral besides uncertain benefits, fear of over diagnosis and poor patient compliance makes screening for T2DM in the dental setting difficult to justify. The model findings are in line with previous estimates on AUSDSRISK as a screening tool.

In financially constrained health system resource allocation will need to be based on favourable evidence that screening can reduce disease levels in the community, demonstrate health benefits at an acceptable cost. A two-step opportunistic screening that includes a risk assessment followed by a Point-of-Care (PoC) HbA1c may offer some benefits in the low- and middle-income countries.
## II. Abbreviation

<table>
<thead>
<tr>
<th>Acronym</th>
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<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>ACCORD</td>
<td>Action to Control Cardiovascular Risk in Diabetes</td>
<td>LADA</td>
<td>Latent autoimmune diabetes in the adult</td>
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<td>ADA</td>
<td>American Diabetes Association</td>
<td>MeSH</td>
<td>Medical Subject Headings</td>
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<td>ADAVB</td>
<td>Australian Dental Association Victoria Branch</td>
<td>NDSS</td>
<td>National Diabetes Service Scheme</td>
</tr>
<tr>
<td>AGE</td>
<td>Advanced glycation endproducts</td>
<td>NGT</td>
<td>Normal Glucose Tolerance</td>
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<tr>
<td>ARCPHOH</td>
<td>Australian Research Centre for Population Oral Health</td>
<td>NHANES</td>
<td>National Health and Nutrition Examination Survey</td>
</tr>
<tr>
<td>CI</td>
<td>Confidence intervals</td>
<td>NHS</td>
<td>National Health Service</td>
</tr>
<tr>
<td>CKD</td>
<td>Chronic Kidney Disease</td>
<td>NIDDM</td>
<td>Non-Insulin Dependent Diabetes Mellitus</td>
</tr>
<tr>
<td>CPI</td>
<td>Community Periodontal Index</td>
<td>NIHR</td>
<td>National Institute for Health Research</td>
</tr>
<tr>
<td>CVD</td>
<td>Cardiovascular diseases</td>
<td>NNS</td>
<td>Number Needed to Screen</td>
</tr>
<tr>
<td>DALY</td>
<td>Disability Adjusted Life Years</td>
<td>OGTT</td>
<td>Oral Glucose Tolerance Test</td>
</tr>
<tr>
<td>DHP</td>
<td>Dental health professionals</td>
<td>OHP</td>
<td>Oral Health Professionals</td>
</tr>
<tr>
<td>DM</td>
<td>Diabetes Mellitus</td>
<td>PICO</td>
<td>Population, intervention, comparison, outcomes</td>
</tr>
<tr>
<td>DRAD</td>
<td>Diabetic retinopathy at diagnosis</td>
<td>PLS</td>
<td>Plain Language Statement</td>
</tr>
<tr>
<td>FBG</td>
<td>Fasting Blood Glucose</td>
<td>PoC</td>
<td>Point-of-Care</td>
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<tr>
<td>FINDRISC</td>
<td>Finnish Diabetes Risk Score</td>
<td>PPV</td>
<td>Positive predictive values</td>
</tr>
<tr>
<td>FPG</td>
<td>Fasting Plasma Glucose</td>
<td>QALY</td>
<td>Quality Adjusted Life Years</td>
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<tr>
<td>GBD</td>
<td>Global Burden of Disease</td>
<td>RBG</td>
<td>Random Blood Glucose</td>
</tr>
<tr>
<td>GDM</td>
<td>Gestational Diabetes Mellitus</td>
<td>RCT</td>
<td>Randomised Controlled Trials</td>
</tr>
<tr>
<td>GP</td>
<td>General Practitioner</td>
<td>TRIAD</td>
<td>Translating Research Into Action for Diabetes</td>
</tr>
<tr>
<td>HIV</td>
<td>Human Immuno-deficiency Virus</td>
<td>T1DM</td>
<td>Type 1 Diabetes Mellitus</td>
</tr>
<tr>
<td>HTA</td>
<td>Health Technology Assessment</td>
<td>T2DM</td>
<td>Type 2 Diabetes Mellitus</td>
</tr>
<tr>
<td>ICDAS</td>
<td>International Caries Classification and Management Systems</td>
<td>UK</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>ICER</td>
<td>Incremental cost-effectiveness ratio</td>
<td>UKPDS</td>
<td>United Kingdom Prospective Diabetes Study</td>
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<tr>
<td>Acronym</td>
<td>Definition</td>
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<tr>
<td>IDF</td>
<td>International Diabetes Federation</td>
<td>WHO</td>
<td>World Health Organization</td>
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<tr>
<td>IFG</td>
<td>Impaired Fasting Glucose</td>
<td>WP</td>
<td>Western Pacific</td>
</tr>
<tr>
<td>IGT</td>
<td>Impaired Glucose Tolerance</td>
<td>YLD</td>
<td>Years of Life lived with Disability</td>
</tr>
<tr>
<td>IHME</td>
<td>Institute of Health Metrics and Evaluation</td>
<td>YLL</td>
<td>Years of Life Lost</td>
</tr>
<tr>
<td>KAP</td>
<td>Knowledge, attitude and practice</td>
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Dedication

I would like to dedicate this work to my parents Meenatchi Chinnasamy, Alagappan Chinnasamy, my wife Vidhya Gopinath and my son Shrish Chinnasamy for their love, affection, sacrifices and support during this journey.
Declaration

This is to certify that:

i. the thesis comprises only my original work except where indicated.

ii. due acknowledgement has been made in the text to all other material used.

iii. the thesis is less than 100,000 words in length, exclusive of tables, maps, bibliographies and appendices.

Alagesan Chinnasamy
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1 Literature Review

Screening for Type 2 Diabetes Mellitus initiated through the dental setting: a cost-effectiveness analysis

1.1 Background

Since the turn of the 20th century, mortality from communicable diseases has reduced significantly in the industrialised world and this has been overtaken by the emergence of non-communicable diseases. If detected early, there is a modest chance of managing the condition with minimal complication, whereas a late diagnosis significantly increases the likelihood of complications manyfold (Wilson & Jungner, 1968).

Globally, death due to non-communicable diseases is more than any other cause combined. Approximately 60% of all-cause mortality can be attributed to non-communicable diseases. In 2012, 38 million death was due to non-communicable diseases and is projected to reach 52 million by 2030 (World Health Organization, 2014). The four major non-communicable diseases are cardiovascular diseases (CVD), cancer, chronic respiratory diseases and Diabetes Mellitus (DM) that account for 82% of all the deaths within. About, 42% of all mortality occurred before the age of 70 of them 72% in low and middle income countries (World Health Organization, 2014).

Children and adults of all age are vulnerable to the risk of non-communicable diseases with unhealthy diets, physical inactivity, and the adverse effect of tobacco and alcohol use. For example, globalization of unhealthy lifestyles that include consumption of unhealthy foods contribute to high blood pressure, elevated blood glucose and cholesterol levels, in combination with sedentary lifestyle leads to DM (World Health Organization, 2005).
Early detection and appropriate intervention can reduce the impact of chronic diseases. Evidence shows that such interventions generally offer excellent value for money, in terms of improved quality of life and if implemented early, can reduce the need for more expensive treatment. Achieving effective risk assessment requires a multidisciplinary approach that may include early identification of non-communicable diseases risk through screening by different health care providers (World Health Organization, 2005).

1.2 Diabetes Mellitus

DM is a group of metabolic diseases characterized by high blood glucose levels due to defects in insulin secretion, insulin action, or a combination of both (Wild, Roglic, Green, Sicree, & King, 2004). Chronic hyperglycemia is associated with long-term damage, dysfunction, and organ failure, especially the eyes, kidneys, nerves, heart, and blood vessels (American Diabetes Association, 2010a).

DM is one of the leading causes of death globally with a devastating impact on individuals and their families. Amongst 20 to 79-year-olds, 10.7% of all deaths were attributable to DM, and in 2017, an estimated 4 million deaths were directly caused by DM or indirectly due to high blood glucose (International Diabetes Federation, 2017). It is recognized as the world’s fastest-growing chronic condition and projected to become the 7th leading cause of death by 2030 (World Health Organization, 2016).

DM is an expensive disease to treat (Dieleman et al., 2016; Zhuo et al., 2014). It results in substantial economic loss to individuals and their families. It also causes excess strain on the national health care system and a significant financial burden through direct costs like long term patient care, medication and the use of medical devices. In addition, indirect cost includes premature mortality contributes to reduced quality of life and loss in productivity that impacts the overall economy (Costa, Arroyo, & Sabate, 1997).
1.2.1 Aetiology and natural history

DM is a metabolic disorder of multiple etiology characterized by chronic hyperglycemia due to disturbance in carbohydrate, fat and protein metabolism that leads to defects in insulin secretion, insulin action, or both (World Health Organization, 1999). T2DM often presents a background genetic predisposition (Almgren et al., 2011; Hirschhorn, 2003; Poulsen, Kyvik, Vaag, & Beck-Nielsen, 1999). Insulin resistance is aggravated by ageing, physical inactivity, and overweight or obesity. Among obese patients, weight loss often reduces the degree of insulin resistance and may delay T2DM onset or lessen its severity, thereby reducing the risk of life long complications (Jianping, 2013).

The natural history of T2DM can be broadly classified into five stages, each with its own characteristic. The initial stage is the compensatory stage in which insulin secretion increases to offset the insulin resistance and shrinking β cell mass to maintain the average glucose levels (Festa, Williams, D'Agostino, Wagenknecht, & Haffner, 2006; Meier et al., 2008; Polonsky et al., 1988). The reason for this metabolic defect and therefore the cause of T2DM is mostly unknown (Ndisang, Vannacci, & Rastogi, 2017). Obesity, physical inactivity and ageing are some of the other well-documented risk factors for insulin resistance to develop (Venables & Jeukendrup, 2009; Venkatasamy, Pericherla, Manthuruthil, Mishra, & Hanno, 2013). This is followed by the second stage in which blood glucose levels rise to levels of 5.0 – 6.5 mmol/l (89 –116 mg/dl) with a stable states of cell adaptation (Weir & Bonner-Weir, 2004). In the third stage, there is transient instability in the compensation with a marked increase in the glucose levels leading to stage 4 which is more of a stable decompensation(Weir & Bonner-Weir, 2004). Stage 5 represents marked cell failure leading to ketosis. Movement from stage 1 to 4 can be either side. Lifestyle modification can bring about change in these stages (Pedersen, 2017; Weir & Bonner-Weir, 2004).

T2DM progresses slowly from normal glycemia to asymptomatic subclinical hyperglycemia, and finally to DM which can take up to 10 years (Harris, Klein, Welborn, & Knuiman, 1992; M. I. Harris & Eastman, 2000). During the subclinical phase, vascular changes may have gone unnoticed, and condition as retinopathy and neuropathy may be discovered accidently at the time of diagnosis of DM (American Diabetes Association, 2010b). Over time, the disease
progresses to cause long-term irreversible impairment, organ dysfunction and failure. Some of the characteristic symptoms such as thirst, polyuria, blurred vision and loss of weight (Alberti & Zimmet, 1998) may become apparent. In the most severe form ketoacidosis and non-ketotic hyperosmolar state develops. This can cause deterioration of mental function and an altered level of consciousness where the sufferer may become entirely unresponsive in the absence of treatment; death ensues (American Diabetes Association, 2010a).

1.2.2 Events of historical significance and interest

The term “DM” was first coined by Apollonius of Memphis around 230 BC, but the characteristics of the disease had been described in Ebers Papyrus written approximately 1500 BC. Francesco Zaccardi and collaborators made an excellent review on the historical developments in the understanding of DM (Zaccardi, Webb, Yates, & Davies, 2016). Initial findings in the pathophysiology of DM centred around polyuria and was considered to be diagnostic. Thomas Willis in 1600, used the sweet taste of diabetic urine to distinguish between DM and diabetes insipidus (Poretsky, 2010). Mathew Dobson in 1776, further augmented that the sweetness of the urine is due to the sugar content. He also explained that the presence of sugar in the urine was preceded and accompanied by high blood sugar. The understanding of hyperglycaemia leading to glycosuria, that later became the hallmark for the detection of DM as a systemic medical condition dates back a few hundred years (Eknoyan & Nagy, 2005; Zajac, Shrestha, Patel, & Poretsky, 2010).

In 1889, Von Mering and Minkowski surgically removed the pancreas of dogs to demonstrate that they suffered signs and symptoms of DM. Findings from this animal experiment linked DM for the first time to a specific organ of the body (Karamanou, Protagorou, Tsoucalas, Androutsos, & Poulakou-Rebelakou, 2016; Von Mering & Minkowski, 1890). This leads to increased interest in the pancreatic content, and at the end of the first decade of the 20th century, Sharpey and Schafer proposed that a substance secreted by the β cells of pancreatic islets was deficient among sufferers of DM and named it “insulin”. By then, it became increasingly apparent of the link between pancreas, insulin and DM. One of the significant findings in the treatment of DM came in 1921 when Banting, Best, and Macleod demonstrated a reversal in DM of pancreatectomized dogs with the introduction of intravenous insulin (Karamitsos,
2011). In the following year 1922, extracts of the bovine pancreas were introduced into a human for the first time that leads to a reduction in blood sugar (Karamitsos, 2011).

In the mid-1920s it was recognized that DM might exist in two forms. A decade from then, Himsworth, distinguished type 1 and type 2 DM based on his extensive research (Himsworth, 1936; Holt, Cockram, Flyvbjerg, & Goldstein, 2017). However, reliable measure of circulating insulin using radioimmunoassay made more apparent the distinction between insulin-dependent and Non-Insulin Dependent Diabetes Mellitus (NIDDM) was not available any time before the 1950s (Holt et al., 2017; Yalow & Berson, 1960).

1.2.3 History of the cause and management of diabetes mellitus

Most of the medieval literature paid little attention to DM and obesity as the condition was regarded somewhat uncommon and rare during that time. However, in the 17th century, DM was showing up to become an increasing concern to doctors as they start to see more number of cases (Furdell, 2008). Shane O’Donnell, made a discourse analysis with the writings of prominent experts from 1800 to 1950s, on the origin and management of illness related to DM (O’Donnell, 2015). The author separated the discourse into three main distinct historical periods for analysis. The first is 1800–1850, during which physicians primarily considered DM as a lifestyle problem. The social causation theory was discussed between 1850 and 1920. Finally, the re-emergence of the lifestyle thesis from about 1920 to 1950. The article covers a long journey from 1800 to 1950 showing how highly unequal circulation of materials resource and power played an influencing factor in the social significance of chronic illness like DM (O’Donnell, 2015).

Despite the dominant explanation supporting lifestyle linking appetite, there was also beliefs on prolonged despair and suffering contributing towards the cause (O’Donnell, 2015). However, the cause for DM largely remained a mystery to the medical profession throughout the 17th and 18th century but like many other illnesses was looked at as a consequence of wicked activities like overindulgent eating, drinking and sexual intercourse (Furdell, 2008).
As noted in the medical literature, the defining moment in the understanding of DM came in the early and mid-19th century when belief in religious ideologies was used in interpreting illness. But such an ideology started to wane of paving the way for the inclusion of secular values of objectivity and rationality (Sanders, 2002). Therefore, widely held Christian beliefs about sin and blasphemy as a cause in the past was moderated with more emphasis placed on specific biological pathogenesis. Shortly after this, physicians began relating DM to obesity. Thus various incarnations of Rollo’s calorie-restricted diet became popular in the treatment and prevention of both the condition (O'Donnell, 2015).

It was not until the early to the middle of the 20th century that western medicine made a distinction between Type 1 Diabetes Mellitus (T1DM) and T2DM (Furdell, 2008). T2DM was increasingly connected to obesity, and increasing emphasis was placed on body size which then took center stage in the medical community explanation for the cause of the illness. Controlling body weight gain was looked at as self-discipline and thinness were equated with godliness and moral worth during the Victorian era. Despite this new rational explanation, the widely-held perception of the misconduct and immorality as the cause for DM did not loosen and die away but remained mostly intact. Overall, laziness, overindulgence and self-neglect emerged as a dominant description for those with DM during the 19th century (O'Donnell, 2015; Vester, 2010).

**Social causation theory in the latter half of the 19th century**

By the middle of the 20th century, it became increasingly apparent that the lifestyle theory had some serious limitation in explaining personal habits as a possible cause of the disease. The pleasure-seeking and wicked habits didn’t tie well with the character of the patient who was being treated for DM. These patients were the most successful in life and occupied good standing in society (O'Donnell, 2015; W. Thomas, 1885). The possibility of lifestyle to blame for their illness of any kind appeared to be an ill-fitting and inappropriate theory. Although, diet and exercise remained an essential part of the clinical picture of DM, physicians began to propose an alternative explanation for DM. So that, the reputation and stature of their high-status clients were not compromised (O'Donnell, 2015).
The re-emergence of the lifestyle theory in the 20th century

By the turn of the 20th century, it became increasingly apparent that DM was rapidly increasing at an alarming rate, globally and few reports emerged that the disease is making inroads into people of all social status contrary to the widely held beliefs of the 19th century (Tuchman, 2011). Due to sedentary lifestyle and abundance of food, obesity rates increased globally. The discovery of insulin in 1921 followed this.

In the industrialized nations around the world, the changing disease level from communicable to chronic illnesses was becoming more apparent and serious public health concern in the 20th century (Getting, 1950). The epidemiological community which strongly backs the socio-environmental causation of disease failed to accept the environmental aetiology for DM. As an alternative, a strictly reductionist biomedical view of disease causation had become the dominant model (Susser & Stein, 2009).

The scientific discourses between 1800 and 1950 around T2DM highlighted how lifestyle just being one of the many contextual explanations for the causes of T2DM that were interpreted by the physician according to circumstance, social class of the patient and the wider cultural context (O'Donnell, 2015).

1.2.4 Early Disease Detection

The term early disease detection refers to recognition or uncovering of a disease at an early stage through screening and or physical examination so that disease-modifying treatment can have a positive outcome on the quality of life and at a reduced cost. Historically, in the early screening era, endemic communicable diseases like Malaria, Nematode infestations, Leprosy and Trachoma were examined. Screening for non-communicable chronic disease is a late development because of the change in disease pattern in the developed world (Wilson & Jungner, 1968).

Evolution of early disease detection
Early evidence from the literature on the concept of early disease detection can be traced back to 1861 when an English physician named Horace Dobell advocated for periodic health examination (H. J. Johnson, 1967). In the United Kingdom (UK) screening of school children for the contagious disease started in 1906 (The National Archives, n.d.). Similar ideas emerged across the Atlantic, later, by the end of the 19th century it was suggested that school children in the USA be screened for contagious disease, but it was not until the turn of the 20th century that the concept of periodic examination was put into practice following a U.S physician, speech at the American Medical Association (Charap, 1981; Reiser, 1978).

The concept of periodic health screening progressed with acceptance by the medical regulatory bodies despite any effectiveness being established. Supporters of the screening claimed health benefits while others felt it was diverting physicians away from the important task of treating illness in the society (Han, 1997). With no clear evidence through controlled studies, the American Medical Association was convinced in 1922 of the long-term health benefits of the annual check-up and officially supported it (Emerson, 1923; Han, 1997). Since then, the popularity of periodic health screening started to grow eventually becoming a multimillion-dollar industry in the world.

Convincingly, a higher rate of disease was detected among asymptomatic personnel and was reported in several studies (Bolt, Tupper, & Mallery, 1955; Frame & Carlson, 1975b; Franco, 1956). But most of the incidental findings were of chronic in nature, and early diagnosis did little to change the course of the disease progression (Franco & Gerl, 1955). Other concerns also existed like the screening was of one-time effort with no long-term follow-up (Baker, 1956; Guidotti, 1957) and among those who had to follow up; the disease was not confirmed (Bates & Yellin, 1972).

In spite of the early controversy surrounding the annual health examination and the procedures involved, it remained largely unchallenged until 1970s when Frame and Carlson critically examined the feasibility of screening procedures in their series of four articles for selected 36 diseases (Frame, 1986; Frame & Carlson, 1975a, 1975c, 1975d). This suggestion replaced the annual health examination with a periodic health check based on socio-cultural, demographic
and other risk factors. In 1983, the American Medical Association Council on Scientific Affairs questioned the value of its own recommendation issued in 1947 that adults older than 35 years should have an annual medical examination. Factoring in the findings from Frame and Carlson appraisal the American Medical Association came with a new recommendation for medical examination as once every five years before the age of 40 and everyone to three years after that (American Medical Association, 1983). The value of the periodic health examination has repeatedly been questioned in the literature (Han, 1997). Although, some studies can demonstrate value to an evidence-based executive physical examination when performed by qualified board-certified physicians (Burton, Chen, Conti, Schultz, & Edington, 2002).

Employers were attracted to the idea of regular health examination for its executives and the notion at that time for the employer was to provide regular health examination so that they can retain the bright and talented minds with decreased disruption in productivity and at an affordable cost compared to treatment (Burton et al., 2002). The public image of business executives of a large organization in the early and middle of the 20th century is a harried and hurried man with the reduced longevity of life due to stress and cardiovascular disease as an occupational hazard (Thorner & Crumpacker, 1961). This fallacy conflict with the conclusion drawn from studies on the relationship of occupation, social status, and mortality which generally indicate an inverse relationship between these variables. Although, it may be difficult to single out the contribution of the periodic health examination its input probably did bring about reduced mortality experience among the executives (Thorner & Crumpacker, 1961).

The preliminary report of a more extensive physical examination in the 1960s for early disease detection among apparently healthy, company sponsored executives identified on an average, five diseases per individual, unknown to the person (Sharpe & Marxer, 1962). Gastrointestinal, cardiac, metabolic and urinary disorder accounted for almost 75% of the illnesses. About half of that newly detected disease was of significant health consequence. Many of those unknown diseases like DM and gallstones were asymptomatic in the individual. Of the 23 cases of newly diagnosed NIDDM, nine required treatment and the remaining had an occult or latent form that needs monitoring and other lifestyle adjustments. One of the limitations of this study is it used urine samples and one hour postprandial blood sugar analysis which is considered by today's standard to be an underestimate (Sharpe & Marxer, 1962).
Advancement in biomedical research and technology following the second world war brought curative medicine with glamour to the forefront overshadowing the merits of preventive medicine (Battista, Beaulieu, Feightner, Mann, & Owen, 1984). This trend continued indisputably until the early 1970s when the limitations eventually surfaced out. This lead to a renewed interest in the potential gains from periodic health examination (Battista et al., 1984).

1.2.5 Types of diabetes mellitus

Several pathogenic processes are involved in the progression towards DM. The vast majority of DM fall within three categories, Type 1 Diabetes Mellitus (T1DM), T2DM and Gestational Diabetes Mellitus (GDM)(World Health Organization, 1980, 1985, 1999).

Type 1 diabetes mellitus

Insulin is essential for life. In people with T1DM, there is an absolute insufficiency of insulin due to β cell destruction that ultimately leads to DM. This form of DM accounted for approximately 10% or less of DM and was previously referred to as Insulin Dependent Diabetes Mellitus or juvenile-onset DM. T1DM results from cellular-mediated autoimmune destruction of the pancreatic β cells (International Diabetes Federation, 2017; World Health Organization, 1999).

Type 2 diabetes mellitus

T2DM is the most common and accounts for 90% of all those affected. It was previously referred to as NIDDM or adult-onset DM. T2DM has a slow onset as the hypoglycaemia is often less severe to provoke appreciable symptoms in the early stage (American Dental Association, 2012; M. I. Harris, 1993) and remains largely unnoticed for years. This type includes individuals with insulin resistance and relative insulin deficiency. Most often, such individuals can survive without the need for extrinsic insulin treatment, in the early stages as long as the hyperglycaemia is under control. As the disease progress and blood glucose build up to unmanageable level insulin therapy will be needed throughout their lifetime (American Dental Association, 2018).
**Gestational diabetes mellitus**

Glucose intolerance at the onset or first recognition during childbirth is defined as GDM. Individuals at risk of GDM include older women with a history of glucose intolerance, those with a history of larger babies, specific high-risk ethnic groups and pregnant women with elevated Fasting Plasma Glucose (FPG). It has become customary to screen pregnant women in a high-risk population in the first trimester to detect DM that may have gone unnoticed. Formal systematic screening for GDM is usually done during the 24th to 28th week of gestation (American Dental Association, 2012).

**Other specific types**

Other less common types of DM include those, where the underlying defect can be recognised in a relatively precise manner. These can be broadly classified into 1. A defect in β cell function and 2. Genetic defect of insulin action 3. Disease of the exocrine pancreas 4. Endocrinopathies 5. Drug-induced 6. Infections 7. Uncommon forms of immune-mediated

The defect of the β cell function is common among the less common types of DM. This form is often characterized by the onset of mild hyperglycaemia at an early age (generally before age 25 years). They are usually inherited in an autosomal dominant trait and was formerly referred to as Maturity Onset Diabetes Mellitus of the Young (American Diabetes Association, 2010a).

**1.2.6 Prevalence and epidemiology**

DM is a global epidemic in terms of incidence, health care cost, and overall complications. As of 2017, 80% of all individuals with DM live in low and middle-income countries (International Diabetes Federation, 2017). The number of people developing DM is increasing, and the age-standardised global prevalence has nearly doubled since 1980, rising from 4.7% to 8.5% in the adult population, while prevalence had quadrupled from 108 million in 1980 to 422 million in 2014. Population growth and ageing alone accounted for 40% of the increase in prevalence, 28% from a rise in age-specific prevalence, and 32% from the interaction of the two (Non
Communicable Disease Risk Factor Collaboration, 2016). The two most populous nations, India (9%, 72.9 million) and China (10%, 114.4 million) account for the highest number of adults with DM than any other country in the world. The World Health Organization (WHO) Eastern Mediterranean region has experienced the most significant rise in DM prevalence and is now the WHO region with the highest prevalence of 13.7% (International Diabetes Federation, 2017; World Health Organization, 2016).

At a national level, high prevalence rates are reported in Mexico (13.1 %) and Egypt (17.3 %) (International Diabetes Federation, 2017). More recently, Mauritius recorded a marked surge in the prevalence of T2DM from 13.0% in 1987 (Magliano et al., 2012) to 22 % in 2017 (International Diabetes Federation, 2017).

**Western Pacific region**

The Western Pacific (WP) region comprises 39 countries and territories and is the most populous WHO region. It includes regional heavyweight China along with many least populous nations in the world. Around 37% of the people with DM globally live in this region. In 2017, 158.8 million (8.6 %) of adults aged 20-79 years were estimated to be living with DM, and over half (54.1 %) of them were undiagnosed (International Diabetes Federation, 2017). China accounts for the most number of people with DM in the world. The WP region also accounts for both some of the highest and lowest prevalence’s of DM in the world, ranging from 4.4% in Cambodia up to 30.5 % in the Marshall Islands. There are also 127 million adults with impaired glucose tolerance (IGT) in the region, at increased risk of developing DM. By 2045, it is estimated that there will be 193 million adults with DM in this region, that corresponds to 10% of the adult population (International Diabetes Federation, 2017).

**Australia**

Prevalence of DM among Australians more than doubled from 1.5% to 4.2%, between 1989-90 to 2010-2011. However, it is worth noting that the proportion remained largely unchanged between 2007-2008 (4.1%) and 2011-2012 (4.2%), whilst the number of people with DM
continued to rise from around 898,800 in 2007–2008 to about 999,000 in 2011-2012 (4.2%) (Australian Institute of Health and Welfare, 2013). The 2014-2015 national health survey reported that 5.1% (1.2 million) of the Australian population had some type of DM (Australian Institute of Health and Welfare, 2015).

The National Diabetes Service Scheme (NDSS) monitors and provides up-to-date information on the prevalence of DM in Australia. It is estimated that, as at June 2018, 1.7 million (5.1%) Australians are living with DM, of which 1.27 million are registered and diagnosed with DM (National Diabetes Service Scheme, 2018).

**Region, ethnicity and groups in Australia**

In Australia, DM is more common in men (5.2%) than in women (4.7%), and the Northern Territory has the highest prevalence (10.6%) with the lowest in the Australian Capital Territory at 3.8%. High burden of T2DM in Indigenous Australians echoes the reason for the high prevalence in the Northern Territory (Australian Institute of Health and Welfare, 2013). The Australian Aboriginal and Torres Strait Islander Health Survey (AATSIHS), 2012-2013 reported that 8.6% of Aboriginal and Torres Strait Islander people aged two years and over indicated that they had T1DM or T2DM and/or high sugar levels in their blood or urine (Australian Bureau of Statistics, 2014). Within Australia, the prevalence of DM is higher among people of North African, Middle-Eastern origin, and several Asian countries compared to those born in Australia (Holdenson, 2003).

**1.2.7 Disease burden**

At the turn of the 20th century, DM was the 27th leading cause of death by disease (Tokuhata, Miller, Digon, & Hartman, 1975). In 2016, it was the seventh leading cause with 1.6 million deaths among both sexes (World Health Organization, 2018). However, this ranking position given to DM among major causes of death is grossly distorting because a third of the countries do not have any reliable data on DM-related mortality; alternatively, existing data often underestimate DM related mortality (McEwen et al., 2011).
Until the 1970s, in developed nations, DM received little recognition as a public health problem in spite of its serious health complication, premature deaths and economic burden (Fuller, Elford, Goldblatt, & Adelstein, 1983; Tokuhata et al., 1975). DM was not included in the United Nations Millennium Development Goals in spite of its strong association with poverty, maternal health and infectious disease (International Diabetes Federation, 2017). One of the main reasons recognized as a limitation and complicating the case for DM was the way the disease was classified and reported in the past as a cause of death on death certificates (Will, Vinicor, & Stevenson, 2001a). During that time, mortality reporting systems recorded only one disease as the primary cause of death even when several often related and contributing diseases were diagnosed in the same patient. Also, the very definition of the disease as chronic in nature and often seen as an underlying cause in the presence of more visible disease which may, in fact, have been caused either directly or indirectly by DM (Will et al., 2001a).

Improved recording of DM on death certificates could result in a better appreciation of the burden that this disease imposes on individuals, society, the health care system and a nation as a whole. In the United States (US), during the 1980s and 90s, the mortality data of persons with a history of DM identified that fewer than 40% made any mention of DM, whilst ischaemic heart disease featured most often (D. E. Bild & Stevenson, 1992; Will, Vinicor, & Stevenson, 2001b) even though DM is a well-known risk factor for ischaemic heart disease and the death may well be caused directly or indirectly by DM (Geiss, Herman, & Smith, 1995; Grundy et al., 1999). Because of the inherent problems in the cause of death recorded in death certificates the International Diabetes Federation (IDF) uses a modelling approach to estimate mortality (International Diabetes Federation, 2017).

The WHO estimated that the proportion of premature mortality attributable to high blood glucose during the period 2000-2012 increased for both sexes across the world with the exception of women in the WHO European region. During that period, the WP region by far had the highest proportional change, up by 92% (n = 944,000) from what was reported in the year 2000 (n = 490,000), in premature death attributable to high blood glucose levels.
1.2.8 Complications

DM increases the risk of developing adverse health issues. It affects nearly every organ in the body causing disability and life-threatening health problems. DM is the leading cause of CVD, blindness, kidney failure, and limb amputation. DM complications have traditionally been categorized into macrovascular (coronary, peripheral arterial diseases and stroke) and microvascular (diabetic nephropathy, neuropathy, and retinopathy) conditions. Although overshadowed by the traditional complications already mentioned, T2DM is also known to directly or indirectly affect other systems including musculoskeletal, hepatic, and digestive systems, as well as the cognitive functioning and mental health (Lu, Lin, & Kuo, 2009). People with DM are also at increased risk of developing several types of microbial and fungal infections. Having said that, complications are not uncommon even in those with well-controlled blood glucose levels.

Most of the available data on DM relates to prevalence, cause of death, or years of life lost or years lived with disability (International Diabetes Federation, 2017). There is very little information on global estimates of all the DM-related complications. Where data are available – mostly from high-income countries, they vary hugely between countries and are often less clear (Moxey et al., 2011; The United States Renal Data System, 2014).

Over past decades, the relative risks of morbidity from microvascular complications among people with DM, derived mainly from high-income country cohort studies, were thought to be at least 10–20 times that of the non-diabetic population, whereas rates of macrovascular complications were only 2–4 times those of people without DM (Donnelly, Emslie-Smith, Gardner, & Morris, 2000; Kannel & McGee, 1979; Klein & Klein, 1995; Reiber, Boyko, & Smith, 1995).

Cardiovascular diseases

CVD may cause fatal complications that can lead to heart attack and stroke. Most of the mortality among people with DM is due to CVD (International Diabetes Federation, 2017).
Adults with DM historically have two to three-times higher risk of CVD than those without DM. Approximately, 10% of the vascular cause of death in developed countries can be attributed to DM among adults (Sarwar et al., 2010) and this trend is likely to continue further in spite of falling cardiovascular events among T1DM and T2DM in North America, and northern European countries. The decrease in cardiovascular events is mostly due to the reduction in tobacco use and improved DM and associated CVD risk factors (Danaei, 2014; World Health Organization, 2016).

Diabetic nephropathy

DM and hypertension are the leading causes of Chronic Kidney Disease (CKD) in both the developing and the developed world. CKD is an important cause of death and loss of disability-adjusted life-years globally (Jha et al., 2013). Kidney disease is much more common in people with DM than in those without DM. Worldwide, CKD is the most common and by far the costliest of all the DM related illness (Slabaugh, Curtis, Clore, Fu, & Schuster, 2015). This is partly due to the resources towards renal replacement therapy adding a considerable proportion to the cost of treatment. DM can damage the microvasculature in the kidneys leading to the organs becoming less efficient or failing altogether. Maintaining near-normal levels of blood glucose and blood pressure can significantly reduce the risk of kidney disease. Between 1990 to 2010, CKD rose from being the 27th to the 18th global cause of death (Jha et al., 2013; Lozano et al., 2012). This rapid ascent was second only to HIV and AIDS. CKD accounts for the third highest in life years lost due to premature death which is an 82% increase compared to that reported in the year 1990. Here again, DM (93%) is the second largest and only next to the Human Immuno-deficiency Virus (HIV) and directly or indirectly contributed to the CKD (Jha et al., 2013).

Rao and colleagues analysed the mortality data among US and Australian peers and concluded that a significant proportion of individuals died of DM had renal failure. But the death records were coded for uncomplicated DM. Renal failure was neither included nor recorded as a complication of death (Rao, Adair, Bain, & Doi, 2012). In estimating the global prevalence of CKD from 33 countries, the DEMAND study identified that 50% of patients with T2DM, but without a known history of renal disease or proteinuria, had some evidence of CKD (Parving,
Early identification of CKD and appropriate management can help reduce or reverse the deterioration in kidney function by as much as 50% (D. W. Johnson, 2004). In Australia, less than 10% of people are aware they have CKD, which translates into more than 1.5 million of the affected individuals being unaware of this disease indicator (Australian Bureau of Statistics, 2013).

**Diabetic neuropathy**

Is very common and one of the most troublesome complications of DM. There are different types of diabetic neuropathy and the most common are the peripheral and autonomic neuropathy. Around 50% of those with DM have peripheral neuropathy (Pop-Busui et al., 2017; Young, Boulton, MacLeod, Williams, & Sonksen, 1993) while 30% have autonomic neuropathy (Izenberg, Perkins, & Bril, 2015). Other less common type are focal and proximal neuropathies. The Danish ADDITION trial identified prevalence of diabetic neuropathy as 13% among those newly diagnosed with T2DM and the cumulative incidence was 10% in the 13 year follow-up period in those with good glycaemic control (Andersen et al., 2018).

Diabetic neuropathy leads to significant morbidity and mortality and results in a substantial economic burden for DM care (Holzer et al., 1998; Vinik, Nevoret, Casellini, & Parson, 2013). It is the most common form of neuropathy in high-income countries that account for higher hospitalization than all the other DM complications combined and is responsible for 50% to 75% of non-traumatic amputations (Caputo, Cavanagh, Ulbrecht, Gibbons, & Karchmer, 1994; Holzer et al., 1998).

DM causes nerve damage to the whole body, that can lead to impaired digestive function and erectile dysfunction. One of the most commonly affected areas are the extremities, particularly
the lower limb. Nerve damage in these areas leads to pain, tingling, and loss of sensation. DM significantly increase the risk of lower extremity amputation because of the risk of non-healing infected foot ulcers (19). Amputation among people with diagnosed DM is typically 15 to 20 times higher than those without DM (Diane E Bild et al., 1989; Crawford et al., 2010; Pscherer, Dippel, Lauterbach, & Kostev, 2012). However, the number of lower extremity amputation had reduced considerably in the last two decades in the UK, Sweden, Denmark, US and Australia (Moxey et al., 2011).

Life style changes has been shown to be effective in preventing the progression of neuropathy in those with IGT but the role of glycaemic control in slowing the progression of diabetic neuropathy in those with T2DM is limited (Callaghan, Callaghan, Little, Feldman, & Hughes, 2012; Ismail et al., 2010).

**Diabetic retinopathy**

People with DM may develop eye disease (retinopathy), that can damage vision and cause blindness. Persistent high levels of glucose in the blood is an important cause for this condition. Damage to the microvasculature in the retina can lead to blindness. Retinopathy, however, can become quite advanced before it starts to affect vision, and it is important that people with DM have their eye checked regularly. Early identification and appropriate care to control blood glucose can reduce the risk and prevent blindness (International Diabetes Federation, 2017).

Globally, in 2010, there were 32.4 million blind and another 191 million visually impaired of which diabetes retinopathy contributed to 0.8 million blind and 3.7 million visually impaired. In the last two decades from 1990 to 2010, this translated into a 27% increase in blindness and 64% for visual impairment. In 2010, diabetic retinopathy was responsible for 2.6% of all blindness and 1.9% of all visual impairment. This is an increase of 2.1% and 1.3% from the 1990 values. The Age-standardized prevalence of blindness and visual impairment was higher among the sub-Saharan African and South Asian people (Leasher et al., 2016).
Osteoporosis

Osteoporosis is a skeletal disorder characterized by the reduced bone density that affects the bone microarchitecture, leading to increased bone fragility and higher risk of fracture. DM and osteoporosis often coexist as both these conditions are related to ageing. The relationship between diabetes and osteoporosis is controversial and a subject of intense debate (Leidig-Bruckner & Ziegler, 2001; A. Schwartz, 2003). Several studies have confirmed the low bone mineral density association with T1DM (Christensen & Svendsen, 1999; Gunczler et al., 2001; Krakauer et al., 1995; Miazgowski & Czekalski, 1998; Vestergaard, 2007) and high bone mineral density with T2DM (De Liefde et al., 2005). Excessive body weight is often cited as the reason for the higher BMD among T2DM which may sound protective against fracture, but this happens in conjunction with reduced bone turnover (Akin, Göl, Aktürk, & Erkaya, 2003; Starup-Linde, 2013). Several studies have demonstrated the higher incidence of fracture among T2DM linked to poor glycaemic control, and those with diabetes-related complication (Bonds et al., 2006; De Liefde et al., 2005; Dede, Tournis, Dontas, & Trovas, 2014; Janghorbani, Van Dam, Willett, & Hu, 2007; Melton, Leibson, Achenbach, Therneau, & Khosla, 2008). Poor glycaemic control and diabetes-related complication like retinopathy, peripheral neuralgia and stroke increase the risk of falls and is the reason for the higher incidence of fractures among persons with T2DM (Dede et al., 2014; Maurer, Burcham, & Cheng, 2005; A. V. Schwartz et al., 2002; Strotmeyer et al., 2005).

Pregnancy complications

DM during pregnancy risk several complications. To avoid any organ damage to the developing foetus, those with T1DM or T2DM should maintain target glucose levels before conception. All those with DM or GDM should attempt for target blood glucose levels during pregnancy to avoid any untoward complications. Hyperglycaemia during pregnancy can cause complication for both the mother and child. Increase foetal weight can rapidly deteriorate the child blood glucose immediately after delivery. Prolonged exposure to high blood glucose in the womb maximises the chance of developing DM in the future (Zhu & Zhang, 2016).
1.2.9 Periodontal disease

Periodontal disease is the most common cause of tooth loss among adults, and uncontrolled DM is a significant risk factor as it is known to accelerate periodontal tissue destruction leading to edentulism (Taylor, 2001). A survey among US adults had demonstrated those with poorly controlled DM expressed higher prevalence of periodontal disease (Tsai, Hayes, & Taylor, 2002). Estimates show a three to four-fold higher risk of destructive periodontitis in those with T2DM (Emrich, Shlossman, & Genco, 1991; Nelson et al., 1990; G. W. Taylor et al., 1998). Several interrelated mechanisms like microangiopathy, neutrophil dysfunction, altered subgingival microflora and genetic predisposition have been proposed as contributing to periodontal tissue destruction (Manouchehr-Pour & Bissada, 1983; Murrah, 1985; Salvi, Lawrence, Offenbacher, & Beck, 1997; Wilton et al., 1988). As a consequence, the root surface of the tooth is exposed which increases the risk of developing dental caries (Garton & Ford, 2012). Around, 90% of tooth loss is attributable to DC and periodontal disease. (Australian Institute of Health and Welfare, 2014). Further to the widely recognized classic five complications of DM (eyes, heart, blood vessels, kidney and nervous system), periodontal disease had been recently recognized as the “sixth complication” (Loe, 1993).

Pathogenic interrelationship

The two primary mechanisms by which DM affects periodontal tissues is by reducing its renewal rate and altering the local immune defence mechanism (Weinspach et al., 2013). The elevated proinflammatory cytokines present among diabetics promote the destruction of periodontal tissues and reduces periodontal pathogen elimination (Mealey, 2006). Patient with DM is known to have a higher level of Advanced Glycated End products in the periodontium compared to those with no DM (Schmidt et al., 1996). These Advanced Glycated Endproduct and collagen interplay to produce collagen macromolecules that are highly stable and resist degradation through physiologic enzymes (Monnier, Glomb, Elgawish, & Sell, 1996), and thereby altering the renewal of periodontal tissues in people with uncontrolled DM. This mechanism explains the reason as to why people with DM are at increased risk of developing periodontal disease. On the other hand, periodontal disease contributes to insulin resistance that may alter glycaemic control (Weinspach et al., 2013).
**Microbial flora**

The efforts to determine the mechanisms that account for the higher incidence of periodontal disease in people with DM have focused on the differences in the subgingival microbiota. The microorganism strongly implicated in the etiopathogenesis of periodontal disease was the red (Porphyromonas Gingivalis, Treponema Denticola, and Tannerella forsythia) and green complex microorganism (Aggregatibacter Actinomycetemcomitans). (Haffajee & Socransky, 1994; Socransky & Haffajee, 2005). The red complex microorganisms is a group of bacteria often associated with a severe form of periodontitis. A few reports suggest that hyperglycaemia is associated with an altered subgingival microbiota (Castrillon et al., 2015). A study conducted to quantify sulcular microbiota identified that higher numbers of red complex and A. Actinomycetemcomitans present in those with poor glycaemic control compared to those healthy and non-diabetic (Aemaiman, Animan, & Taweechaisupapong, 2013). A population-based cross-sectional study in Japan identified body mass index and waist hip ratio were independently associated with the number of red complexes among apparently healthy individuals suggesting oral microbes association with obesity in the healthy population (Matsushita et al., 2015). However, some researchers identified no difference in subgingival microbiota in those with or without DM (Sastrowijoto, Hillemans, van Steenbergen, Abraham-Inpijn, & de Graaff, 1989; Tervonen et al., 1994).

**Bidirectional relationship**

The relationship between DM and periodontal disease is one of the most researched and remains the subject of controversy. Despite this, some studies support the idea that periodontal infection can impact on diabetic person glycaemic control (G. W. Taylor, 1999). Also, a few researchers suggest that periodontal disease may predispose individuals to incident DM (Demmer, Jacobs, & Desvarieux, 2008). There are a few well-documented studies on the link between DM and periodontal disease that show DM can deteriorate periodontal tissues health. Alternatively, periodontal disease can impact glycaemic control (Mealey, 2006). On the contrary, the novel randomized controlled trial had failed to convince periodontal therapy improved the level of glucose control (Engebretson et al., 2013). Periodontal therapy in combination with systematically administered antibiotics demonstrated significant reductions in mean HbA1c, reaching up to 10 percent from the pre-treatment values in a three months
period (Grossi et al., 1997). The mechanisms by which this association exist are under investigation and require validation (George W Taylor, 2001). Evidence suggests that periodontitis-induced bacteraemia cause an increase in proinflammatory cytokine levels. The proinflammatory cytokines contribute to hyperlipidaemia, insulin resistance that further lead to pancreatic β cells destruction (Iacopino, 2001). This theoretical framework leads to increased interest in treating chronic periodontal infections may help glycaemic control in people with DM (Grossi, 2001).

A recent Cochrane systematic review that investigated the effects of periodontal therapy on glycaemic control identified scaling and root surface debridement to be beneficial in people with DM. It estimated a mean percentage reduction in HbA1c of 0.29% at 3-4 months period; however, this reduction gradually waned of in four months after therapy. The study further identified no difference in terms of effectiveness with different modalities of periodontal therapy in glycaemic control (Simpson et al., 2015a). A reviewer identified that the overall quality of the evidence was low and recommended that future Randomised Controlled Trials (RCT) studies should have a long-term follow up with interventions in reducing periodontal inflammation and adjunctive drug therapies in periodontal treatment (Rodriguez-Medina, Agudelo-Suarez, & Botero, 2016; Simpson et al., 2015a, 2015b).

Borrell and colleagues used the National Health and Nutrition Examination Survey (NHANES) III data to determine if family history of DM, hyperlipidaemia and hypertension, exhibit clinical evidence of periodontitis. This study highlighted periodontitis added significant predictive ability in identifying individuals with undiagnosed DM (Borrell, Kunzel, Lamster, & Lalla, 2007). One other study conducted in the dental setting to screen for T2DM using HbA1c also identified 26% of dental patients with deep pockets or ≥ 4 missing teeth were identified as pre-diabetes or DM in 72% of those who had the HbA1c test. This figure reached 75% of the total population (Lalla, Cheng, Kunzel, Burkett, & Lamster, 2013). Also, the prevalence of DM is more than twice as high in people with periodontal disease than those that are periodontally healthy. Thus, a high number of dental patients with periodontal disease may have undiagnosed T2DM or pre-diabetes.
1.2.10 National priority in Australia

In 1996, health ministers agreed to give DM a higher profile in the health system and made it as one of the five national health priority areas. The rationale for this decision was in recognition of the threat to public health and the impact that DM has on the Australian community with increased morbidity, reduction in lifespan, multi-organ complication, and ever-rising cost in dealing with DM and related conditions, putting an extra burden on the already stretched health care system. Also, of concern was the significant proportion of people with DM remain undiagnosed and disproportionate prevalence and higher incidence in certain population groups, especially Indigenous people (Australian Institute of Health and Welfare, 1997).

1.2.11 Early identification

Globally, DM is rapidly increasing when compared to many other chronic diseases due to a blend of factors including population growth, under-performing health systems, low awareness among people, health professionals and slow onset of symptoms or progression of the disease. With this combination of factors, the condition goes unnoticed and remains undetected for many years (World Health Organization, 2016).

Approximately, one in two adults with DM is undiagnosed, Globally. It has been estimated that as many as 212.4 million people or half of all adults between 20 to 79 years with DM are unaware of their disease (International Diabetes Federation, 2017). Early-stage T2DM is often asymptomatic; diagnosis may be delayed sometimes up to 4 or 8 years (Samuels, Cohen, Brancati, Coresh, & Kao, 2006). Further to disease identification, many individuals at the time of presentation show evidence of DM-related complications. As such, identifying the true incidence is often difficult and complicated.

Pre-diabetes is an asymptomatic precursor to DM, and the term is often used to refer individuals who do not meet the diagnostic criteria for DM but have a blood glucose levels high enough to be considered any healthy. These individuals are defined as having IFG level 100–125 mg/dL (5.6-6.9 mmol/L), IGT level 140–199 mg/dL (7.8-11 mmol/L), and/or an HBA1c value of 5.7–
6.4%. As far as the pathophysiology of pre-diabetes is concerned, insulin resistance and β cell dysfunction are the underlying cause for this disorder (Buysschaert, Medina, Bergman, Shah, & Lonier, 2015).

The IDF in 2017 estimates the global prevalence of IGT was estimated to be 352.1 million, which is 7.3% of the adult population. A vast majority (72.3 %) of them live in the low and middle-income countries (International Diabetes Federation, 2017). In 2012, an estimated 8.1 million US adults were living with undiagnosed DM and another 86 million with pre-diabetes. Between 2007 and 2012, the national burden increased to 82% for undiagnosed DM and 74% for pre-diabetes (Dall et al., 2014). The IDF projects an increase in the prevalence of IGT to 587 million (8.3%) in the 20 to 79 years, globally by 2045 (International Diabetes Federation, 2017).

There is also regional variation in the reporting of Undiagnosed T2DM globally, 84.5 % of all those estimated live in low- and middle-income countries (International Diabetes Federation, 2017).

1.2.12 Challenges with early diagnosis

The starting point for living well with DM is early diagnosis. But this is not without challenges. Most individuals with pre-diabetes and to some extent those with DM are asymptomatic and unaware of their condition. Additionally, pre-diabetes reference range and diagnostic criteria have become a concern. Bennett and Knowler (1984), using the NHANES II data, identified 43% of those with undiagnosed DM had FPG levels of less than 100 mg/dl, a further 44% have levels between 100 and 139 mg/dl and only 13% had levels more than or equal to 140 mg/dl. Thus recommending the need for some form of glucose tolerance test to cover all those undiagnosed cases (Bennett & Knowler, 1984). However, the reference range for fasting glucose tolerance used in this study is very different from that of what is in practice currently. In the past, several organizations have defined the criteria for pre-diabetes, but they are differed invariably (Bansal, 2015). Some studies identified poor correlation between HbA1c, IFG and IGT (Gosmanov & Wan, 2014; Guo, Moellering, & Garvey, 2014; van ’t Riet et al., 2010).
Markers for pre-diabetes have low reproducibility approximately 50% of the occasion than DM that have around 70% (Bansal, 2015). With this multitude of factors compounded with population growth and ageing, quadrupled the number of people with DM between 1980 and 2014 (Non Communicable Disease Risk Factor Collaboration, 2016) has made the disease an ever-increasing challenge to contain.

1.3 Screening

The Commission on Chronic Illness Conference on Preventive Aspects of Chronic Disease, held in 1951, defined screening as "the presumptive identification of an unrecognized disease or defect by the application of tests, examinations, or other procedures which can be applied rapidly. Screening tests sort out apparently healthy persons who probably have a disease from those who probably do not. A screening test is not intended to be diagnostic. Subjects with positive or suspicious findings must be referred to their physicians for diagnosis and necessary treatment." (Commission on Chronic Illness, 1957). The definition includes unrecognized symptomatic as well as pre-symptomatic disease and the use of questionnaire or physical examination as part of the screening process as long as it is quick and simple (though not necessarily unsophisticated) to apply.

1.3.1 Criteria for screening

In an attempt to stimulate international thinking, through discussion and suggestion, Wilson and Jungner, in their landmark Public Health Papers in 1968 attempted to define screening criteria to guide conditions that would be suitable for screening (Wilson & Jungner, 1968).

Wilson and Jungner classic screening criteria are

1. The condition sought should be an important health problem.
2. There should be an accepted treatment for patients with the recognized disease.
3. Facilities for diagnosis and treatment should be available.
4. There should be a recognizable latent or early symptomatic stage.

5. There should be a suitable test or examination.

6. The test should be acceptable to the population.

7. The natural history of the condition, including development from latent to declared disease, should be adequately understood.

8. There should be an agreed policy on whom to treat as patients.

9. The cost of case-finding should be economically balanced about possible expenditure on medical care as a whole.

10. Case-finding should be a continuing process and not a “once and for all” project.

Screening is often considered to be more economical than periodic physical examination because it can be performed with less of training to carry out the tests, thereby saving the cost of the highly trained professionals. Having said that, there are circumstances when the economics of screening may prove otherwise, where a condition is universally prevalent, and mass screening will only add to the cost of almost certain diagnosis. Secondly, the cost of screening in a community is no lesser compared to conventional medical care since more people will be in need and eventually become eligible (Wilson & Jungner, 1968).

The objective of screening is to detect the disease early before it becomes clinically apparent. In theory, therefore, screening is an admirable approach to combat disease at an early stage before it could impact on the individual and the wider community (Wilson & Jungner, 1968).

“The central idea of early disease detection and treatment is essentially simple. However, the path to its successful achievement (on the one hand, bringing to treatment those with the previously undetected disease, and, on the other, avoiding harm to those persons not in need of treatment) is far from simple though sometimes it may appear deceptively easy” (Wilson & Jungner, 1968).
There are greater resources in the developed compared to the developing countries, but in financially constrained health systems across the world, increasing emphasis is being placed on the ability to demonstrate that healthcare interventions are not only effective but also cost-effective (Briggs, Sculpher, & Claxton, 2006). With limited resources and never-ending treatment needs for curative services, it becomes difficult to divert resources aimed at preventative services.

1.3.2 Types of screening

Screening can be categorized broadly into one of the following types depending on the objectives, target group or setting.

Mass screening

This term refers to a screening of large population groups. This form of screening is aimed at a large, generally diverse population where the probability of individuals having a preclinical form of the disorder of interest is likely to be variable.

Multiple or multiphasic screening

Multiphasic screening is defined as "the application of two or more screening tests in combination with large groups of people" (Commission on Chronic Illness, 1957). This type combines various diagnostic screening tests on the same occasion for large groups of adults, at low cost (e.g., an annual health check-up). This type of screening is not independent of the other type of screening but is designated multiphasic because it involves screening for several disorders on the same occasion pre-military exams for example often employ multiphasic screening to test for possible disorders such DM, hypertension, and hearing impairment in prospective soldiers (Oleckno, 2008).

Selective screening
Selective or targeted screening is applied only to high-risk groups with specific exposure or individuals with greater than average probability of having a preclinical form of the disorder of interest (e.g. screening for elevated levels of Lead in the blood among inner-city children); Selective screening can be expected to result in the detection of more positive cases of a given disorder than mass screening because of the higher probability that members of the group have preclinical forms of the disorder (Oleckno, 2008; Wilson & Jungner, 1968).

**Opportunistic screening**

Opportunistic screening (or case finding) usually occurs in the clinician’s office where patients come in with unrelated problems, and the clinician takes the opportunity to perform in order one or more screening tests. The main objective is to identify the disease early and provide preventative or curative treatment. In this way, it differs from epidemiological surveys where the primary aim is to study the incidence, prevalence and the natural history of the disease or condition (Wilson & Jungner, 1968). Unlike mass or selective screening where an individual with positive screening results is referred for follow-up testing, opportunistic screening places the responsibility for follow up on the physician performing or supervising the screening tests. Therefore, opportunistic screening is more likely to result in follow up than other types of screening (Oleckno, 2008). Examples of opportunistic screening include screening for cervical cancer using a Pap test, heart disease using a stress test and DM using blood glucose, HbA1c or urine test (Fletcher, Fletcher, & Fletcher, 2012; Oleckno, 2008).

1.3.3 **Rationale for screening diabetes mellitus**

Screening has important implications for public health policy. Screening asymptomatic adults for DM may lead to early identification so that intensive treatment may be initiated early to prevent or delay the negative outcomes. While the early detection and treatment of DM seem logical regarding minimizing complications, there is currently no direct evidence through high quality RCT as to whether this is beneficial in terms of minimising cardiovascular, cancers and diabetes-related mortality (Simmons et al., 2012b; Waugh, Shyangdan, Taylor-Phillips, Suri, & Hall, 2013a).
However, the theoretical framework in favour of T2DM screening is that there is a latent pre-clinical stage during which people could be diagnosed early, and treatment could be initiated early to prevent complication (Rahman, Simmons, Hennings, Wareham, & Griffin, 2012). Further, modelling studies on T2DM identified screening to be cost effective if started between 30 to 45 years and showed it would reduce cardiovascular morbidity (Chen, Yen, & Tung, 2001; Richard Kahn et al., 2010). Lifestyle and pharmacological interventions have proven effectiveness in delaying the progression to DM in those with IGT (International Diabetes Federation, 2015). Some prospective analytical studies have shown that early identification of DM improves outcome, although the evidence in support of this argument is weak and controversial for screening the entire population (Gillies et al., 2008; R. Simmons, Echouffo-Tcheugui, & Griffin, 2010). Despite this lack of direct evidence, early detection through screening is taking place and is recommended by some organizations throughout the world (International Diabetes Federation, 2015).

1.3.4 The case for and against screening for diabetes mellitus

Although there are several recommendations, some suggest that screening for undiagnosed DM and pre-diabetes should be implemented to slow down the progression and complication of the disease (Chatterjee, Narayan, Lipscomb, & Phillips, 2010). Despite the evidence being equivocal and not clear if it is effective in reducing DM related morbidity or mortality (Lauritzen et al., 2000). Moreover, there has been limited consideration of the economic aspects of screening (Chen et al., 2001; Lee, Remington, Madagame, & Blustein, 2000; Raikou and McGuire, 2003).

One of the important criteria for screening set out by the UK; National Screening Committee is that there should be evidence from RCT that any screening programme is effective in reducing mortality or morbidity (Criterion 13). In his regard, population screening for T2DM has failed to live up to expectation and brings into question the case for screening as the evidence is less strong than it was in the 2007 effectiveness review (Waugh, Shyangdan, Taylor-Phillips, Suri, & Hall, 2013b).
It would be logical to assume that early diagnosis of DM further to screening would capture at-risk individuals with minimal microvascular complication. However, this was not found to be true, thereby only complicating the case for screening (Spijkerman et al., 2003). Novel rigorous studies done in Europe showed varied results on the effectiveness and failed to identify any reduction in cardiovascular complication following population screening and early diagnosis of DM (Lauritzen et al., 2000; Simmons et al., 2012b; Tao et al., 2015; Waugh et al., 2013b).

The ADDITION-Cambridge study (Simmons et al., 2012b) is a large, robust cluster randomized, primary care based, screening and intervention trial for T2DM with a median duration of follow-up of 9.6 years. The trial has two phases namely the screening and intervention (intensive multifactorial therapy) phase. The screening trial estimated 3% of those screened were diagnosed as DM. Other significant findings include no difference between screen and the control group in all-cause morbidity, mortality, cardiovascular mortality, cancer mortality or any other cause of death untreated to DM. The cumulative probability of results suggests that population-based screening for DM is associated with no reduction in mortality within ten years in the age group 40 to 69 years (Simmons et al., 2012a). The intervention phase of the ADDITION-Europe multicentre cluster randomized controlled trial reported intensive treatment five years after screen diagnosis of T2DM as resulting in no significant reduction in the frequency of microvascular events compared to routine care. Also, intensive treatment was not found to be cost effective (Sandbaek et al., 2014; Simmons et al., 2016). Another less rigorous trial identified a moderate but significant reduction in all forms of mortality but limited information on morbidity. However, this study fell short regarding quality and was regarded as mediocre to poor by the U.S Preventive Service Task Force (USPSTF) (Siu, 2015).

Analysis of the Ely trial cohorts identified that T2DM screening resulted in cases being identified on an average of 3.3 years from the time of actual onset (Rahman et al., 2012). This is much shorter compared to the older study (Harris et al., 1992) where it was estimated to be 9 to 12 years. One possible reason for the reduction in the latent period is the increasing awareness in the clinical setting on the high prevalence of undiagnosed T2DM and the frequent testing and early detection in the UK. This relatively short period is one other reason why the
Both epidemiological and clinical trials provided some evidence that early recognition and timely lifestyle or pharmacological intervention can delay or prevent the onset of T2DM by preserving the deterioration of β cell numbers and function. The United Kingdom Prospective Diabetes Study (UKPDS) that recruited patients with newly-diagnosed T2DM, where early intensive glycaemic control achieved 0.9% lower HbA1c compared to conventional treatment. This indicates a 12-25% reduction in microvascular complications after a median duration followup of 10 years (American Diabetes Association, 1998; Holman, Paul, Bethel, Matthews, & Neil, 2008). In the 10-year post-trial follow-up of UKPDS participants, early intensive glycaemic control had a legacy effect that reduced the risk of cardiovascular complications and all-cause mortality (David C Klonoff, 2008; Mogensen). There was considerable disparity in the results of UKPDS compared to the Action to Control Cardiovascular Risk in Diabetes (ACCORD) study where intensive treatment over a period of ten years after diagnosis showed several of the trial participants developed DM related complications with poor tolerance to hypoglycaemia (Cushman, Evans, & Cutler, 2015; Mogensen; Skyler et al., 2009). This indicates, early intensive treatment at a stage where complications are less severe and side effects better tolerated is preferred over delayed treatment where side effects are more pronounced, and consequences are severe. Given that 20 to 50% of those with T2DM remain undiagnosed globally (International Diabetes Federation, 2017), early recognition may be more beneficial as treatment is relatively inexpensive and more effective than a late-stage disease where treatment tends to be more complex (Kong, Luk, & Chan, 2016). Despite this controversy, the WHO and IDF recommend screening to improve both the longevity and quality of life by preventing or delaying long-term complications. Thereby resulting in potential savings on health care resources (Charlton, Latinovic, & Gulliford, 2008; World Health Organization, 2003).

In this present circumstance, there appears to be some justification for opportunistic screening as a viable option which offers value for money. Also, opponents of population screening also argue on the possibility for opportunistic screening to reduce the number of cases of
undiagnosed T2DM in the population (Bertram, Lim, Barendregt, & Vos, 2010; Pereira Gray, Evans, Wright, & Langley, 2012).

Opportunistic screening offers the potential to reduce the pre-diagnosis interval by a few years under current clinical practice. As such, it would be logical to assume that early identification of the disease further to screening would capture at-risk individuals with minimal microvascular complications. Moreover, the progression from pre-diabetes to T2DM is not inevitable and available evidence suggests that it less expensive to treat T2DM than to treat its complications (Herman & Eastman, 1998).

1.3.5 Early detection by screening

Since DM is asymptomatic in the early stages, it escapes detection and remains unnoticed for years. At the time of diagnosis, some may have developed DM-related complications of varying intensity. Again, if no screening was done, individuals with undiagnosed DM will continue to accumulate glycaemic burden and an “unfavourable” legacy effect, which could result in a higher prevalence of DM-related complications. The question should, therefore, not be whether we can afford to screen for DM; rather, it should be whether we can afford not to (Unnikrishnan & Mohan, 2015).

1.4 The scope for opportunistic screening in dental setting

The concept of having dentists screen for medical condition was proposed as early as 1926 in the Gies report (Gies, 2012) and restated again by Glick in 2002 (M. Glick, 2002b). Some studies have indicated the utility, potential efficacy, and cost-effectiveness of screening patients for medical conditions in the dental setting (Genco et al., 2014; M. Glick & Greenberg, 2005; Strauss et al., 2010).

Periodontal disease is one of the leading causes of tooth loss, and DM is an established risk factor for periodontal disease. Dental patients with poorly controlled DM experience far greater
periodontal problems and poorer treatment outcomes, eventually leading to tooth loss, compared to those who keep the blood sugar within normal limits (Lamster, Lalla, Borgnakke, & Taylor, 2008; Mealey & Rose, 2008).

Dental practice offers a good setting for the chance discovery of patient’s medical problems as they are extremely likely to encounter asymptomatic patients with undiagnosed DM and pre-diabetes (Beikler, Kuczek, Petersilka, & Flemmig, 2002). Until now, very little is known as to how well OHP incorporate into practice on the evidence supporting the link between periodontal disease and systemic diseases. With the close link between DM and periodontal disease, dentists have an unrealized opportunity to identify risk groups and refer them to physicians for further evaluation and care (E. Lalla, C. Kunzel, S. Burkett, B. Cheng, & I. B. Lamster, 2011).

Dentists are also in a favourable position to screen medical conditions since many systemic conditions have oral manifestation. The dental education curriculum includes medical condition of importance to dentistry. Periodontitis was suggested to be included as the sixth complication of DM (Löe, 1993). Dentists can diagnose and relate periodontal disease and other oral manifestation of DM that many physicians may find it less familiar and difficult to relate to. Blood samples required to test blood glucose may also be obtained within the mouth from the gingival crevicular area during routine periodontal examination. This gives a unique opportunity for OHP in screening for DM. Other advantages include previous experience of treating patients with medical condition that puts OHP in a bright spot for screening systemic condition like DM and CVD.

But in reality, this untapped opportunity to identify asymptomatic medical condition is not being utilized to the full potential by OHP. Even though OHP get information on patient’s serum glucose and cholesterol levels, it is not found to be a routine for them to check patient blood pressure or screening for DM in the dental setting (M. Glick, 2002a). There would be no contraindication to performing such procedures if the information gathered can be used to establish presence or risk of systemic diseases that may impact oral health treatment and
facilitate referral to a qualified healthcare provider for early identification of the asymptomatic chronic diseases (M. Glick, 2002a; Strauss et al., 2010).

Achieving effective DM risk assessment in the general population may necessitate a multidisciplinary effort that includes health care providers from several disciplines to identify individuals at risk. Routine screenings performed by OHP can be extended to cover medical conditions such as DM (Sultan, Warreth, Fleming, & MacCarthy, 2014). This provides OHP with the opportunity to screen for medical condition among those who may not seek medical care otherwise.

The WHO and IDF have recommended that screening for early identification can improve on the longevity and quality of life by preventing or delaying the long-term complications with potential savings on the essential health care resources which otherwise may have to be spent on dealing with complications like hospital admission and length of stay (Charlton et al., 2008; World Health Organization, 2003). Despite, a lack of affirmative evidence on the benefit of screening for T2DM, treatment for IFG and IGT was found to delay progression to DM (M. I. Harris & Modan, 1994; Knowler, 1994; Selph et al., 2015; Siu, 2015).

The rationale for this recommendation comes from the fact that there is a long, latent, asymptomatic period in which the condition can be detected (Harris et al., 1992; Thompson et al., 1996). With the rise in prevalence (Guariguata et al., 2014; M. I. Harris & Eastman, 2000), a substantial proportion of people with T2DM are undiagnosed and complicated with microvascular disease at the time of presentation (Beagley, Guariguata, Weil, & Motala, 2014; Donnelly et al., 2000; Harris et al., 1992; Nazimek-Siewniak, Moczulski, & Grzeszczak, 2002; Rajala, Laakso, Qiao, & Keinanen-Kiukaanniemi, 1998; Wang, Ip, & Lam, 1998; A. Wright et al., 1998). The evidence is supportive of early intervention to control blood glucose, lipids and blood pressure in the prevention and delay of complications. Such efforts had resulted in a substantial decline in early mortality (Charlton et al., 2008; Ohkubo et al., 1995; UKPDS, 1998).
Some studies have identified screening for undiagnosed T2DM or pre-diabetes to be cost-effective and valuable only when it is used on high-risk groups (Andrei Barasch et al., 2012; Dye & Genco, 2012). While some claim that targeted medical screening in the dental setting may be effective in identifying those individuals that are unaware of their risk of developing DM, CVD, HIV and are not regularly engaged with their health care provider, screening (M. Glick & Greenberg, 2005; Jontell & Glick, 2009; E. Lalla, C. Kunzel, S. Burkett, B. Cheng, & I. Lamster, 2011) for DM can be combined with cardiovascular associated events and hypertension since dental setting provides an ideal opportunity to combine and screening associated risk actors together (Sultan et al., 2014).

Because early detection and timely intervention may reduce the disease burden, the American Diabetes Association (ADA) recommends opportunistic screening in routine clinical practice and other health care settings (Ealovega, Tabaei, Brandle, Burke, & Herman, 2004). Periodic opportunistic screening of high-risk individuals as part of ongoing medical care is suggested to be beneficial since population, and selective screening has demonstrated low yield, poor follow-up, high operational cost and potential for resource wastage (Engelgau, Narayan, & Herman, 2000).

By stretching the number of contact points between health care providers and individuals seeking care, there is plenty of opportunity for early detection of asymptomatic individuals at risk of DM. Shared responsibility for early identification will also lessen some of the load imposed on the medical community. In this context, the dental setting offers all that is required for DM and associated risk factor screening (E Lalla et al., 2011). The DM risk calculator and other devices used in the dental setting does help to identify risk groups but not reliable enough for confirmative diagnosis. OHP has a duty of care for referral of test positive patients to their physician, but their roles do not go further in making a diagnosis as they are not covered medico-legally to make such judgment (Sultan et al., 2014).

Michael Glick in the editorial mentioned the one-stop shopping that embraces expanded scope of services provided in the dental setting that include screening for medical conditions (Michael Glick, 2007). For example, Glick and Greenberg applied the Framingham-based risk
calculation scoring system to a sample of subjects with no previous history of coronary heart disease but visited an oral health care provider and not a GP in the previous 12 months. The study identified 18% of male subjects were identified to be at increased risk of experiencing CVD in future (M. Glick & Greenberg, 2005).

A recent field trial, utilising invasive and non-invasive risk test carried out for screening DM in different dental settings in Rhodes Island, had identified little over 12% of patient diagnosed with DM and another 23% at high risk of developing the disease among the 45 year and older patients, who were unaware of the DM status at the time of presentation but later diagnosed with DM (within a year of follow up) and pre-diabetes (R. J. Genco et al., 2014).

There are four different methods used for screening DM; 1. FPG, 2. Oral Glucose Tolerance Test (OGTT), 3. Random Blood Glucose (RBG), and, 4. Glycosylated haemoglobin A1c (HbA1c). RBG and HbA1c are more feasible in the dental setting since they do not require the patient to fast for DM screening. HbA1c essentially records the level of glucose bound to haemoglobin in the previous three months. Recently the ADA advocated HbA1c as the gold standard test for screening DM (Consensus Committee, 2007). Some studies have identified laboratory HbA1c using gingival crevicular blood having sensitivity and specificity correlation similar to that of fingerstick blood, hence suggest both are most appropriate measurement to use (Strauss et al., 2012). But measuring HbA1c is more expensive and time-consuming that erodes some of its advantages (Sultan et al., 2014).

Parker and colleagues in 1993, identified comparable results that had a strong correlation between gingival crevicular blood glucose and finger-prick blood glucose when analysed using the self-monitoring blood glucose device (Parker, Rapley, Isley, Spencer, & Killoy, 1993). This lead to considerable interest in measuring blood glucose pain-free and non-invasive (Kost, Mitragotri, Gabbay, Pishko, & Langer, 2000) but the search lead to no significant improvement in routine clinical practice (D. C. Klonoff, 1997). The earliest study to utilize gingival crevicular blood in the dental setting to identify the risk of DM among patients was proposed in 2002 by a group of German investigators(Beikler et al., 2002). Drawing blood from the gingival crevicular area was considered to less traumatic to the patient when compared to finger
puncture with a sharp lancet. This study substantiated previous findings of Parket and colleagues with comparable measurements and correlation. Other advantages include a small amount of blood in the range between 0.3 to 0.6 ml required for self-monitoring device (Beikler et al., 2002; Garton & Ford, 2012). Since many US state dental board do not approve dentist performing finger stick for the screening of DM, gingival crevicular blood was regarded as a viable alternative to finger stick (Sultan et al., 2014).

1.4.1 Oral systemic complication

Despite supporting evidence that demonstrates periodontal disease as an early complication of DM, it is yet unclear if periodontal disease is a predictor for incident DM (Demmer et al., 2008; Ide, Hoshuyama, Wilson, Takahashi, & Higashi, 2011). However, pre-existing periodontal disease predicts poor cardiovascular and renal outcomes in patients with established DM (Saremi et al., 2005; Shultis et al., 2007).

Even with supporting evidence of a link between DM and periodontal disease only 10 of 852 general dental practice and 268 specialist practice of Dental Practice-Based Research Network routinely screened for DM even in patients at high risk of developing the disease (Andrei Barasch et al., 2012). Barasch and colleagues identified that more than 98% of the practices in the US and Sweden confirmed that they have no onsite blood glucose monitoring device. The T2DM screening in that study was conducted by the Dental Practice-Based Research Network, and this is the largest of its kind covering a wider geographic distribution. It also identified that testing blood glucose levels do not seem to be a widespread practice in dental offices in the US and Sweden. Nevertheless, the findings from this study should be regarded as a step towards implementing DM screening in the dental setting because of the possibility for identifying undiagnosed DM or pre-diabetes that may be a cost-effective strategy (A. Barasch et al., 2012).

1.4.2 Dental visits

The overall dental attendance pattern in Australia is largely in line with the US and other industrialised nations around the world (Australian Institute of Health and Welfare, 2014; Centers for Disease Control and Prevention, 2008; Special Eurobarometer 330/Wave 72.3 –
TNS Opinion & Social, 2010; US Department of Health Human Services, 2010). The “Australian Research Centre for Population Oral Health” (ARCPOH) regularly updates oral health care in Australia and is indexed in the Australian Institute of Health and Welfare. In 2013, 63% of Australians, 25 years and over, had visited a dentist at least once in the last 12 months and 83.5% of males and 85.1% of females of all age groups visited a private dental practice. Most patients visit their dentists on a regular basis for routine and preventive oral care but see their physicians when they exhibit physical signs and symptoms (Glick & Greenberg, 2005). Such findings give oral health care professionals a favourable position to investigate for underlying medical conditions in the dental setting and a referral to the physician.

1.4.3 Screening in the dental setting using risk assessment tool

The use of a diabetes risk assessment tool or questionnaire in the dental setting had been reported in 13 studies. Table 1.1 summarises the study characteristics with the type of diabetes risk assessment tool used. Eight studies were from the United States, two from the UK, one from Turkey and Australia. One other study used samples from two different countries (US and Sweden). All the studies except for two (Bould, Scott, Dunne, & Asimakopoulou, 2017; Wright, Muirhead, Weston-Price, & Fortune, 2014) used Point-of-Care (PoC) blood glucose estimation along with the diabetes risk assessment questionnaire. Three of the 12 studies did not include the number of screened positives with the diabetes risk assessment questionnaire. Nine of the 13 studies had used a validated risk assessment tool or questionnaire. Of which three (Barasch et al., 2013; Genco et al., 2014b; Giblin, Rainchuso, & Rothman, 2016) used the ADA – Risk Questionnaire (ADA -RQ), two (Akyil, Miloglu, Olgun, & Bayrakdar, 2014; Bould et al., 2017) used the Finnish Diabetes Risk Score (FINDRISC) and the remaining four used one of the Heikes or NICE or NHANES or AUSDRISK diabetes risk scores. Of the 13 reported studies, only two used it as a pre-requisite for risk stratification to be eligible for screening with the index test (Franck, Stolberg, Bilich, & Payne, 2014; Rogers, Pawlak, Law, Carroll, & Sharp, 2017).
<table>
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<th>year</th>
<th>Country</th>
<th>Age</th>
<th>Screening strategy (PoC)</th>
<th>Risk test</th>
<th>Blood test</th>
<th>OGTT</th>
<th>GP/ hospital attended</th>
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<td>436</td>
<td>110</td>
<td>208</td>
</tr>
<tr>
<td>Strauss (Strauss et al., 2012)</td>
<td>2012</td>
<td>USA</td>
<td>23–87</td>
<td>NSQD–HbA1c + GCB</td>
<td>n/a</td>
<td>46</td>
<td></td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Herman (Herman, Taylor, Jacobson, Burke, &amp; Brown, 2015)</td>
<td>2015</td>
<td>USA</td>
<td>≥ 30</td>
<td>DRQ–RBG (F)</td>
<td>1033</td>
<td>n/a</td>
<td>1033</td>
<td>354</td>
<td>100</td>
</tr>
<tr>
<td>Giblin (Giblin, Rainchuso, &amp; Rothman, 2016)</td>
<td>2016</td>
<td>USA</td>
<td>≥ 18</td>
<td>ADA-RQ–HbA1c</td>
<td>154</td>
<td>64</td>
<td>41</td>
<td>25</td>
<td>-</td>
</tr>
<tr>
<td>Mulligan (Mulligan, Lipson, &amp; Heaton, 1990)</td>
<td>1990</td>
<td>USA</td>
<td>≥ 65</td>
<td>DRQ–FBG</td>
<td>n/a</td>
<td>n/a</td>
<td>73</td>
<td>n/a</td>
<td>8</td>
</tr>
<tr>
<td>Franck (Franck, Stolberg, Bilich, &amp; Payne, 2014)</td>
<td>2014</td>
<td>USA</td>
<td>&gt;19</td>
<td>Heikes–RBG–HbA1c</td>
<td>104</td>
<td>75</td>
<td>74</td>
<td>34</td>
<td>-</td>
</tr>
<tr>
<td>Barasch (Barasch et al., 2013)</td>
<td>2013</td>
<td>USA &amp; Sweden</td>
<td>&gt;19</td>
<td>ADA-RQ–RBG</td>
<td>491</td>
<td>418</td>
<td>418</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>Wright (D. Wright, Murthhead, Weston-Price, &amp; Fortune, 2014)</td>
<td>2014</td>
<td>UK</td>
<td>&gt;25</td>
<td>NICE–DRS</td>
<td>166</td>
<td>79</td>
<td></td>
<td>-</td>
<td>21</td>
</tr>
<tr>
<td>Genco (R. J. Genco et al., 2014)</td>
<td>2014</td>
<td>USA</td>
<td></td>
<td>ADA-RQ–HbA1c</td>
<td>1022</td>
<td>619</td>
<td>1017</td>
<td>416</td>
<td>146</td>
</tr>
<tr>
<td>Lalla (Lalla et al., 2013)</td>
<td>2013</td>
<td>USA</td>
<td>≥ 30</td>
<td>NSQD–HbA1c</td>
<td>591</td>
<td>275</td>
<td>51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rogers (Rogers, Pawlak, Law, Carroll, &amp; Sharp, 2017)</td>
<td>2017</td>
<td>Australia</td>
<td>≥ 18</td>
<td>AUSDRISK–HbA1c</td>
<td>371</td>
<td>192</td>
<td>193</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

FINDRISC = Finnish diabetes risk score; FBG = Fasting blood glucose; OGTT = Oral glucose tolerance test; NSQD = Non structured diabetes questionnaire; DRQ = Diabetes risk questionnaire; ADA RQ = American diabetes association risk questionnaire; HbA1c = Glycated Haemoglobin; RBG = Random blood glucose; Perio = periodontal assessment, NICE-DRS = National Institute of Clinical Excellence diabetes Risk questionnaire, PoC point of care
1.4.4 Dentists knowledge attitude and practice towards diabetes screening

Despite a number of available studies on OHP behaviour in managing patients with systemic diseases (Forbes, Thomson, Kunzel, Lalla, & Lamster, 2008; C. Kunzel, E. Lalla, & I. Lamster, 2007) only a handful have assessed OHP knowledge and opinion on DM (D. W. Paquette, K. P. Bell, C. Phillips, S. Offenbacher, & R. S. Wilder, 2015). Studies conducted by Kunzel in the northeast of the US identified significant differences in the level of clinical management of patients with DM. The reason for this difference is largely due to many of the referral patients were complicated with different severity of DM (Carol Kunzel, Evanthia Lalla, & Ira Lamster, 2007).

With the rapid progress in medical science, physicians find it difficult to cope with new research findings and integrate into practice. Studies have identified clinicians take several years to change behaviour and employ new evidence to change existing practice (Limbert & Lamb, 2002). In 1989, a study that compared self-reported and actual behaviour among clinician’s attitude towards caesarean section identified a vast majority of gynaecologist expressed agreement towards the new guidelines introduced two years prior and claimed to have reduced the number of caesarean sections performed. But in reality, the number of caesarean sections carried out only went up against the expressed views and attitude in clinical practice (Lomas et al., 1989).

Clinical guidelines were introduced to overcome some of these limitations, but clinicians often found it difficult to implement them into their routine practice.(Mittman, Tonesk, & Jacobson, 1992). One important reason for the slow uptake of new medical procedures is due to the vast number of sources in which research findings get published. There are several studies on behavioural change in patients and consumers, but that of the clinicians were very limited (Perkins et al., 2007). To date, very few had explored the factors that were considered important to clinicians in their decision making process to accept or comply with any particular clinical guideline (Limbert & Lamb, 2002).
In an attempt to predict behaviour several psychological models were developed and the model that has found an established niche is the Theory of Planned Behaviour. This model is an extension of the Theory of Reasoned Action (Ajzen & Fishbein, 1980), with the addition of the perceived behavioural control measure. This model has performed well against others in predicting clinicians intentions to follow certain clinical recommendations (Limbert & Lamb, 2002). With the limited number of studies available the theory for planned behaviour model has good backing for applicability in understanding clinicians behaviour (Perkins et al., 2007).

According to this theory, knowledge, attitudes and beliefs are strong predictors of intentions and intention predicting behaviour forms the fundamental of these theories (Limbert & Lamb, 2002; Perkins et al., 2007; Walker, Grimshaw, & Armstrong, 2001). Studies among a variety of health care providers including dentist show clear evidence of these theories translating into practice (Edwards et al., 2001; Greenberg, Glick, Frantsve-Hawley, & Kantor, 2010; Limbert & Lamb, 2002; Walker et al., 2001). Therefore, to effectively promote chairside medical screening by OHP, one needs to understand their knowledge, attitudes and perceived barriers in implementing this strategy.

A survey of practicing OHP in the US that assessed the attitudes, acceptance and perceived barriers towards screening for medical conditions in the dental setting identified an overwhelming majority of 69 to 86% expressed their willing to perform chairside screening for the specific medical conditions like CVD, DM, hypertension, HIV and hepatitis infection (Greenberg et al., 2010). More region-specific studies in North Carolina identified a high proportion of dentist aware of the relationship between oral health and systemic diseases. Yet, they reported feeling less comfortable and less willing to participate in the active management of patients’ systemic conditions that include counselling for risk behaviours, referral for further investigation, or in-office diagnostic screening for systemic diseases (Paquette, Bell, Phillips, Offenbacher, & Wilder, 2015). Barasch et al. (2009) identified several dental practitioners regard blood glucose testing to be outside their scope of practice, and only a few dental practices own or use a glucometer (A. Barasch et al., 2012).
To date, little is known about OHP KAP towards identification, management and referral of medical conditions of importance to dentistry, in Australia. Without the participation of the OHP screening for T2DM cannot be integrated as a mainstream approach in the dental setting.

1.5 Economic evaluation in health care

In financially constrained health systems around the world, increasing attention is being placed on the ability to demonstrate that healthcare interventions are not only clinically effective but also cost-effective. Health care workers are under pressure to adopt more cost-effective treatment practices because of the emphasis being put forth by the major third-party payers, government, and others in the business. Treatment that provided the greatest benefit per unit cost had gained more interest in the healthcare sector to demonstrate efficiency in resource management. It has become increasingly important that alternative interventions are compared to determine if they may increase effectiveness. Economic evaluation provides a complete consideration of the value of intervention including a thorough picture of benefit can be acquired at varying costs. With the ever-increasing health care cost, consideration of the benefit is pivotal for screening. Economic evaluation is increasingly used to help in the allocation of scarce health resource.

In health care, economic evaluation systematically analyse and considers all costs and outcomes associated with an interventions (Drummond, Sculpher, et al. 2005) and have been widely used in health care policy that assess disease prevention programs like vaccination, screening, and several other health promotion activities that include screen diagnosis or medical (drug or surgical) interventions.

The origin of the discipline “Health Economics” can be traced back to the 17th century when William Petty FRS (1623–1687) an English economist, analyst and philosopher, and one of the founding member of the Royal Society, noted for his contribution towards valuing human life based on contribution to national growth (Fein, 1980). Petty was known at the time of the great bubonic plague in Britain when he arrived at a monetary value and calling it as excellent
financial investment had people left London during the major epidemic (Mills, 2014; Petty, 1927).

Edwin Chadwick, a social reformer and notable public health pioneers known for his work on human capital, influenced health care legislation in the early part of the nineteenth century. Chadwick positioned his viewpoint on disease prevention to offer a greater benefit than investing in hospitals that essentially treat diseases (Chadwick, 1862; Morley, 2007).

In the low and middle-income countries, some of the earliest literature on HE reflects how disease impact the society and the nation as a whole, especially the literature on malaria. British medical doctor and malariologist, John Alexander Sinton in 1935 sought to quantify the economic cost, for example calculating the cost of treatment and days of work lost due to malaria (Sinton, 1935) and noting that the risk of malaria could inhibit the exploitation of fertile land (Ketterer, 1953). Such evidence expanded the scope of malaria eradication efforts in the 1950s and 1960s.

The development of HE as a discipline is usually credited to Nobel Laureate Kenneth Arrow (Arrow, 1963). Arrow wrote a seminal paper differentiating the characteristics of medical care market to that of goods and services. Also, he made explicit reference as to why private markets might fail in the provision of health care or health cover through insurance.

1.5.1 Direct costs

Treating DM and related complication had cost 232 billion US dollars in 2007, globally. This figure is expected to reach as much as 302 billion by 2025. A big portion of this money (80%) is spent in a few wealthy countries. Majority of the global DM is present in low and middle-income countries but very little is being spent on treating DM and related condition (Kozak, Tjota, & Close, 2012)
The costs of macrovascular complications among people with DM is three times higher compared to those without macrovascular complications. Further, the difference in the cost can reach up to seven times compared to those without DM. Patient care and pharmacy expenditure are all higher in patients with T2DM. Inpatient cost, in particular, is the main drive among those with macrovascular diseases while medication cost forms the major component within (Gandra et al., 2006; Nichols & Brown, 2002). Among those with DM, the cost for microvascular complications is approximately two times more to that of those with no microvascular complications. Overall, people with microvascular complications use more oral antidiabetic medication, insulin, longer hospital stay and outpatient visits (Pelletier, Shim, Ben-Joseph, & Caro, 2009).

1.5.2 **Indirect cost**

Studies have suggested around 65% of cases of T2DM are due to being overweight or obese (Bray, 2004; Hart, Hole, Lawlor, & Davey Smith, 2007). DM and related conditions increase productivity loss by work-related absenteeism creating a substantial economic burden.

Loss of productivity can be measured using absenteeism (time lost from work due to illness), presentism (time at work impaired due to illness) or the combination of both that include time lost from work due to illness in addition to reduced efficiency at work due to impairment. All of these contribute towards early retirement. A recent systematic review investigating the impact of DM on the ability to work outcomes identified days lost annually from work per employee ranged between 5.4 and 18.1 days for people with DM compared to 3.4 to 8.7 for those without DM. Among those with a combination of DM and depression, the number of days lost due to illness was 78.5 days. Overall, absenteeism from work was two to 10 days more annually for people with DM compared to those without DM (Breton et al., 2013). Other indirect cost includes reduced quality of life and life expectancy. In the UK, life expectancy among people with DM is reduced by 10 years (Roberts, 2006).
1.5.3 Type of economic evaluation

There are four different methods of economic evaluation: cost-minimization, cost-effectiveness, cost-utility, and cost-benefit. In all economic evaluation, costs in a common format measured in monetary units (dollars), but each evaluation types differ in the way they measure outcomes or benefits. These differences play a pivotal role in formulating criteria for effectiveness (Drummond, Sculpher, Claxton, Stoddart, & Torrance, 2015; Robinson, 1993).

Cost-minimization analysis

Economic evaluation sometimes referred to in the literature as cost minimization analysis. This analysis can be performed in two or more alternatives under consideration achieve the given outcomes to the same extent, then the difference in cost between alternative can be measured. This type of cost evaluation is often used in evaluating the cost of a specific treatment when two drugs have similar therapeutic effect at an equivalent dosage. However, it is not appropriate to view cost minimization analysis as a form of full economic evaluation (Drummond et al., 2015).

Cost-effectiveness analysis

Cost-effectiveness analysis is an idea that can be traced back to an article by nineteenth-century French economist Jules Dupuit (1804-1866) (Numa, 2016). The kinds of projects for which benefit-cost analyses may be conducted include highways, training programs, and healthcare systems. This term was later embraced by economists during the 1950s.

The analysis where the costs are associated with a single common effect that may differ in magnitude between alternative programs is usually referred to as cost-effectiveness analysis. The cost and effectiveness are not measured in comparable units. However, their ratio provides a benchmark with which relative (productive) efficiency can be assessed (Phelps & Mushlin, 1991). Cost is measured in monetary values, effectiveness is considered independently as clinical outcome such as lives saved, complications prevented, or diseases cured. When the outcomes are associated with costs, a ratio (known as a cost-effectiveness ratio) of the net
change in costs divided by the net change in outcomes can be determined. The net difference in costs reflects the additional expenditure required to achieve the variance in the outcome (such as life years gained), where the ratio is expressed as the cost per outcome gained, such as the cost per life year gained or the cost per life saved (Higgins & Harris, 2012). The results of such an analysis can be stated as incremental cost per unit of effect or effects per unit of cost (life years gained per dollar spent) (Drummond et al., 2015). Cost-effectiveness analysis is most useful in a situation where a decision maker, operating at a fixed budget, is contemplating a limited range of options within a given field (Drummond et al., 2015). Such an analysis provides little allowance in evaluating the relative effectiveness of interventions that measure higher benefits at greater cost or lesser benefit at a lower cost (Birch & Gafni, 1992).

The biggest limitation of cost-effectiveness analysis is that it is difficult to assess the opportunity cost (benefits foregone) because of the specific measure of effect used in evaluating a given treatment programme. In other words, this analysis is not suitable for comparing interventions with differing natural effects (Drummond et al., 2015). For example, interventions that aim at life years gain as outcome cannot be reliably compared to those that improve physical functioning (Palmer, Byford, & Raftery, 1999). Hence, allocative efficiency cannot be directly added by cost-effectiveness analysis (Birch & Gafni, 1992).

Cost-utility Analysis

Cost-utility analysis is essentially a variant of cost-effectiveness analysis and now represent the most widely published form of economic evaluation. The only difference to cost-effectiveness analysis is that they use, for the consequences, a generic measure of health gain., this offers the potential to compare programmes in different areas of healthcare such as treatment of heart disease and cancer, and to assess the opportunity cost (on the budget) of adopting programmes (Drummond et al., 2015). The generic outcome usually measured as Quality Adjusted Life Years (QALY). In general, utilities can range from 0 (equivalent to death) to 1 (equivalent to full health) (Drummond et al., 2015). Cost-utility analysis measure intervention effect on both qualitative and quantitative aspect of health namely morbidity and mortality using a utility-based measure such as QALY (Torrance, 1986). QALY is obtained by multiplying the number of life-years gained to utility value. Utility values refer to the
preferences given to a particular set of health outcomes given by an individual or society. Other outcome measures such as Healthy Years Equivalent (Mehrez & Gafni, 1989), the Disability Adjusted Life Years (DALY) (Edejer et al., 2003), and the Saved Young Life Equivalent (Nord, 1995) have been proposed as alternatives to the QALY. An intervention is considered productively efficient when the outcome results in higher (or equal) benefit at a considerably lower cost. In the cost-utility analysis, the optimal decision rule involves ranking the incremental cost-utility ratio of more than one interventions and selecting the one with the lowest ratios (best value) until the budget is curtailed (M. Weinstein & Zeckhauser, 1973; M. C. Weinstein & Stason, 1977). With the use of a single measure to record health benefit, several healthcare interventions can be compared. Cost-utility analysis can address both productive and allocative efficiency (Palmer et al., 1999). The advantage of cost-utility analysis is that they permit comparison of several interventions across a variety of disease states to determine interventions that result in a larger gain for a given cost (Higgins & Harris, 2012).

**Cost-benefit Analysis**

This type of analysis has a long track record on areas of economic analysis other than health sectors like transport and environment (Drummond et al., 2015). In this analysis both the cost and benefits are measured in monetary units. All the cost is added up and subtracted from the monetary value of the outcome when the resulting total is positive; then the potential benefits outweigh the cost, then the intervention is favoured. As with the cost-utility analysis, the use of the decimal system (metric) of measurement enables comparison between studies that evaluate different outcomes or interventions, such as extending life, in monetary terms. Objections to valuing health benefits in monetary terms and practical measurement difficulties have limited the use of cost benefit analysis in health care. However, recent approaches using the concept of “willingness to pay and social capital” have renewed interest in this type of analysis (Higgins & Harris, 2012; Palmer et al., 1999).

**1.5.4 Perspective in economic evaluation**

Before undertaking an economic evaluation, the study perspective should be determined. Economic evaluation of health can be performed from different perceptive. The perspective is
the point of view adopted when deciding which type of costs and health benefits will be included in the economic evaluation. The choice of perspective is the major determinant of the cost and outcomes that need to be considered in the analysis. The perspective can be from the much narrower approach of the patient alone and their families, public sector/government health care system or the society. The societal perspective is the most appropriate as it includes all the cost and consequences of anyone who pays the cost or who incurs the benefits. (Green, Emneus, Christiansen, & Björk, 2005; Polimeni, Vichansavakul, Iorgulescu, & Chandrasekara, 2013).

1.5.5 Time horizon

In economic evaluation of health care intervention time is an important factor to consider since intervention and consequences affect estimated costs and effects. These issues should be reflected in the health care economic model. Time horizon is the period over which the costs and the effect of alternative options being compared might be expected to differ. Often the appropriate time horizon will be patients life time in the case of chronic disease, but clinical studies do not follow all patients up until they die. An important role of decision models is to bridge the gap between what has been observed in trials and what would be expected to happen in terms of cost and effect over a long-term time horizon. It is often necessary to extrapolate when the options being compared differ in term of mortality, and this difference is to be expressed in terms of life years or QALY gained. The use of modelling to extrapolate beyond the follow up period in the clinical study involves predicting what the survival curves will look like beyond what has been observed (Benbassat & Baumal, 2007).

1.5.6 Modelling in health economics

In health economic evaluation, models are typically used in two situations. Firstly, when a clinical trial was proposed and yet to commence and did not capture relevant economic data, then a decision analytic models can be used to synthesize the best available data. Secondly, when clinical trials measure intermediate endpoint where mathematical models are employed to extrapolate beyond the trial endpoints such as disease progression or survival (Buxton et al., 1997).
Uses of modelling

1. Extrapolating beyond the data observed in a trial: before undertaking a modelling study, previous clinical trial as a source of reliable data of effectiveness of health care intervention should be looked at. Although clinical trials provide comparative data with less confounding, they are often constrained in terms of the range of outcome collected, or the length of follow-up. In such situations, economists will need to extrapolate beyond the period observed in the clinical trial. This is because ‘life years saved’ is a much more relevant outcome measure compared to the percentage of patients surviving a few days or weeks (Buxton et al., 1997).

2. Linking intermediate clinical endpoints to final outcomes: In chronic disease, the consequence of disease can take several years to manifest and clinical trials often assess effectiveness at the intermediate endpoint. Cholesterol management and osteoporosis are good examples where the impact can be measured with changes in lipid profile or bone mineral density. In such situation comparison between therapies can be assessed in terms of incremental cost per percentage change(Logan, Milne, Achber, Campbell, & Haynes, 1981). Results from the intermediate endpoint may not reflect well in the long-term outcome as it the case of some chronic disease like hypertension. A therapy for lowering blood pressure may be twice effective, but a linear relationship between blood pressure reduction and the number of morbid events such as strokes is not proven (Buxton et al., 1997).

3. Generalizing to other settings: it is desirable that the economic evaluation is generalisable in all settings. There are two aspects of generalising the findings. Firstly, generalizing from trials to regular practice and generalizing from place to place. For example, an economic evaluation of a drug trial can give varying results based on the compliance of patients taking the medication in steady state clinical setting and adjustments are often made through a decision tree to factor in the varying compliance issues. Secondly, resources in terms of cost for therapy, clinical management and hospitalization period would vary between countries and can give varying results. For example, the diagnostic and hospital admission criteria may vary between countries.
1.6 Literature on health economics

As with DM, some controversy still exists towards the economic justification of screening, despite its questionable benefit in reducing the morbidity and mortality (Engelgau et al., 2000). With early identification of people with undiagnosed or pre-diabetes, they could better control their conditions and experience better health outcomes. Early recognition and intervention delay the disease progression at a reduced cost compared to the cost of treating illness related to late diagnosis. Therefore, utilization of health services, such as hospital and emergency department visits, can be reduced, thus decreasing overall healthcare expenses. The benefits of having additional years of life gained or improved quality of life may well be a stronger defense to offset the lifetime cost of screening and early treatment (CDC Diabetes Cost-Effectiveness Study Group, 1998).

1.6.1 Economic evaluation of diabetes screening in the medical setting

One of the earliest studies that estimated the cost-effectiveness of T2DM screening used computer simulation models to identify lifetime cost and benefit of one-time opportunistic screening, compared with current clinical practice (CDC Diabetes Cost-Effectiveness Study Group, 1998). The incremental cost of opportunistic screening in those ≥ 25 years was estimated at US$ 236-449 per life years gained and US$ 56,649 per QALY gained. The cost per QALY gain for universal DM screening was lower for younger than for older people. This amounts to $13,376 at age 25 to 34 years, increasing to $116,908 at age 55 to 64 years. The modelling study obtained data from clinical trials, epidemiological studies, and population surveys and a single payer perspective was assumed for the analysis. This study concludes that opportunistic screening of T2DM may reduce the lifetime incidence of microvascular complication and results in a gain in both life years and QALY (CDC Diabetes Cost-Effectiveness Study Group, 1998; T. Hoerger et al., 2004). The limitation of this study is this study model utilized findings from T1DM and made a projection for the microvascular complication of T2DM.

FPG remained the gold standard for screening and diagnosing DM and IGT until the end of the 20th century, but there were practical difficulties of having the subjects to fast for measuring
the plasma glucose in the community or work site. One of the earliest studies to look at alternative indicators to perform a cost-effectiveness analysis for DM screening was done in 1994. The purpose of economic evaluation in this study was to clarify the second-best indicator to the FPG test. The alternative indicators used in this study utilized 1,5-anhydroglucitol, HbA1c, and Fructosamine as screening tests to perform the economic evaluation. This study identified Fructosamine to be the most cost effective compared to the other two. However, 1,5-anhydroglucitol and HbA1c were identified to show larger effectiveness compared to Fructosamine (Shirasaya et al., 1999).

A large-scale US study estimated the cost of screening for pre-diabetes in the 45-74-year-old adults comparing five different strategies namely OGTT, FPG, HbA1c, capillary blood glucose and a risk assessment questionnaire. It estimated the cost per case identified between US$ 176 to 332 and screening with OGTT was the most effective. However, capillary blood glucose test and risk assessment questionnaire were found to be most efficient. The study concluded that a trade-off would need to be reached between effectiveness and efficiency, where identifying more cases or reducing the cost per case need to be determined (P. Zhang et al., 2003).

One of the serious limitations of all economic evaluation studies done on T2DM before the turn of the century was, they all failed to factor in the incremental cost-effectiveness. For a meaningful comparison, it is necessary to examine the additional cost that one service or cost imposes on other (Drummond et al., 2015). The Cooperative Health Research in the Region of Augsburg (KORA) survey conducted in Germany was the first of its kind to use the incremental cost-effectiveness ratio (ICER) in the screening of T2DM (Icks et al., 2004). This study compared four strategies but with a combination of one of three tests namely (Fasting Blood Glucose, OGTT, and HbA1c). Apart from the initial test, an OGTT was performed in follow-up subjects with borderline results. The study subjects were 55 to 74 years’ men and women not previously diagnosed with DM in the last one year. The main outcome measure includes screening cost, number of newly detected true positive cases compared to the whole screening population, and the ICERs. A decision analytic model was used to measure the cost-effectiveness of different screening procedures(Icks et al., 2004).
The KORA study identified OGTT from the health insurance perspective to involve the lowest cost (€4.90 per patient) compared to others. OGTT combined with Fasting Blood Glucose (FBG) incurred the lowest from the societal perspective (€10.85). But both of these screening strategies detected only one third and one-fourth of subjects with previously undiagnosed DM. In contrast, HbA1c followed by OGTT in those who had an elevated HbA1c was the most effective with more than half (54%) of all case detected but was also the most expensive with a cost of €21.44 and €31.77. High detection rate with HbA1c group followed by OGTT is due to complete participation of all subjects. This again is due to the very reason of not requiring a special visit but at one of the scheduled appointments to the physician (Icks et al., 2004).

Despite the lower cost of identified with screening in the KORA study compared to a study done in the US it became problematic to translate results from one country to that of others since cost-effectiveness ratio largely depends on unit costs and purchasing power parities are difficult to adjust for differences in unit costs. Despite all the issues, one of the significant findings of this study is that HbA1c combined with OGTT is most effective, but also the most expensive, the findings were expected to be similar in few other countries irrespective of unit cost or purchasing power parities (Icks et al., 2004).

One other study that utilized data from the UKPDS and Hypertension Optimal Treatment trial, which is a multi-centric trial involving 26 countries, to estimate the incremental cost-effectiveness of screening for the diagnosis of T2DM targeted to people with hypertension and universal screening from a health care perspective identified that incremental cost-effectiveness ratios were more favorable when screening was targeted towards people with hypertension than to that of universal screening, at all ages. The results further identified that screening was more cost-effective when performed between 55 and 75 years of age than to that of the younger age group. The study concluded that targeted screening of those with a certain medical condition is more cost-effective than universal screening (T. J. Hoerger et al., 2004).

Hoerger and colleagues identified that the benefits of screening predominantly come from a reduction in coronary heart disease events by intensive control of hypertension rather with reduction of microvascular compilation such as end-stage renal disease or blindness by
intensive glycaemic control. The benefits of screening at the thirties are predominantly from decreasing end-stage renal disease since the risk of coronary heart disease events are uncommon in this age group. This study identified greater benefits of intensive control of hypertension at the age of fifties and sixties, and the benefits are realized much sooner than are the benefits of intensive glycaemic control (R. P. Harris et al., 2003; T. J. Hoerger et al., 2004). Although this study failed to demonstrate any reduction in microvascular complication, it did identify a substantial reduction in hypertension-related adverse events with the intensive control of hypertension initiated following the screening.

A systematic review conducted in 2003 on the economics of T2DM arrived at many conclusions (Raikou and McGuire, 2003). By far the most important assumptions made through this review was, intensive treatment for T2DM compared to conservative treatment appeared to be cost-effective. Also, primary prevention of T2DM was identified to be to be cost effective particularly in high-risk groups. The opportunistic screening was identified to be more effective but may prove to have a lower cost-effectiveness ratio for younger age group compared to existing standard policies that tend to implement screening programmes in those over 45 years of age (Raikou and McGuire, 2003).

The UK, Health Technology Assessment (HTA) programme, now part of the National Institute for Health Research (NIHR), provides high-quality research findings on the cost, effectiveness, impact of health technology on those who use, manage and provide care in the National Health Service (NHS). Research undertaken by HTA is used to influence decision making bodies such as the National Institute for Health and Clinical Excellence (NICE) and the National Screening Committee (National Institute for Health Research, 2017).

An HTA literature review and economic modeling conducted in 2005 (Waugh et al., 2007a) and published in 2007 concluded that screening for T2DM to be beneficial because of the greater possibility for CVD risk reduction, primarily with the use of statins, and because of the rising prevalence of obesity and hence T2DM (Waugh et al., 2007b). The study also identified that screening for IGT is a valuable option since it can prevent people from developing or delay the onset of DM and reducing CVD complication and concluded that population screening for
T2DM is worth the effort because of the greater possibility of reduction in CVD with the use of statins and the addressing the rising prevalence of obesity and T2DM (Waugh et al., 2007b). Further research is needed on the duration of undiagnosed DM before being clinically identified without screening. However, 4 to 7 years, as of now is now regarded as the average time period before being diagnosed clinically. The review also recommends further research in the natural history of IGT and what determined progression to DM (Waugh et al., 2007b).

The HTA made the suggestion that T2DM screening is cost-effective at 40–70-year age band. The study identified T2DM was cost-effective for the hypertensive and obese groups with 50–59 and 60–69-year being more cost-effective compared to the 40-49 age group. However, the study was unable to determine the appropriate screening interval due to insufficient data and recommend future research to address this issue. The pragmatic approach till then would be to screen risk factors at age 45 years, screen by BG in those who were risk-factor positive and then re-screen a random sample of BG-negative people at, say, 5 years as part of a research project (Waugh et al., 2007b).

The HTA recognized that only 12 of the 22 criteria set out by the National Screening Committee are met for screening T2DM. Three of the criteria are unmet and some uncertainty with another three. Four are not applicable for DM screening. By far, the most significant of this criterion is the criteria 13 which required evidence from high-quality RCT to identify if screening programme is effective in reducing mortality or morbidity (Waugh et al., 2007b). Having said that, The ADDITION Study is underway now, and this criterion is likely to be met when the inclusion of the results from that trial in the next HTA on T2DM screening. The ADDITION Study is an RCT of systematic screening and targeted cardiovascular risk reduction in primary care, being carried out in Cambridge, Denmark and the Netherlands (Lauritzen et al., 2000).

With the inclusion of the ADDITION trial in the 2013 HTA effectiveness review on T2DM screening, this criterion has been met. Although the ADDITION trial is not a trial for T2DM screening, it did address the important question “once diabetes has been diagnosed by screening, does intervention reduce cardiovascular morbidity and mortality?”. Despite an
overall but non-significant improvement in weight reduction, and systolic and diastolic blood pressure in the intensive treatment group, the ADDITION trial identified no difference among newly diagnosed diabetics in the incidence of cardiovascular events and all-cause mortality between the routine care and the intensive treatment arms. With this finding, the 2013 HTA effectiveness review concluded no evidence for universal screening for T2DM amongst persons aged > 40 years. In the western world, reduction in the proportion of undiagnosed DM between 20% and 30% from the traditional level of 50% (Diabetes Australia, 2018; Public Health England, 2015) is attributed to opportunistic screening in primary care (Pierce, Zaninotto, Steel, & Mindell, 2009; D. Simmons & Zgibor, 2017). The National Screening Committee recommend opportunistic screening as a viable option and value for money in these circumstances (Webb et al., 2011).

In Brazil, a large population screening strategy for the entire nation to diagnose DM was introduced in 2001, and it is also the first screening campaign of any kind for T2DM in Brazil. Adults 40 years and over were invited to participate. A capillary blood glucose screening test and a confirmatory diagnosis were offered. The initial impact of the program identified 3.4 million as test positive of the 22 million screen test performed, and 10.1% of that screen positive were diagnosed as new cases of DM (Toscano et al., 2008). The number of screening tests needed to detect one case of DM was 64, and the cost per case diagnosis is US$ 76. The cost per new case diagnosed was lower than previously reported. This study had several limitations. Since it’s a national program and first of its kind, there were mistakes in the way data were recorded. 2 of the 50 municipalities were excluded due to incomplete records in the analysis. Other difficulties experienced include a change of address and location of the subject in the less privileged settings of Brazil. The study does not rule out the possibility of an underestimate of true yield and thus overestimate of true cost per case identified as there was inadequate pre-campaign access to health care. Additionally, information regarding confirmatory testing and follow-up care were based on self-reports given by screening participants during interviews conducted one year later, rather than on actual confirmatory testing, leading to inaccuracies. Finally, the OGTT was rarely used for the diagnosis of DM in the clinical setting in Brazil in 2001, many cases of DM by isolated 2 h hyperglycemia were missed by the Campaign (Toscano et al., 2008)
A study published by Kahn and colleagues in 2010 used a mathematical model to address some of the issues, on the cost-effectiveness of sequential screening strategies to identify new cases of T2DM. This study compared eight simulated screening strategies along with no screening as a control group. The results showed all screening strategies for DM reduced the incidence of myocardial infarction and DM-related microvascular complications. The study also identified that screening prevented mortality (simulated as 5 death per 1000 people in the US) and improved the QALY. Five screening strategies had costs per QALY of less than US$10 500. When screening costs were calculated from the age of 45 years and repeated every year, it incurred a higher cost of $15 509. One other scenario where the screening was started at 60 years and repeated every 3 years has a QALY of $25 738. By far the highest was screening at six months’ interval from the age of 30 that incurred a cost of $40 778. The study concluded that screening for T2DM was cost-effective when started at the age of 30 to 45 years with screening repeated at three to five-year interval (R. Kahn et al., 2010).

A study conducted among Thai adults to compare the performance, cost, and cost-effectiveness of screening to identify individuals with IFG. The subjects (2977), 35 – 60 years of age, were recruited from annual health checkup with no prior history of abnormal fasting glucose. All subjects completed one of the four different screening questionnaires with a different set of items (questions) followed by FPG test. The results identified the total cost of screening per one newly detected case were US$ 59.12 to 69.62 in Thailand. This is one of the screening tests, and the results have a sensitivity range from 71 to 92%, while specificity was between 31 to 57%. Compared to the universal FPG, all screening methods using questionnaires were relatively more cost-effective, but differences were not significantly different (Srichang, Jiamjarasrangsri, Aekplakorn, & Supakankunti, 2011).

A Danish study (Dalsgaard et al., 2010) examined the costs of three different screening strategies for identification of T2DM in general practice. The cost to detect one case of glucose intolerance using random blood sugar or HbA1c in all those screened positive with the DM risk assessment questionnaire (Danish DM risk score) was € 536 for the mail-distributed approach; €229 and € 240 for out-patient-direct and out-patient-subsequent approaches, respectively. The cost of detecting one person with T2DM was € 1058 for the mail-distributed approach and € 707 and € 727 for OP-direct and OP-subsequent approaches respectively. The
results show that opportunistic screening identified cases with the lower number of individuals screened to detect one case, less number of consultations to detect one case and lower cost per person detected for T2DM. The study went further to conclude that the opportunistic screening test taken concomitantly with the actual consultation was better at detecting people with glucose intolerance than the mail-distributed or the out-patient subsequent approach. This study is not without limitations as it calculated the cost of screen positive per individual is based on one-time screening alone. Other limitations include, direct costs relating to the screening procedure and lifetime costs of treating individuals with T2DM were not considered (Dalsgaard et al., 2010).

A study published in 2012 to analyze the cost of opportunistic screening for T2DM in the UK general practice utilizing electronic medical records to determine the frequency of OGTT undertaken for non-pregnant adults without known DM over three consecutive years, identified an average cost per new screen-detected diagnosis was £377. This cost is based on FPG and oral glucose tolerance tests. One of the limitations of this study is that the screening was carried out in one single general practice and the policy adopted for opportunistic screening may not necessarily standardized with other general practices in other countries. Other limitations include non-standardised approach in the delivery of screening, variability in the implementation of a screening program with some practices in the ADDITION-Cambridge study, the cost analysis did not factor in the time spent by GPs in discussing the reasons for the test as it was assumed to be part of the routine clinical care. Indirect cost as with patient costs, as in many other programmes, were not measured in this study (Pereira Gray et al., 2012).

Another modeling study from the UK utilized cross-sectional data from ADDITION-Leicester, a population-based study on DM screening (Kamlesh Khunti et al., 2012). Although the ADDITION-Leicester was part of the larger multi-center ADDITION-Europe trial, it was used to construct the cost per case detected for several screening strategies for both T2DM alone and in combination with impaired glucose regulation for diagnosis of pre-diabetes. It estimated the costs per case identified for the 18 most sensitive strategies varied from £457 to £1639 (526–1886, for £1 = s1.15) for DM and £148–913 (170–1050) for both DM and impaired glucose regulation. The study concluded that screening a population using a non-invasive risk
stratification tool followed by a screening blood test was the most cost-effective method of screening T2DM and abnormal glucose tolerance (K. Khunti et al., 2012).

A Chinese modelling study estimated the clinical and economic consequences of screening for undiagnosed DM and pre-diabetes (Liu et al., 2013). The preventive strategies include one-off screening for undiagnosed DM and IGT, with lifestyle interventions that include diet, exercise and the combination of both in those with IGT. Compared to the control group, all the simulated screening approach prolonged life at every age of initiation between 25 and 40 years, delayed the onset of DM and increased the QALY. The savings were at least US $2017 per participant. However, the study identified no statistical significance was observed with different strategies in the group. The cost savings were reduced when screening was affected by poor performance and noncompliance. The study concluded that one-off screening for undiagnosed DM and IGT along with lifestyle interventions for those with IGT were cost saving in young adults (Liu et al., 2013).

Another Chinese study evaluated the performance and cost-effectiveness of two screening methods for identifying undiagnosed DM in primary care settings. The main economic outcome measures in this study were, the total cost of screening per 1000 persons, the proportion of undiagnosed DM detected, and cost per undiagnosed DM identified from the societal perspective (both direct and indirect cost were included). This study concluded that fasting capillary glucose test performed better than the Chinese Diabetes Risk score as a first-line screening tool in a primary care setting. All the screen positive subjects were further tested in the laboratory with either OGTT or HbA1c for confirmatory diagnosis. The study identified that the lay personalized, non-invasive diabetes risk score was feasible and detected more cases but was also identified to be more expensive. The average cost per case identified was US$ 96 for FCG and US$ 121 for diabetes risk score. The cost-effectiveness is for one-time screening and did not include long-term costs such as the cost of treating newly diagnosed cases or benefits of prevention (health-related quality of life). However, the best strategy will depend on the purpose of the screening; there is often a trade-off between more cases to detect or have a lower cost per case. When the results of the capillary blood glucose test in this study were compared with the study done in Brazil (Toscano et al., 2008), it was found to be having a higher cost per case diagnosed. However, the cost of laboratory tests and other indirect cost
vary across systems and countries, and it will be difficult to compare our results directly to that of others (Y. Zhang et al., 2013).

An HTA modeling analysis was conducted on the English population in the 40 -74 years’ age group to estimate and compare the cost-effectiveness of screening for T2DM using an HbA1c test versus FPG test. The results indicate that screening using an HbA1c test is more cost-effective than using an FPG. As per the NICE recommended screening strategies, a cost saving of £12 and QALY gain of 0.0220 per person is attained with HbA1c when a risk score is used prior to screening with blood samples. However, the cost savings is reduced significantly when the pre-test risk score was not utilized (£30 with a QALY gain of 0.0224). Sensitivity analysis indicates 98% for HbA1c with risk scores compared to 95% with no risk assessment prior to screening using the FPG. The study also identified that the DM risk score questionnaire (Leicester Practice Risk Score) recommended by NICE is more cost-effective than a random capillary glucose test for pre-screening. One of the limitations of this study is that the study analyzed the cost of one-time screening procedure (Gillett et al., 2015).

In Columbia, a study was conducted to compare the effectiveness and cost involved in the most commonly used schemes for screening and diagnosis of T2DM (Quitian et al., 2015). This study evaluated four different strategies with all involving the FBG but two with and two without previous screening with FINDRISC scale. The confirmatory diagnosis was established using HbA1c or OGTT. The strategy using FINRISC, FBG and OGTT reported a total cost of € 7,306 for identifying 969 cases compared to a cost of € 10,880 for identifying 983 cases using FBG and OGTT scheme. The study concluded that FINDRISC plus FBG test along with OGTT is the most appropriate strategy for screening and diagnosis of T2DM in Colombia (Quitian et al., 2015)

Most of the countries in the world will spend 5-13% of their healthcare budget in treating DM and related condition (Ping Zhang et al., 2010). Cost estimates from the recent systematic review recognized the annual direct global cost to be more than US$ 827 billion (Non Communicable Disease Risk Factor Collaboration, 2016; Seuring, Archangelidi, & Suhrcke, 2015). In the period 2003 to 2013, DM health care spending had increased more than three
times, this surge in the health expenditure is due to population growth, an increase in the average age of the population, and the rise in prevalence of DM at each age group (International Diabetes Federation, 2015).

1.6.2 Economic evaluation of diabetes screening in the dental setting.

To our knowledge, there is currently no literature, except for one (Neidell, Lamster, & Shearer, 2017), on economic evaluation of DM screening in the dental setting. This is because dentists do not screen for DM and the approach is novel and still in the experimental stage. The only available economic evaluation report (Neidell et al., 2017) on T2DM screening in the dental setting is a secondary analysis of data from two studies (Lalla et al., 2015; E Lalla et al., 2011) that used blood sugar estimation for identifying dental patients with undiagnosed diabetes. Of these two studies, one is essentially screening for DM and pre-diabetes in the dental setting, and the other used the rate of adherence for follow-up for medical care and weight loss programme for patients identified with dysglycaemia. The economic evaluation used the Archimedes disease simulation model to project the cost-effectiveness (Neidell et al., 2017). The cost was calculated based on the T2DM screening, medical follow-up and weight loss intervention for those identified to be in the pre-diabetes range. Based on these assumptions, the model produced a range of health outcomes. Two scenarios for weight loss were considered, one with a 10% permanent loss in body weight and another with a 10% loss that decay over time. The decay path identified a cost of $21,243 per QALY for 10% weight reduction over a three-year period. If the same weight reduction is to be achieved within a year time the cost per QALY reduced to $6,655. In the non-decay path, with 10 and 20 years of intervention, the cost per QALY was $647 and $15,873. This study identified that the weight loss intervention for pre-diabetes as cost-effective.
1.8 Bibliography


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DM is the fastest growing chronic condition in Australia (Diabetes Australia, 2018). It is estimated that 30% of Australian with diabetes are undiagnosed (Diabetes Australia, 2018). T2DM is by far the most common type and is asymptomatic in the initial stages. Some estimates suggest, affected individuals may be unaware of their disease status as long as 3.3 to 12 years before the clinical presentation (Harris, Klein, Welborn, & Knuiman, 1992; Rahman, Simmons, Hennings, Wareham, & Griffin, 2012). Early identification of those individuals by screening can delay or prevent the onset of T2DM with minimal complication.

In the WP region, Australia has the highest per capita spending on diabetes (US$7,652 to US$14,498) (International Diabetes Federation, 2015). The total annual cost of DM in Australia is estimated at 14.6 billion Australian Dollars (AUD) (Diabetes Australia, 2018). With the rising cost of healthcare, increasing emphasis is being placed on the ability to demonstrate that any health care interventions are not only practical but also cost-effective (Briggs, Sculpher, & Claxton, 2006).

By stretching the number of contact points between health care providers and individuals seeking care, there is plenty of opportunity for the early detection of asymptomatic individuals with DM. Shared responsibility for early identification will also lessen some of the load imposed on the medical community. In this contest, the dental practice offers an excellent setting for opportunistic screening of asymptomatic patients with undiagnosed diabetes (Beikler, Kuczek, Petersilka, & Flemmig, 2002) because DM is an established risk factor for periodontal disease and periodontal disease is one of the leading cause of tooth loss in adults. Despite this close link between DM and periodontal disease, little is known about OHP KAP around DM

The rationale for this study is twofold; one is to explore the OHP knowledge, attitude and practice around DM and the other is to model a care pathway and evaluate the overall economic justification of opportunistic screening for T2DM initiated through the dental setting.
2.1 Research question

1. What is the current knowledge of Victorian oral health professionals regarding DM?

2. What is the attitude of Victorian oral health professionals towards chairside screening for T2DM and do they foresee any barriers?

3. Is screening for T2DM and pre-diabetes initiated through the dental setting cost-effective?

2.2 Aims and objectives

The aim of this study is two-fold

1. To describe the current knowledge, attitudes, and practices of Victorian OHP around T2DM.

2. To identify patients at risk of T2DM in the Victorian dental setting; assess the cost and benefits compared to no screening.

Specific objectives are to identify

1. OHP willingness to do chairside screening for T2DM in the dental setting,

2. Perceived barriers regarding screening for T2DM in the dental setting.

3. OHP knowledge about the evidence associating periodontal disease with DM.

4. The overall economic justification of opportunistic diabetes risk assessment initiated through the dental setting.

5. The cost and effectiveness of diabetes risk assessment in identifying dental patients at risk of T2DM and pre-diabetes.

6. The number of undiagnosed diabetes, pre-diabetes identified in one-year period.
7. Number of new cases of diabetes and pre-diabetes identified over a five- and ten-year period.
2.4 Bibliography


3 A survey among Oral Health Professionals

Diabetes related knowledge, attitudes and practice - A survey among oral health professionals in Victoria, Australia.

3.1 Background

DM is the fastest growing chronic condition in Australia. Its prevalence is higher than in nearly all western European nations (Whiting, Guariguata, Weil, & Shaw, 2011). It is estimated that 1.7 million people are known to have DM and three million will develop DM by the year 2025 (Diabetes Australia, 2018; Shaw & Tanamas, 2012). Approximately, 30% of Australians with type 2 DM (T2DM) are undiagnosed and unaware of their DM status (Sainsbury, Shi, Flack, & Colagiuri, 2018).

DM affects nearly every organ in the body causing disability and life-threatening health problems. This can lead to a substantial economic loss to the individual, families and the national health care system. In the Western Pacific region, Australia has the highest per-person spending on DM (International Diabetes Federation, 2015) with an annual direct cost of AUD 4390 (C. M. Lee et al., 2013). One-third of preventable hospital admissions were directly or indirectly linked to DM, and the economic cost is estimated to be at A$ 14.6 billion in the year 2010 (C. M. Lee et al., 2013).

The starting point for living well with T2DM is an early diagnosis. Early identification of at-risk individuals can delay or prevent the onset of T2DM with minimal microvascular complications (Bansal, 2015; Buysschaert, Medina, Bergman, Shah, & Lonier, 2015; Li et al., 2008). The Ely cohort study identified that screening could bring forward the diagnosis of T2DM on average by 3.3 years (Rahman, Simmons, Hennings, Wareham, & Griffin, 2012). However, the challenges with early diagnosis are that many individuals with prediabetes and some with undiagnosed DM are asymptomatic, leading to late presentation to the health care provider.
DM is an established risk factor for periodontal disease, and periodontal disease is one of the leading causes of tooth loss in adults. Dental patients with poorly controlled DM experience far greater periodontal problems and poorer treatment outcomes compared to those who keep their blood glucose within normal limits (Lamster, Lalla, Borgnakke, & Taylor, 2008; Mealey & Rose, 2008). With this close link between DM and periodontal disease, the dental practice offers a good setting for the opportunistic recognition of patients’ medical problems as Oral Health Professionals (OHPs) are extremely likely to encounter asymptomatic patients with undiagnosed DM and pre-DM (Beikler, Kuczek, Petersilka, & Flemmig, 2002; E. Lalla, Cheng, Kunzel, Burkett, & Lamster, 2013; E Lalla, Kunzel, Burkett, Cheng, & Lamster, 2011).

A survey among US dentists identified that an overwhelming majority (68 -85%) were willing to undertake chairside screening of a medical condition (Barbara L. Greenberg, Michael Glick, Julie Frantsve-Hawley, & Mel L. Kantor, 2010). However, only 56% of the respondents were comfortable drawing blood with a finger stick for blood glucose measurement (Barbara L. Greenberg et al., 2010). Some of the important barriers identified in screening for medical conditions in the dental setting include lack of training, knowledge, fear of being judgemental or fear of offending the patient (Albert et al., 2005; Curran et al., 2010; J. Y. Lee et al., 2012; Patton, Ashe, Elter, Southerland, & Strauss, 2006). Furthermore, Barasch and colleagues in 2009 identified that many dental practitioners regarded blood glucose investigation as outside their scope of practice, and only a few dental offices owned and use a glucometer (Barasch et al., 2012).

In Australia, little is known about the OHP KAP around identification of patients with diagnosed and undiagnosed DM. To explore OHPs’ knowledge on DM, referral, and pathway of care, an understanding of risk factors for DM, opinions about and perceived barriers to screening is important. As such, the aim of this study is to determine Victorian OHPs’ 1. Knowledge and opinions on DM and periodontal disease. 2. attitudes and practice behaviours towards T2DM screening in the dental setting.

3.2 Methods

The population investigated in this survey were practicing Oral Health Professionals (OHP) in Victoria, Australia. This includes registered dental hygienists, dental therapists, oral health
therapists, general dentists and specialist dentists. As of March 2017, there was 5113 OHP registration in Victoria which represents 23% of all the OHP in Australia. Excluding the dental prosthetist and those with dual registration there were 4633 registration that includes 3492 (75%) general dentists, 429 (9%) specialist dentist, 346 (8%) oral health therapists, 218 (5%) dental hygienists, 148 (3%) dental therapists (Dental Board of Australia, 2017).

3.2.1 Sampling and sampling procedures

Further to consultation with the staff at the Australian Dental Association Victoria Branch (ADAVB), an e-survey was chosen as a practical option. A representative sample of OHP registered with the professional dental organization was invited by email with a weblink to participate in the e-survey. Alternatively, the study was posted in the ADAVB and eviDent page of Twitter and Facebook to maximise response rate among group members. eviDent Foundation is a health-promotion charity supporting Australia’s only Dental Practice Based Research Network. It is an initiative of the ADAVB and the Oral Health Cooperative Research Centre. For the pilot survey, opportunistic sampling was conducted using a hard copy of the e-questionnaire among registered post graduate dental students, teaching staff and those who attended a workshop at the University of Melbourne dental school between May and September 2017.

Inclusion criteria

1. Practising OHP from Victoria (this includes dentists, dental hygienists, dental therapists, and oral health therapists.

2. Students pursuing higher education at The University of Melbourne.

Exclusion criteria

1. Dental prosthetists and dental assistants.

2. OHP not in active clinical practice.

3.2.2 Sample size

For the qualitative descriptive cross sectional survey, we used the Krejcie & Morgan method (Krejcie & Morgan, 1970) of sample size calculation. With a 95% confidence level and a
margin of error of 0.05, we anticipate a minimal sample size of 355, in order to be able to
generalise our findings to the Victorian OHP.

\[
\text{Sample size} = \frac{x^2NP(1-P)}{d^2(N-1)+x^2P(1-P)}
\]

\[
\text{Sample size} = \frac{1.96^2 \times 4633 \times 0.5 (1 - 0.5)}{.05^2 (4633 - 1) + 1.96^2 \times 0.5 (1 - 0.5)}
\]

Sample size = 355

Where:

\[
X = \quad \text{Z value (e.g. 1.96 for 95% confidence level)}
\]

\[
N = \quad \text{Population size (4633 OHP)}
\]

\[
P = \quad \text{Population proportion (expressed as decimal) (assumed to be 0.5 (50%))}
\]

\[
d = \quad \text{Degree of accuracy or margin of error (5%), expressed as a proportion (.05)}
\]

The sample size for multiple regression with two and ten predictors was conducted in G* Power
with alpha set at 0.05, power at 0.80, and medium effect size of \( f^2 = 0.15 \) (Faul, Erdfelder,
Buchner, & Lang, 2013). Based on these assumptions, the sample size was determined as 68
for two predictors and 118 for ten predictors.

### 3.2.3 Questionnaire

Evidence from the literature on the relationship between DM and periodontal disease along
with OHP’ opinion and practice behaviour towards the management of patients with DM was
used in framing the quantitative self-report questionnaire. A large portion of the items were
derived from previous KAP studies in the literature (B. L. Greenberg, M. Glick, J. Frantsve-
Hawley, & M. L. Kantor, 2010; Greenberg, Kantor, & Bednarsh, 2016; Owens, Wilder,
Southerland, Buse, & Malone, 2011; D. W. Paquette, K. P. Bell, C. Phillips, S. Offenbacher,
& R. S. Wilder, 2015). A total of 74 questions were drafted and etthics approval was obtained
from the Human Ethics Advisory Group of the Melbourne Dental School (Ethics ID: 1647537). Further to the pilot survey and some modification to the existing Plain Language Statement (PLS) and the questionnaire, the number of items was reduced to 53. The ethics approval is presented in Appendix 7.1.1 and the full list of items in the PLS and questionnaire is presented in Appendix 7.1.2.

The first part of the questionnaire consists of six items seeking information on the socio demographic and practice characteristics. The reminder of the questions were four- and five-point Likert scaled and categorised into three domains of knowledge, attitude and practice behaviour. A Likert scale is a series of statements, which asks how much a person agrees or disagrees with the statement or question. The five-point Likert scales consists of different ratings where 1 = “least important” to 5 = “most important or “strongly disagree/ never” to “strongly agree/ always.” In the four-point Likert, the choices were 1 = negligible, 2 = low, 3 = moderate and 4 = significant.

The knowledge domain consisted of 23 questions divided into three constructs / sub-groups. The questions included general knowledge on DM, risk factors and complications of DM. The attitude domain comprised eight questions that sought OHP’ opinions about screening for T2DM in the dental setting. The practice management domain included 11 questions in two scales seeking information related to DM regimen and treatment. Finally, one standalone barriers scale with five questions sought information on important considerations about implementing DM screening in the dental setting.

3.2.4 Pilot survey

A pilot survey was conducted with a representative sample of 40 OHP comprising dentists, dental therapists, dental hygienists and post graduate dental students from The University of Melbourne and eviDent members. The majority of participants (n = 24) were oral health therapists, who were attending a University of Melbourne continuing professional development workshop; this opportunity was utilised to distribute paper copies of the e-questionnaire to get their response and feedback. These purposely selected participants were recruited to ensure that the response category of the items was appropriate for individual domains and to gain valuable feedback on the readability, uniformity, clarity, completion time and user friendliness.
of the e-questionnaire before rolling it out to the wider dental community. In addition, we also recruited 13 OHP from the Royal Dental Hospital of Melbourne staff and post graduate students as they constitute part of the whole OHP in Victoria. Analysis of the responses showed that the questionnaire was able to gather the information sought with only one respondent having difficulty with the wording in the questionnaire. The readability of the questionnaire was cross checked, and it was found to be of no significant concern.

Cronbachs alpha

The pilot survey response was examined for its suitability for reliability analysis (internal consistency). One of the basic requirements for Cronbach's alpha is the variable measure should be continuous. Since most of the items in our questionnaire were multiple 5-point Likert fashioned, it satisfied the requirement for Cronbach’s alpha and could be treated as continuous despite being ordinal data.

Cronbach’s alpha can be written as a function of the number of test items and the average inter-correlation among the items (as cited by, Shafiei, Samari, & Ghodrati, 2013; Bruin, 2006). The formula for Cronbachs alpha is

\[
\alpha = \frac{N \ast \bar{c}}{\nu + (N - 1) \ast \bar{c}}
\]

Where

\(N\) = number of items

\(\bar{c}\) = average inter-item covariance among items

\(\nu\) = average variance

If the number of items is increased, Cronbach’s alpha increases. Further, if the average inter-item correlation is low, Cronbach’s alpha will become less. As the average inter-item correlation increases, Cronbach’s alpha increases (when the number of items remains as constant) (Bruin, 2006). The response from the pilot survey was used to calculate the
Cronbach’s alpha for the knowledge (0.56; 0.81 and 0.81), attitude (0.87), practice (0.76;0.88;) and barriers domain scales.

### 3.2.5 Participant recruitment and data collection

A request was submitted to the ADAVB, Australian Dental and Oral Health Therapist (ADOHTA) and Dental Hygienist Association of Australia to assist with the distribution of the survey to all the currently registered OHP in Victoria. The professional associations represent approximately 70-80% of the OHP in Victoria. The ADAVB and ADOHTA sent the weblink of SurveyMonkey through email to 2722 registered dentist and 176 registered dental hygienists, oral health therapists and dental therapists. In addition, the study was advertised in the ADAVB and eviDent newsletter, Twitter and Facebook to maximise response rate among the group members. The email link detailed the purpose of the study in a plain language statement with a consent option for the willingness to take part. The SurveyMonkey platform, [www.surveymonkey.com](http://www.surveymonkey.com) (SurveyMonkey Inc, San Mateo, California, USA) allowed invitations to be sent and responses to be obtained securely. Survey Monkey has a built-in feature that enables response data to be transported into a spreadsheet instantly including SPSS. Data from the pilot study obtained in the paper format were added to the main data pool obtained through survey monkey. All the participants were informed that the results of the study were to be published. No monetary benefits or gifts as incentives were offered and participation was at their own will.

### 3.2.6 Data analysis

Descriptive statistics with frequencies and percentages were used to summarize sociodemographic variables. For the KAP and barriers scale ordinal variables, frequencies, percentages and a Kruskal-Wallis rank sum test were conducted to determine if differences existed in the OHP responses. Subsequently, post-hoc pairwise multiple comparisons with a Bonferroni correction were performed using Dunn's (1964) procedure (Dunn, 1964) to identify the level of significant difference.

For the bivariate and multivariate analysis, the knowledge domain response was dichotomised into “agree” and “do not agree.” The sum scores for the individual cases for the knowledge
questions and the average scores for the attitude and practice behaviour were derived to form a scale variable. A Pearson correlation was conducted to determine the relationship between the KAP variables. Cohen's standard was used to evaluate the strength of the relationships (Cohen, 1988). To predict if KAP response was influenced by sociodemographic variables and further to test if practice behavior was influenced by knowledge and attitude, a multiple linear regression was conducted. Dummy variables were created, and a separate code was assigned to the different categories within each sociodemographic independent variable. The assumptions for normality, multicollinearity, homoscedasticity, and absence of outliers were studied before conducting the multiple linear regression. All the analyses were performed using Statistical Package for the Social Sciences software (SPSS for Windows, Version 24, Chicago, IL).

### 3.2.7 Ethics approval

Ethical approval (Appendix 7.1.2) was obtained from the human ethics advisory group at the Melbourne Dental School (Ethics ID: 1647537). The proposed survey methods made it eligible for a minimal risk ethics consideration because of the low risk of potential side effects involved for the study participants or researchers. Participation in this study was voluntary and all information collected was confidential, subject to legal limitations.

### 3.1 Results

One hundred and seventy-five OHP responded to the e-survey. With the inclusion of the pilot data, the number of responses was 215. Respondents who did not complete any answers (n = 6) were excluded from the analysis. Listwise deletion was used to eliminate a further 12 participants with large amounts of missing data. A total of 197 OHP were included in the final analysis of the results.

Sociodemographic characteristics of the respondents are presented in Table 3.1. Females constituted 60.7% of the respondents (n = 119). The majority of the OHP were private practitioners, and little over half (n = 102) of the responding OHP were from a suburban setting, with the least number from rural location (6.5%). Inner city or regional practices accounted for approximately 20% of the responses. The most frequently observed category of OHP was
general dentists (65%), while specialist dentists constituted approximately 10% of the respondents. More than 95% of the specialist dentists were from suburban and inner-city locations. The average years in dental practice were 18.90 ± 13.86 (range, 1 -51) with approximately 40% having less than 10 years of work experience. Almost all with 10 years or less (93%) or 40 years or more (100%) work experience had obtained their primary dental qualification in Australia.

3.2.8 Diabetes mellitus related knowledge scores

Table 3.1 and 3.2 presents the results of the DM related knowledge scores. There was no significant difference in the overall knowledge score for any of the categories within the sociodemographic variables. Few OHP indicated that osteoporosis (n=23;12%) and stroke (n=78; 39.6%) were a significant complication of DM compared to other questions in that scale. The lowest number of respondents (n = 110; 55.8%) among those who agreed/strongly agreed to the knowledge question was DM as a risk factor for “high blood pressure”. Compared to their Australian peers, overseas qualified dentists in Australia were 20% less likely to agree that the Aboriginal and Torres Straits Islanders were at increased risk of DM. Among the knowledge variables, the question with which the greatest number of OHP neither agreed nor disagreed was “Patients reporting a glycated haemoglobin level (HbA1c) of less than 5.7% is indicative of good glycaemic control” (n = 71; 36%). The mean knowledge score was 2.59 (SD = 0.25) with a range of 1.6 to 3.

3.2.9 Diabetes mellitus related attitude scores

Tables 3.1 and 3.3 present the DM related attitude scores. The mean attitude score was 2.78 (SD = 0.26) with a range of 1.7 to 3. Close to 90% or more of the OHP felt that a patient’s overall health is important for better treatment outcomes and screening for T2DM would offer new opportunities to identify patients with undiagnosed T2DM or at risk of T2DM. However, fewer felt it is essential (58%) or appropriate (70%) for OHP to perform or conduct chair-side screening for DM.

Individual attitude item analysis identified more females (67%) OHP agreed or strongly agreed that “It is important for OHP to perform or conduct chair-side screening for T2DM”. Public
sector OHP (n= 31, 79%) compared to private practitioners (n = 78, 55%) also responded that chairside screening for T2DM is important and this difference was statistically significant ($\chi^2(2) = 8.03, p = .018$).

There was a significant difference in the overall attitude score by gender and practice type. The female OHP had a significantly higher DM related mean attitude score ($p = 0.01$) compared to males. Since the overall test was significant ($P =0.04$) for the practice type, a post-hoc pairwise multiple comparisons was performed to examine responses within each category, but no significant difference was observed between private, public or other practice types.

### 3.2.10 Diabetes mellitus related practice behaviour scores

Table 3.1 and 3.4 presents DM related practice behaviour scores. The mean practice score was 2.43 (SD = 0.46) with a range of 1.1 to 3. There was a significant difference in the overall practice behaviour scores and practice location ($P = 0.03$). Even though the overall test was significant, none of the individual pairwise comparisons identified significant differences within the group.

Individual item analysis of practice variables identified approximately 80% or more of the respondents indicated (very often/ always) that they make a detailed inquiry of the patient’s medical history and provide thorough periodontal therapies. Around half the responding OHP cited (very often/ always) that they thoroughly assess their patients DM risk or adjust the frequency of dental visits based on DM risk. Around 65% indicated their willingness to collaborate more with physicians and nurses to improve patient care behaviour. Only 29% responded (as very often/ always) that their staff’s knowledge about DM was up-to-date.

### 3.2.11 Important considerations for implementing T2DM screening

Table 3.1 and 3.5 presents the important considerations for implementing T2DM screening in the dental setting. The mean barriers score was 2.1 (SD = 0.38) with a range of 1 to 3. Significant differences were observed within categories of location, type of practice, OHP and work experience. However, pairwise comparisons failed to identify that this difference existed within the categories of practice location. Overall, OHP with more than ten years of work
experience rated as of lower importance, patient willingness, legal liability, time and insurance coverage for implementing T2DM screening. Pairwise comparison of the type of practice and OHP identified significant differences in the response of dental hygienists, dental therapists and general dentists and between private practitioners and others. Individual item analysis identified “patient willingness” as the most important barrier (mean = 2.3) and “insurance coverage” least important barrier (mean = 1.9) and no significant difference within groups was observed.
Table 3.1 Group difference of independent variable to KAP variables

<table>
<thead>
<tr>
<th>Sociodemographic Variable</th>
<th>n</th>
<th>%</th>
<th>Knowledge Mean ± SD</th>
<th>Attitude Mean ± SD</th>
<th>Practice behaviour Mean ± SD</th>
<th>Barriers Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Test value p value</td>
<td>Test value p value</td>
<td>Test value p value</td>
<td>Test value p value</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>119</td>
<td>(60.6)</td>
<td>2.6 ±0.23 U = 5064.0</td>
<td>2.8 ±0.27 U = 5189.0</td>
<td>2.4 ±0.43 U = 4672.5</td>
<td>2.1 0.40 U = 4367.5</td>
</tr>
<tr>
<td>Male</td>
<td>77</td>
<td>(38.9)</td>
<td>2.5 ±0.28 0.213</td>
<td>2.7 ±0.27 0.01</td>
<td>2.3 ±0.52 0.41</td>
<td>2.1 0.35 0.35</td>
</tr>
<tr>
<td>Practice location</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regional</td>
<td>38</td>
<td>(19.2)</td>
<td>2.6 ±0.30 K = 0.2</td>
<td>2.7 ±0.29 K = 2.7</td>
<td>2.3 ±0.50 K = 8.4</td>
<td>2.1 0.31 K = 7.9</td>
</tr>
<tr>
<td>Rural</td>
<td>12</td>
<td>(6.1)</td>
<td>2.5 ±0.29 0.97</td>
<td>2.6 ±0.37 0.43</td>
<td>2.57±0.38 0.03</td>
<td>2.3 0.46 0.04</td>
</tr>
<tr>
<td>Suburban</td>
<td>102</td>
<td>(51.5)</td>
<td>2.6 ±0.21</td>
<td>2.7 ±0.24</td>
<td>2.3 ±0.49</td>
<td>2.0 0.37</td>
</tr>
<tr>
<td>Inner city</td>
<td>42</td>
<td>(21.2)</td>
<td>2.5 ±0.27</td>
<td>2.8 ±0.27</td>
<td>2.6 ±0.36</td>
<td>2.2 0.42</td>
</tr>
<tr>
<td>Practice type</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private</td>
<td>145</td>
<td>(73.2)</td>
<td>2.5 ±0.24 K = 1.0</td>
<td>2.7 ±0.28 K = 6.2</td>
<td>2.3 ±0.48 K = 5.7</td>
<td>2.1 0.33 K = 14.0</td>
</tr>
<tr>
<td>Public</td>
<td>43</td>
<td>(21.7)</td>
<td>2.6 ±0.29 0.60</td>
<td>2.8 ±0.21 0.04</td>
<td>2.5 ±0.43 0.05</td>
<td>2.2 0.47 0.001</td>
</tr>
<tr>
<td>Other, please specify</td>
<td>9</td>
<td>(4.5)</td>
<td>2.6 ±0.32</td>
<td>2.8 ±0.34</td>
<td>2.4 ±0.44</td>
<td>2.6 0.50</td>
</tr>
<tr>
<td>Type of OHP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dental hygienist &amp; therapist</td>
<td>47</td>
<td>(23.7)</td>
<td>2.5 ±0.30 K = 1.3</td>
<td>2.8 ± 0.26 K = 1.3</td>
<td>2.5 ±0.43 K = 1.9</td>
<td>2.3 0.50 K = 25.1</td>
</tr>
<tr>
<td>General Dentist</td>
<td>128</td>
<td>(64.6)</td>
<td>2.6 ±0.24 0.52</td>
<td>2.7 ±0.26 0.52</td>
<td>2.4 ±0.47 0.37</td>
<td>2.0 0.31 0.001</td>
</tr>
<tr>
<td>Specialist Dentist</td>
<td>21</td>
<td>(10.6)</td>
<td>2.5 ±0.21</td>
<td>2.6 ±0.33</td>
<td>2.3 ±0.56</td>
<td>2.0 0.27</td>
</tr>
<tr>
<td>Primary dental qualification</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In Australia</td>
<td>159</td>
<td>(80.3)</td>
<td>2.5 ±0.25 U = 2666.5</td>
<td>2.5 ±0.25 U = 2546.0</td>
<td>2.4 ±0.47 U = 2087.0</td>
<td>2.1 0.39 U = 2587.5</td>
</tr>
<tr>
<td>Overseas</td>
<td>33</td>
<td>(16.7)</td>
<td>2.5 ±0.27 0.882</td>
<td>2.5 ±0.27 0.872</td>
<td>2.5 ±0.42 0.158</td>
<td>2.10.32 0.489</td>
</tr>
<tr>
<td>Work experience in years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 or less</td>
<td>75</td>
<td>(38)</td>
<td>2.5 ±0.26 U = 4173.0</td>
<td>2.8 ±0.24 U = 4353.50</td>
<td>2.3 ±0.47 U = 3634.0</td>
<td>2.3 0.49 U = 5079</td>
</tr>
<tr>
<td>Over 10</td>
<td>113</td>
<td>(57)</td>
<td>2.6 ±0.24 0.860</td>
<td>2.7 ±0.28 0.507</td>
<td>2.4 ±0.46 0.300</td>
<td>2.0 0.26 0.001</td>
</tr>
</tbody>
</table>

*U* = Mann–Whitney U test, *K* = Kruskal Wallis Test
### Table 3.2 OHP response to knowledge variables

<table>
<thead>
<tr>
<th>Knowledge Variable</th>
<th>Level of agreement in n (%)</th>
<th>Scale 1</th>
<th>Scale 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Strongly disagree/ disagree</td>
<td>Neutral</td>
</tr>
<tr>
<td>DM may go unrecognized by the patient for many years from the actual onset</td>
<td>197</td>
<td>3(1.5)</td>
<td>4(2)</td>
</tr>
<tr>
<td>Early identification of &quot;at-risk individuals&quot; can delay or prevent the onset of the disease, with minimal complications</td>
<td>197</td>
<td>3(1.5)</td>
<td>7(3.6)</td>
</tr>
<tr>
<td>Treatment of periodontal disease by scaling and root surface debridement may improve glycaemic control in people with DM</td>
<td>194</td>
<td>19(9.6)</td>
<td>35(17.8)</td>
</tr>
<tr>
<td>Some ethnic groups such as Aboriginals and Torres Straits Islanders are at increased risk of DM</td>
<td>197</td>
<td>1(0.5)</td>
<td>14(7.1)</td>
</tr>
<tr>
<td>Recognizing uncontrolled DM is difficult because patients with DM respond to periodontal therapy similarly to non–diabetics*</td>
<td>196</td>
<td>15(7.7)</td>
<td>34(17.3)</td>
</tr>
<tr>
<td>There is good evidence to support the bi-directional link between periodontal disease and poor glycaemic control(F)</td>
<td>196</td>
<td>5(2.6)</td>
<td>24(12.2)</td>
</tr>
<tr>
<td>Patients reporting a glycated hemoglobin level (HBA1c) of less than 5.7% is indicative of good glycaemic control</td>
<td>196</td>
<td>7(3.6)</td>
<td>71(36.2)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Risk factors for type 2 DM in n (%)</th>
<th>Scale 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Strongly disagree/ disagree</td>
</tr>
<tr>
<td>Genetics</td>
<td>197</td>
</tr>
<tr>
<td>Periodontitis</td>
<td>195</td>
</tr>
<tr>
<td>Increasing age</td>
<td>194</td>
</tr>
<tr>
<td>Physical inactivity</td>
<td>197</td>
</tr>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Cardiovascular disease</td>
<td>192</td>
</tr>
<tr>
<td>Foot ulcers</td>
<td>194</td>
</tr>
<tr>
<td>Blindness</td>
<td>194</td>
</tr>
<tr>
<td>Kidney failure</td>
<td>193</td>
</tr>
<tr>
<td>Tooth mobility</td>
<td>194</td>
</tr>
<tr>
<td>Stroke</td>
<td>194</td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>192</td>
</tr>
</tbody>
</table>

*reverse coded; Note.
Table 3.3 OHP attitudes and beliefs

<table>
<thead>
<tr>
<th>Attitude and beliefs of OHP</th>
<th>N</th>
<th>Strongly disagree/disagree</th>
<th>neutral</th>
<th>Agree/ strongly agree</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>OHP knowledge of a patient’s overall health is important for achieving optimal oral health outcomes</td>
<td>196</td>
<td>2(1.0)</td>
<td>6(3.0)</td>
<td>190(96.0)</td>
<td>2.94</td>
<td>0.26</td>
</tr>
<tr>
<td>Screening patients for DM risk in the dental setting could offer new opportunities to identify patients with possible undiagnosed DM or pre-DM</td>
<td>196</td>
<td>4(2.0)</td>
<td>19(9.6)</td>
<td>175(88.4)</td>
<td>2.86</td>
<td>0.39</td>
</tr>
<tr>
<td>Screening for DM in the dental setting will help patients to understand the link between uncontrolled DM and poor periodontal health</td>
<td>196</td>
<td>5(2.5)</td>
<td>19(9.6)</td>
<td>174(87.9)</td>
<td>2.85</td>
<td>0.42</td>
</tr>
<tr>
<td>It is appropriate for OHP to screen patients for DM in the dental setting</td>
<td>196</td>
<td>15(7.6)</td>
<td>44(22.2)</td>
<td>139(70.2)</td>
<td>2.62</td>
<td>0.62</td>
</tr>
<tr>
<td>It is important for OHP to perform or conduct chair-side screening for T2DM</td>
<td>196</td>
<td>15(7.6)</td>
<td>69(34.8)</td>
<td>114(57.6)</td>
<td>2.5</td>
<td>0.63</td>
</tr>
<tr>
<td>Dental Health Professionals feel comfortable providing oral health care to patients with DM</td>
<td>196</td>
<td>9(4.5)</td>
<td>24(12.1)</td>
<td>165(83.3)</td>
<td>2.78</td>
<td>0.50</td>
</tr>
<tr>
<td>Patients with undiagnosed type 2 DM/pre-DM may benefit from blood glucose screening in a dental setting</td>
<td>196</td>
<td>13(6.6)</td>
<td>43(21.7)</td>
<td>142(71.7)</td>
<td>2.65</td>
<td>0.60</td>
</tr>
<tr>
<td>Periodontal screening and subsequent follow up may facilitate conversation with medical practitioners when patients seek their care</td>
<td>196</td>
<td>3(1.5)</td>
<td>27(13.6)</td>
<td>168(84.8)</td>
<td>2.83</td>
<td>0.41</td>
</tr>
<tr>
<td>Practice behaviour</td>
<td>N</td>
<td>Never/Rarely</td>
<td>Sometimes</td>
<td>Often/very often</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------------</td>
<td>-----</td>
<td>--------------</td>
<td>------------</td>
<td>------------------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>I ask detailed follow-up questions to &quot;Yes&quot; answers on the medical history form</td>
<td>196</td>
<td>-</td>
<td>27(13.6)</td>
<td>171(86.4)</td>
<td>2.86</td>
<td>0.34</td>
</tr>
<tr>
<td>I thoroughly assess my patients for DM risk factors as this may have important implications for their oral health</td>
<td>196</td>
<td>37(18.7)</td>
<td>71(35.9)</td>
<td>90(45.5)</td>
<td>2.26</td>
<td>0.75</td>
</tr>
<tr>
<td>I adjust the frequency of dental visits as needed for patients with DM</td>
<td>196</td>
<td>28(14.1)</td>
<td>65(32.8)</td>
<td>105(53.0)</td>
<td>2.38</td>
<td>0.72</td>
</tr>
<tr>
<td>I provide thorough periodontal therapies to my patients (scaling and root surface debridement, etc.)</td>
<td>196</td>
<td>11(5.6)</td>
<td>29(14.6)</td>
<td>158(79.8)</td>
<td>2.74</td>
<td>0.55</td>
</tr>
<tr>
<td>I am interested in collaborating more with physicians and nurses to improve the coordination of care for my patients</td>
<td>196</td>
<td>11(5.6)</td>
<td>56(28.3)</td>
<td>131(66.2)</td>
<td>2.60</td>
<td>0.59</td>
</tr>
<tr>
<td>My dental staff’s knowledge about DM is up-to-date</td>
<td>196</td>
<td>53(26.8)</td>
<td>90(45.5)</td>
<td>55(27.8)</td>
<td>2.01</td>
<td>0.74</td>
</tr>
<tr>
<td>OHP enquiring patients about regimens to control blood glucose</td>
<td>N</td>
<td>Never/Rarely</td>
<td>Sometimes</td>
<td>Often/very often</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Diet control</td>
<td>196</td>
<td>30(15.2)</td>
<td>64(32.3)</td>
<td>104(52.5)</td>
<td>2.37</td>
<td>0.73</td>
</tr>
<tr>
<td>Insulin control</td>
<td>196</td>
<td>35(17.7)</td>
<td>60(30.3)</td>
<td>103(52.0)</td>
<td>2.34</td>
<td>0.76</td>
</tr>
<tr>
<td>Self-monitoring of glucose levels</td>
<td>196</td>
<td>37(18.7)</td>
<td>70(35.4)</td>
<td>91(46.0)</td>
<td>2.27</td>
<td>0.75</td>
</tr>
<tr>
<td>Medication control</td>
<td>196</td>
<td>24(12.1)</td>
<td>60(30.3)</td>
<td>114(57.6)</td>
<td>2.45</td>
<td>0.70</td>
</tr>
<tr>
<td>Patients perceived level of glycaemic control</td>
<td>196</td>
<td>50(25.3)</td>
<td>60(30.3)</td>
<td>88(44.4)</td>
<td>2.19</td>
<td>0.81</td>
</tr>
</tbody>
</table>
Table 3.5 Level of importance OHP foresee incorporating DM screening.

<table>
<thead>
<tr>
<th>Level importance in n (%)</th>
<th>N</th>
<th>Not important</th>
<th>Not sure</th>
<th>Important</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient willingness</td>
<td>179</td>
<td>47 (26.3)</td>
<td>15 (8.4)</td>
<td>117 (65.4)</td>
<td>2.39</td>
<td>0.87</td>
</tr>
<tr>
<td>Legal liability</td>
<td>179</td>
<td>52 (29.1)</td>
<td>26 (14.5)</td>
<td>101 (56.4)</td>
<td>2.27</td>
<td>0.88</td>
</tr>
<tr>
<td>Cost</td>
<td>178</td>
<td>59 (33.1)</td>
<td>49 (27.5)</td>
<td>70 (39.3)</td>
<td>2.06</td>
<td>0.85</td>
</tr>
<tr>
<td>Time</td>
<td>178</td>
<td>56 (31.5)</td>
<td>52 (29.2)</td>
<td>70 (39.3)</td>
<td>2.07</td>
<td>0.84</td>
</tr>
<tr>
<td>Insurance coverage</td>
<td>186</td>
<td>80 (43)</td>
<td>27 (14.5)</td>
<td>79 (42.5)</td>
<td>1.99</td>
<td>0.92</td>
</tr>
</tbody>
</table>

Table 3.6 summarizes the results of the regression model. Results of the linear regression analysis were significant, $F(2,184) = 12.87, p < .001, R^2 = 0.12$, indicating that approximately 12% of the variance in practice behavior was explainable by knowledge and attitude values. Knowledge and attitude significantly predict practice behavior, $B = 0.33, t(184) = 2.38, p = .018; B = 0.42, t(184) = 3.28, p = .001$. This indicates that on average a one-unit increase in knowledge would increase the practice behavior score by 0.33 units and further a unit increase of attitude would increase the value of practice behavior by 0.42 units.

Table 3.6 Predictive model summary

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>95% CI</th>
<th>P value</th>
<th>β</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>0.41</td>
<td>0.40</td>
<td>(.38-1.21)</td>
<td>.308</td>
<td>0.00</td>
<td>1.02</td>
<td>.308</td>
</tr>
<tr>
<td>Knowledge</td>
<td>0.33</td>
<td>0.14</td>
<td>(0.06, 0.60)</td>
<td>.018</td>
<td>0.18</td>
<td>2.38</td>
<td>.018</td>
</tr>
<tr>
<td>Attitude</td>
<td>0.42</td>
<td>0.13</td>
<td>(0.17, 0.67)</td>
<td>.001</td>
<td>0.24</td>
<td>3.28</td>
<td>.001</td>
</tr>
</tbody>
</table>

Note. Results: $F(2,184) = 12.87, p < .001, R^2 = 0.12$. Unstandardized Regression Equation: practice behaviour = 0.41 + 0.33*knowledge + 0.42*attitude

3.3 Discussion

Oral health professionals are constantly exposed to new research findings that may have implication in patient care. Screening for DM in the dental setting is a relatively new concept. Globally, few studies have explored as to how OHP perceive DM screening in the dental
setting. To my knowledge, this study is the first of its kind in Australia to get an understanding of DM related knowledge, attitudes towards screening and management of patients with DM.

The results of this study show that around 80% of the OHP had adequate knowledge of DM. There was very little difference in the average knowledge scores among the different type of OHP or those with less or more than 10 years of work experience with a mean correct answer of 17 out of 22 questions.

Among the knowledge variable, only 12% of the OHP identified osteoporosis as a significant complication of DM. This may be due to the fact that evidence relating T2DM and bone mineral density is inconsistent and equivocal (Akin, Göl, Aktürk, & Erkaya, 2003; De Liefde et al., 2005; Ma et al., 2012; Migliaccio, Greco, Fornari, Donini, & Lenzi, 2011; Starup-Linde, 2013; Sundararaghavan, Mazur, Evans, Liu, & Ebraheim, 2017). Having said that, several studies have demonstrated higher incidence of fracture among T2DM being linked to glycaemic control, retinopathy, peripheral neuralgia and stroke, thus increasing the risk of fall (Dede, Tournis, Dontas, & Trovas, 2014; Maurer, Burcham, & Cheng, 2005; Schwartz et al., 2002; Strotmeyer et al., 2005).

When we compared our results with a similar survey on U.S general dentists (David W Paquette, Kathryn P Bell, Ceib Phillips, Steven Offenbacher, & Rebecca S Wilder, 2015) and dental hygienists (Bell, Phillips, Paquette, Offenbacher, & Wilder, 2012) on selected (DM risk factors) knowledge items with the same wording we observed Victorian OHP expressing, on an average, 7-8% higher knowledge scores. However, the number of survey respondents in our study was small and may not be representative of the entire Victorian OHP. As such, the results need to be interpreted with caution.

The overall attitude of OHP towards screening for T2DM appears positive with an average 80% agreement. The results were encouraging as the willingness to address this important issue seems to exist. Although 70% of the OHP acknowledged that it is appropriate to screen patients for T2DM in the dental setting, only 58% felt it’s important to perform chairside screening for T2DM. Among the respondents, twice as many (77%) dental hygienists and therapists felt it’s important to perform chairside screening compared to specialist dentists. This difference in
opinion may be due to the fact that a quarter of the specialist dentists were Orthodontists and Paedodontists who would essentially treat children and young adults. Having said that it is not easy to ascertain plausible reasons for the difference in opinion when the responding specialist dentist, dental hygienist and dental therapist number in this survey is small.

When we compared our findings (Figure 3.1) against the first nationwide survey of U.S dental professionals (Barbara L. Greenberg et al., 2010; Greenberg, Kantor, & Bednarsh, 2017), Victorian OHP exhibited 18.6% and 11.8% lower importance to chairside screening of T2DM. However, when compared against the New Zealand dentists (Forbes, Thomson, Kunzel, Lalla, & Lamster, 2008), Victorian dentists expressed 28% higher importance to chairside screening of T2DM. The reduced willingness among the New Zealand dentists may be due to the wording “finger stick test” used in the survey (Forbes et al., 2008). Again, the results need to be interpreted with caution because of the disproportionate participant numbers in all these studies.

Knowledge, attitudes and beliefs are strong predictors of intentions and behaviour (Limbert & Lamb, 2002; Perkins et al., 2007; Walker, Grimshaw, & Armstrong, 2001). Studies among a variety of health care providers, including dentists, show clear evidence of psychological theory translating into practice (Edwards et al., 2001; Barbara L. Greenberg et al., 2010; Limbert & Lamb, 2002; Walker et al., 2001). Our analysis identified that knowledge and attitudes significantly predicted practice behaviour. OHP acknowledged that only 29% of their staff knowledge on DM was up-to-date. With a significant number of patients with DM accessing oral health services, the need for updating staff knowledge with formal training is important. This will help improve their confidence, effectiveness in patient management by asking the right questions and improving on the referral process for medical attention.

Diabetes Australia in partnership with the IDF provides a free online course on DM for health professionals with a certificate on completion of the training module (D-NET The International Diabetes Federation - Diabetes Network for Health Professionals). Findings from this study will help to inform OHP of the need to discuss risk factors for DM if we expect to see any change in the disease level or associated complication of this prevalent yet preventable condition. OHP can also play an important role in creating awareness about the potential oral health consequence associated with DM.
The survey identified patient willingness as the most important consideration among the OHP for implementing T2DM screening in the dental setting. A study conducted in Thailand identified 80-85% of the dental patients in university, hospital and private clinics expressed their willingness for T2DM screening in the dental setting (Tantipoj, Hiransuthikul, Supamornkul, Lohsoonthorn, & Piboonniyom Khovidhunkit, 2018). However, patient compliance for physician referral was identified a significant concern in a study conducted in US (Genco et al., 2014) with only 21.5% of the dental patients from private dental clinics following up with their physician despite a HbA1c value of 5.7 or more and being informed prior of the possibility of being referred to the physician. The reasons for non-adherence are not clear but resistance to comply is a significant barrier and strategies to overcome this need to be explored. The author further recommended a formal contract with the patient to follow up with referral or involve more OHP to monitor the entire process with the referral and follow-up (R. J. Genco et al., 2014). Such concerns need to be explored and addressed to establish and streamline this extended service in the dental setting. To implement T2DM screening in the dental setting, it is important for OHP to appreciate the value, willingness to screen and patient compliance.

Most patients visit their OHP when they perceive themselves as not unhealthy but visit the physician only when they are sick. Such findings give OHP an opportunity to screen asymptomatic patients with underlying medical conditions in the dental setting (Glick, 2002). Australians generally have favourable dental visiting patterns, and dental practice visits offer a largely untapped opportunity for DM screening. By stretching the number of contact points
between health care providers and individuals seeking care, there is plenty of opportunity for early detection of asymptomatic individuals at risk of T2DM. Shared responsibility for early identification will also lessen some of the load imposed on the medical community. Routine oral health screenings can be extended to systematically screen for diseases, such as DM.

3.4 Conclusion

Overall, knowledge, attitude and practice towards DM was positive. However, a significant proportion of the OHP felt chairside screening may not be appropriate or important. To implement T2DM screening in the dental setting, it is important for OHPs to appreciate the value, willingness to screen and patient compliance.

3.5 Bibliography.


Maurer, M. S., Burcham, J., & Cheng, H. (2005). Diabetes mellitus is associated with an increased risk of falls in elderly residents of a long-term care facility. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 60(9), 1157-1162.


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6 Economic evaluation of screening

Economic evaluation of screening for type 2 diabetes mellitus initiated through the dental setting: a modelling study

6.1 Methods

Achieving effective T2DM risk assessment in the general population requires a multidisciplinary approach involving screening by different health care providers. Routine health screening performed by dentists can be extended to systematically screen for particular diseases, such as T2DM. This would provide dentists with the opportunity to screen for significant systemic disease risks among those who may not otherwise seek medical care (Sultan, Warreth, Fleming, & MacCarthy, 2014).

If early diagnosis and subsequent treatment of T2DM results in reduction in the incidence of or delay in the progression of T2DM related complications, it may also lead to a reduction in treatment costs during later years which would potentially offset the cost of screening and early intervention. The benefits of improved quality of life and life years gained potentially make screening and early treatment a desirable choice despite the cost involved. It is logical to assume that early identification of the disease further to screening would capture at-risk individuals with minimal microvascular complications.

6.1.1 Target population and subgroups

Participants will be Victorian dental patients aged between 40 to 74 years, who have never been told by a healthcare provider that they have DM or hyperglycaemia.

The reasons for choosing this age group are:
1. Previous studies on diabetes screening identified that the lowest cost per QALY is for persons aged 45 years (Kahn et al., 2010).

2. The AUSDRISK screening tool is recommended for use in adults 40 years and above (Australian Government - Department of Health, 2016).

6.1.2 Setting and location

Screening using the AUSDRISK will be initiated in the private dental setting across the state of Victoria (figure 6.1). Dental patients identified as at high risk of hyperglycaemia will be referred for follow-up with their physician in the medical setting. In the medical setting, based on the AUSDRISK score and the FPG values, eligible dental patient (identified as high risk by the physician) will be referred by the physician to join the “Life” program. “Life” is a Victorian government initiative to help reduce T2DM and cardiovascular risk using lifestyle modification program.

Figure 6. 1 State of Victoria

Map of Victoria
6.1.3 Screening procedure

A hypothetical cohort of dental patients aged 40 to 74 years (inclusive) who attend the private dental practices in Victoria for their dental needs will be requested to fill in the AUSDRISK tool/questionnaire (Appendix 1) by the receptionist while they are in the dentist’s waiting room. The receptionist will explain to the patient about the T2DM screening using the AUSDRISK questionnaire. The receptionist will also clarify that participation in the screening is voluntary and will not affect the patient’s dental appointment time or the cost of dental treatment they have come for. The patient will be requested to complete an informed consent form before they fill in the AUSDRISK questionnaire. Information on the link between periodontal disease and DM will be provided to the patient on completion of the questionnaire. The patient will then take the completed AUSDRISK questionnaire with them to the dentist in the operating area. The dental nurse in the operating room will review the patient’s responses and compute a risk score. Based on the AUSDRISK scores, patients will be categorised into low or high risk for T2DM. Description of the parameters measured in the AUSDRISK is presented under the “screening tool” in Appendix 3.

1. Low & intermediate risk: score between 0 to <12

2. High risk: >12

If the patient is identified as low risk, the dentist will perform the care required for the patient’s dental needs, but provide no advice, false reassurance or referral to a physician. For scores \( \geq 12 \) (high risk), on completion of the dental care for which the patient had come, the dentist will then provide general advice about making lifestyle improvements to help reduce the risk of developing T2DM and refer the patient to his/her General Practitioner (GP) for a blood sugar investigation. Due to reduced compliance (loss of follow-up) reported among dental patients from private dental clinics for physician follow-up for diabetes screening, the model makes an assumption that only 21.5% \((n = 132,526)\) of those identified as high risk will follow-up with their physician (R. Genco et al., 2014). This adjustment to the entry in the Markov chain modelling was done to avoid unreasonable estimates and reflect as close as to real world example. The model will use the FPG as the test for diagnosis of pre-diabetes and T2DM. The GP will then investigate the patient’s blood glucose and based on the patient risk determine
whether to refer them for lifestyle modification program or not. One of the eligibility criteria for GP clinics for “life” program referral in Victoria is an AUSDRISK score of >12 (Life).

Table 6.1 Diagnostic criteria for pre-diabetes and DM used in this model

<table>
<thead>
<tr>
<th></th>
<th>FPG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normoglycemic</td>
<td>&lt; 6.1mmol/L (110mg/dl)</td>
</tr>
<tr>
<td>Pre-diabetes</td>
<td>≥ 6.1 but ≤ 6.9 mmol/L (111 - 125 mg/dl)</td>
</tr>
<tr>
<td>T2DM</td>
<td>≥ 7.0 mmol/l (≥126 mg/dl)</td>
</tr>
</tbody>
</table>

Royal Australian College of General Practitioners, guidelines for preventive activities in general practice, 2018

6.1.4 Study perspective

This study will employ a societal perspective as all costs and consequences will be included irrespective of who incurs the costs or benefits (Green, Emneus, Christiansen, & Björk, 2005; Polimeni, Vichansavakul, Iorgulescu, & Chandrasekara, 2013). The intervention will be evaluated and compared as if operating under steady state conditions.

6.1.5 Comparators

The comparator for this study will be current dental practice in Victoria (no screening for the risk of T2DM).

6.1.6 Time horizon

The model assumes one-off screening of patients in the dental setting using the AUSDRISK over a one-year period. The model will track the cohort for five- and ten-year period to determine the resulting costs and benefits.

6.1.7 Outcomes

Primary outcome

1. Number of new cases identified as at risk of hyperglycemia in the dental setting
2. Number of new cases identified as undiagnosed T2DM and pre-diabetes (hyperglycaemia not suggestive of DM) initiated through the dental route.

Secondary outcomes

Number of new cases identified as T2DM and pre-diabetes (hyperglycaemia not suggestive of DM) initiated through the dental route over a five- and ten-year period

6.1.8 Costs

Cost for screening in the dental setting will be calculated based on the report published by the Australian Dental Association dental fees survey (Australian Dental Association, 2016). Dental auxiliary staff (dental nurse and dental receptionist) time will be calculated based on the values observed in the PayScale website (PayScale, 2017).

Cost for screening and diagnosis including laboratory charges in the medical setting will be based on the values reported in an Australian study (C. M. Y. Lee et al., 2018). Since the modelling involves opportunistic screening in the dental setting, no additional travel costs will be incurred. Average travel distance of 20 kilometres to a primary health care physician in Victoria was obtained from (McGrail, Humphreys, & Ward, 2015). All costs will be reported in AUD for the reference year.

6.1.9 Model-Based Economic Evaluations

Using a hybrid decision tree and Markov simulation model, the cost-effectiveness of screening in the dental setting will be compared with no screening.

6.1.10 Decision tree cost effectiveness

The decision problem in the model is whether screening for T2DM in the private dental setting is cost-effective in the early identification of undiagnosed T2DM.
The simplest form of decision analytical modelling in economic evaluation is the decision tree. In order to quantify the trade-off for the costs and benefits of screening the decision tree used. The pathways that follow each option correspond to a series of logically controlled different events. The alternatives at each chance node are mutually exclusive, and their probabilities should sum exactly to one. The terminating condition for each pathway is denoted by a terminal node (Petrou & Gray, 2011).

The outcome of the screening and probabilities at each chance node are entered in TreeAge software “TreeAge Pro 2018, R2. TreeAge Software, Williamstown, MA; software available at http://www.treeage.com”. At the terminal nodes, the cost and effectiveness as number of new cases of T2DM or pre-diabetes identified are entered as pay off.

In the dental setting, the outcome of AUSDRISK screening is presented with two outcomes namely, low (AUSDRISK <12) and high risk (AUSDRISK >12). In the medical setting, the number of dental patients identified as pre-diabetes or T2DM in the first cycle will be used to report the cost of screening (dental and medical), and number of screen diagnosed pre-diabetes and T2DM as benefits.

**Markov modelling**

The Markov model tracks the cohort in the medical setting, for ten cycles with each cycle of one-year duration and an assumption of one cycle for the transition between health states. As such, each dental patient entering the first cycle will be categorised in one of the three health states, namely normoglycemia, pre-diabetes and T2DM. The fourth state is the absorbing state and includes those who die during the study period. The model (Figure 6.2 and 6.3) was constructed using TreeAge software. Data from previous studies and reports were used to populate the transition probabilities. The model applies FPG for the diagnosis of pre-diabetes and T2DM in the medical setting. The model assumes that each year, dental patients will be screened with FPG in the medical setting for up to 10 years.
6.1.11 Screening tool

The intervention will use the AUSDRISK questionnaire/tool (Appendix 7.1.3) for screening T2DM in the dental setting. The AUSDRISK was developed in 2008 by the Baker Heart Institute on behalf of the Australian government initiative to identify and reduce the risk of T2DM.

The AUSDRISK consists of a short list of ten questions that include age, gender, ethnicity/country of birth, family history of DM, history of high blood glucose, medication for high blood pressure, history of smoking, fruit and vegetable consumption, physical activity and waist measurement) to help both health professionals and consumers assess the risk of a person developing T2DM over the next five years. Individual scores for each question are added up to give a final AUSDRISK score. The AUSDRISK can be completed by the patient on their own or with the assistance of a health professional (Australian Government - Department of Health, 2016). It takes approximately five minutes to complete the questionnaire.
Figure 6.2 Disease state transition model
Figure 6.3 Screening in the medical setting – Markov model
Data source for the model

Table 6.1 Data source and implication

<table>
<thead>
<tr>
<th>Data information</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incidence and prevalence IFG and DM in Victoria</td>
<td>• National Diabetes Service Scheme (National Diabetes Service Scheme, 2017b)</td>
</tr>
<tr>
<td></td>
<td>• Diabetes Australia (Diabetes Australia, 2018)</td>
</tr>
<tr>
<td></td>
<td>• GGT RFS (Malo et al., 2015)</td>
</tr>
<tr>
<td>Transition probabilities from normoglycemic to T2DM</td>
<td>• AusDiab (Barr &amp; Welborn, 2007; C. M. Y. Lee et al., 2018)</td>
</tr>
<tr>
<td>and mortality</td>
<td>• Pre-diabetes (Bertram &amp; Vos, 2010)</td>
</tr>
<tr>
<td>Victoria resident population profile and estimates</td>
<td>• Australian Bureau of Statistics</td>
</tr>
<tr>
<td></td>
<td>• National Diabetes Service Scheme (National Diabetes Service Scheme, 2017a)</td>
</tr>
<tr>
<td>Dental patient risk of T2DM with AUSDRISK tool</td>
<td>• T2DM screening in Colac Area Health, public oral health services (M. Rogers, Pawlak, Law, Carroll, &amp; Sharp, 2017)</td>
</tr>
<tr>
<td>Cost parameters (hourly estimates/procedural type)</td>
<td>• Pay scale Australia (PayScale, 2017; PaySclae, 2017) (Dental Nurse &amp; receptionist)</td>
</tr>
<tr>
<td></td>
<td>• Dental fees survey Australia 2016 (Australian Dental Association, 2016)</td>
</tr>
<tr>
<td></td>
<td>• Follow-up of patient data from the “Australian Diabetes, Obesity and Lifestyle study” (C. M. Y. Lee et al., 2018)</td>
</tr>
</tbody>
</table>

Diabetes mellitus incidence and prevalence in Victoria

Information on the number of newly diagnosed DM registrants in Victoria was obtained from the NDSS. The NDSS is an Australian Government initiative commenced in 1987 and is
administered with the assistance of Diabetes Australia (National Diabetes Service Scheme). The NDSS provides an up-to-date adjusted estimate of the number of people with known DM and T2DM based on Australian Bureau of Statistics population projection statistics and the number of people with known DM registered with the NDSS. One of the key features of the NDSS is the Australian Diabetes Map (National Diabetes Service Scheme, 2017c).

In 2017, there were a total of 9,404 new registrants between 40 and 74 years in Victoria. As of 31st December 2017, 1.27 million or 5.1% (National Diabetes Service Scheme, 2017a) of Australians with DM were registered with the NDSS, of which 87% (1.10 million) were identified to have T2DM (National Diabetes Service Scheme, 2017a). It is estimated that approximately 30% of all the DM in Australia is undiagnosed (Diabetes Australia, 2018). Data from the Australian Diabetes Map (Table 6.3 to 6.5) were used to determine the number of people with known (diagnosed) DM and T2DM for Victoria and its regions (National Diabetes Service Scheme, 2017c) as well as the proportion undiagnosed.

These data were then used to estimate the number of Victorian adults between 40 – 74 years who were eligible for T2DM screening in the dental setting. Table 6.4 describes the total number of Victorians aged between 40 and 74 years was 2,442,700. Some 8.3% of this population (n =202,750) were diagnosed with DM and registered with the NDSS (both T1DM & T2DM (National Diabetes Service Scheme, 2017c). The number of Victorians aged 40 to 74 years with undiagnosed T2DM was estimated at 60,825, making the total estimated number with DM (prevalence) at 263,575 which is 10.79% of the Victorian population in this age group. Since 202,750 individuals were already diagnosed, the total number of Victorians in the 40 to 74-year-old age group eligible for screening was 2,239,950 (91.70%).

Prevalence estimates of undiagnosed T2DM were obtained from Diabetes Australia. Since there is no available data on the prevalence of undiagnosed T2DM by age group, the 30% estimate reported by Diabetes Australia was applied to the 40 to 74-year old hypothetical model Victorian population.
Table 6.2 Prevalence of DM in Victoria by region for all age group

<table>
<thead>
<tr>
<th>Victoria region based on PHN</th>
<th>Population</th>
<th>NDSS registration</th>
<th>Estimated prevalence of DM</th>
<th>Estimated prevalence of T2DM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DM</td>
<td>(30%) **</td>
<td>(diagnosed + undiagnosed)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
</tr>
<tr>
<td>Western Victoria</td>
<td>669,135</td>
<td>37,085</td>
<td>5.5</td>
<td>32,429</td>
</tr>
<tr>
<td>Murray</td>
<td>648,650</td>
<td>37,123</td>
<td>5.7</td>
<td>32,704</td>
</tr>
<tr>
<td>Gippsland</td>
<td>296,826</td>
<td>19,004</td>
<td>6.4</td>
<td>17,007</td>
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<td>Melbourne (NW)</td>
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<td>76,907</td>
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<td>Melbourne E</td>
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<td>72,097</td>
<td>4.7</td>
<td>62,538</td>
</tr>
<tr>
<td>Melbourne (SE)</td>
<td>1,496,874</td>
<td>72,977</td>
<td>4.9</td>
<td>63,212</td>
</tr>
<tr>
<td>Total *</td>
<td>6,255,254</td>
<td>323,313</td>
<td>5.2</td>
<td>282,324</td>
</tr>
</tbody>
</table>

Data source: Australian Diabetes Map, National Diabetes Service Scheme, N = number, % = percentage, PHN = Primary Health Network, * = the total values may be different to the values for individual region within. ** estimates are made at 30% based on the percentage of DM reported.
<table>
<thead>
<tr>
<th>Victoria region based on PHN</th>
<th>Total Victorian Population</th>
<th>Population by age group</th>
<th>NDSS registration</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>40 - 49</td>
<td>50 - 59</td>
<td>60 - 69</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
</tr>
<tr>
<td>Western Victoria</td>
<td>669,135</td>
<td>87,197</td>
<td>3.3</td>
<td>5,770</td>
</tr>
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<td>Murray</td>
<td>648,650</td>
<td>83,576</td>
<td>3.4</td>
<td>5,795</td>
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<td>Gippsland</td>
<td>296,826</td>
<td>36,980</td>
<td>3.6</td>
<td>2,901</td>
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<td>Melbourne (NW)</td>
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<td>212,585</td>
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<td>Melbourne E</td>
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<td>212,834</td>
<td>2.8</td>
<td>11,700</td>
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<tr>
<td>Melbourne (SE)</td>
<td>1,496,874</td>
<td>205,985</td>
<td>3.3</td>
<td>12,409</td>
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<tr>
<td>Total *</td>
<td>6,255,254</td>
<td>839,157</td>
<td>3.38</td>
<td>54,146</td>
</tr>
</tbody>
</table>

Data source: Australian Diabetes Map, National Diabetes Service Scheme
Table 6.4 Victorians registered as T2DM in 40 to 74 years old

<table>
<thead>
<tr>
<th>Victoria region based on PHN</th>
<th>Total Population</th>
<th>DM All ages</th>
<th>DM 40 – 74 years</th>
<th>Proportion of total DM in 40 - 74-year age group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western Victoria</td>
<td>669,135</td>
<td>32,429</td>
<td>23,061</td>
<td>71.11</td>
</tr>
<tr>
<td>Murray</td>
<td>648,650</td>
<td>32,704</td>
<td>23,058</td>
<td>70.50</td>
</tr>
<tr>
<td>Gippsland</td>
<td>296,826</td>
<td>17,007</td>
<td>12,005</td>
<td>70.58</td>
</tr>
<tr>
<td>Melbourne (NW)</td>
<td>1,600,213</td>
<td>76,907</td>
<td>54,664</td>
<td>70.07</td>
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<td>Melbourne E</td>
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<td>62,538</td>
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<td>45,388</td>
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<tr>
<td>Total *</td>
<td>6,255,254</td>
<td>282,324</td>
<td>202,750</td>
<td>71.81</td>
</tr>
</tbody>
</table>

Data source: National Diabetes Service Scheme, PHN; primary health network
Transition probabilities for health states

Data from the GGT RFS were used to populate the probabilities for normoglycemia, IFG and T2DM in the first cycle (Malo et al., 2015). Thereafter, for the rest of the cycles, health state transitions for each year were calculated based on the five-year follow-up of AusDiab study participants. The average duration of pre-diabetes obtained from the systematic review by Bertram was used to overcome the missing information on the transition probabilities from pre-diabetes to T2DM in the AusDiab study (Bertram & Vos, 2010).

6.1.12 Dental visit patterns of Australians by age groups

Dental visit data for Australian adults were obtained from a report published by the Australian Institute of Health and Welfare (Australian Institute of Health and Welfare, 2015).

Dental attendance patterns were used to determine the number of dental patients to be included in the model. Some 63% of Australians, 25 years and over, had visited a dentist at least once in the last 12 months. Overall, 83.5% of males and 85.1% of females of all age groups visited a private dental practice. The model applies 63% for the dental visit to all the eligible dental patients \((n = 2,239,950)\) in the 40 to 74-year bracket, and an average of 84% (decimals rounded off to the nearest whole number) was used as the dental attendance to private clinics. Based on this assumption, 1.18 million people would be eligible for T2DM screening in the dental setting.

6.1.13 Study that used AUSDRISK tool in Australia.

There is currently one study that had used AUSDRISK in the dental setting (E. A. Rogers et al., 2014); it was conducted by Colac Area Health, a public oral health service in South West Victoria, Australia. Participants were 18+ years presenting to the community dental clinic for general or emergency care. This study used a two-stage screening approach, AUSDRISK followed by PoC HbA1c to identify those with undiagnosed DM. The study identified 7.3% of those with a high (>12) AUSDRISK score were with a Point of Care HbA1c value of 6%. The
model applies AUSDRISK values derived from this study, being the only available study that had used the AUSDRISK in the dental setting in Australia or Victoria.

The model will use the AUSDRISK values derived from “Greater Green Triangle Risk Factor Study” (GGT RFS) carried out in 2004 and 2005 in the Greater Green Triangle region in southeastern Australia (Figure 6.4). Malo et al. (2015) used the GGT RFS survey response data among those aged 40 – 74 years for calculating the AUSDRISK scores with sensitivity and specificity at different cut off values of FPG. The AUSDRISK scores at different cut off points will be applied in the model’s hypothetical dental cohort to project for the Victorian population (Malo et al., 2015).

Figure 6.4 Greater green triangle region of Victoria

The model will also use the AUSDRISK values from participant follow up data from the “Australian Diabetes, Obesity and Lifestyle study” (AusDiab study). The AusDiab is the most extensive population-based longitudinal study examining the prevalence of DM, CVD and kidney disease in Australia. The study commenced in the year 1999-2000 and included 11,247 adults from 42 locations across Australia. The study participants were followed up in 2004/2005 and again in 2011/2012 to provide first-ever information on the incidence of DM.
Data derived from the follow up of the AusDiab study including the cost parameters will be used in the model (Baker Heart and Diabetes Institute; C. M. Y. Lee et al., 2018).

Table 6.5 Decision Tree values

<table>
<thead>
<tr>
<th>Model input values</th>
<th>Population N (%)</th>
<th>Cost in AUD ($) *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Victorian eligible for screening in the 40 to 74-year age group</td>
<td>1,185,382 (100%)</td>
<td></td>
</tr>
<tr>
<td>Cost for screening 1 person in the dental setting with AUSDRISK</td>
<td>$ 41</td>
<td></td>
</tr>
<tr>
<td>AUSDRISK T2DM risk category</td>
<td></td>
<td></td>
</tr>
<tr>
<td>low</td>
<td>177,807 (15%)</td>
<td>$ 7,290,099</td>
</tr>
<tr>
<td>Intermediate</td>
<td>391,176 (33%)</td>
<td>$1 6,038,216</td>
</tr>
<tr>
<td>High</td>
<td>616,399 (52%)</td>
<td>$ 25,272,360</td>
</tr>
<tr>
<td>Total cost for screening in dental setting</td>
<td>1,185,382 (100%)</td>
<td>$ 48,600,675</td>
</tr>
<tr>
<td>Assuming GP follow-up of all those identified as high risk</td>
<td>616,399 (100%)</td>
<td></td>
</tr>
<tr>
<td>Cost for screening 1 person in the medical setting with FPG</td>
<td>$ 114</td>
<td></td>
</tr>
<tr>
<td>Normoglycemia</td>
<td>552,294 (89.6%)</td>
<td>$ 62,961,516</td>
</tr>
<tr>
<td>Pre-diabetes - IFG</td>
<td>46,846 (7.6%)</td>
<td>$ 5,340,444</td>
</tr>
<tr>
<td>Undiagnosed Diabetes Mellitus</td>
<td>17,260 (2.8%)</td>
<td>$ 1,967,640</td>
</tr>
<tr>
<td>Total cost of screening in medical</td>
<td>599,140 (100%)</td>
<td>$ 70,269,600</td>
</tr>
<tr>
<td>Cost for diabetes prevention program/ person</td>
<td>$ 425</td>
<td></td>
</tr>
<tr>
<td>Eligible for diabetes prevention program</td>
<td>46,846 (7.6%)</td>
<td>$ 254634500</td>
</tr>
<tr>
<td>Cost for 1 person with uncomplicated diabetes/ year</td>
<td>$ 4025</td>
<td></td>
</tr>
<tr>
<td>Diabetes management</td>
<td>17, 260 (2.8%)</td>
<td>69,471,500</td>
</tr>
</tbody>
</table>

*Details of the cost calculation are presented in Table 6.7 below
Table 6.6 Model cost parameters and calculation in steady-state conditions

<table>
<thead>
<tr>
<th>Cost category</th>
<th>Source/ comments</th>
<th>Cost in AU $</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dental setting</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Patient time</td>
<td>This is opportunistic screening and does not include additional cost to the patient time at the dental clinic</td>
<td>n/a</td>
</tr>
<tr>
<td>b) Dentist additional time to discuss patient risk scores (5 min)</td>
<td>Dentist earns an average of AUD 435/ hr in Australia – data obtained from the Dental fees survey of private practice members 2016(Australian Dental Association, 2016)</td>
<td>36.25 (P-OP)</td>
</tr>
<tr>
<td>c) Dental Receptionist additional time (10 min)</td>
<td>A dental receptionist earns an average (Median) salary of AU$23.26/hr in Australia (PayScale, 2017)</td>
<td>03.87 (P-OP)</td>
</tr>
<tr>
<td>(Additional time required for informing the patient about the study, distribution of PLS and obtaining the consent and a possible referral)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d) Dental Nurse time (2 min)</td>
<td>A dental nurse earns an average (Median) salary of AUD 23.18/hr in Australia (PayScale, 2017)</td>
<td>0.79 (P-OP)</td>
</tr>
<tr>
<td>(Additional time required for discussing the study scores with the patient)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total cost for screening in the dental setting</strong></td>
<td></td>
<td>41</td>
</tr>
<tr>
<td><strong>Medical setting</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) GP consultation (two consultations to request a blood test and discuss the test results)</td>
<td>Supplementary table (Medicare Benefit Schedule item number 23) (C. M. Y. Lee et al., 2018)</td>
<td>37.05 x 2 = 74.10 (HCP)</td>
</tr>
<tr>
<td>b) Laboratory cost for FPG (Medicare rebate applies for asymptomatic patient)</td>
<td>Blood test - Medicare Benefit Schedule item number (66500) (C. M. Y. Lee et al., 2018)</td>
<td>9.70 (HCP) 1.45 (P-OP)</td>
</tr>
<tr>
<td>c) Patient travel (fuel cost)</td>
<td>Assumption based on fuel cost</td>
<td></td>
</tr>
<tr>
<td>i. For GP session 1 &amp; 2</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>ii. Laboratory travel</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td><strong>Total cost for screening in the medical setting</strong></td>
<td></td>
<td>114</td>
</tr>
</tbody>
</table>

PLS = plain language statement; GP = general practitioner; DM = diabetes mellitus; T2DM = type 2 diabetes mellitus; FPG = fasting plasma glucose; HCP = health care perspective; P-OP = patient out of pocket
6.2 Results

In this section, the results of the risk profiling using the AUSDRISK in the dental setting and screen diagnosis of T2DM and pre-diabetes using the FPG to determine disease prevalence, incidence and risk progression in the medical setting will be discussed. A road map of the entire model and state transition diagram is presented in Figure 6.5.

6.2.1 Cost effectiveness analysis for risk identification

Based on the calculation described in the methods section, the model assumes the number of Victorian dental patients aged between 40 and 74 years screened with the AUSDRISK in one year in the dental setting as 1,185,382. This represents 48.5% of the Victorian population (n = 2,442,700) in this age group.

The decision tree and the results of the screening in the dental setting are presented in figure 6.6 and Table 6.8. Some 15% (177,807), 33% (391,176) and 52% (616,400) of the cohort (n = 1,185,382) were identified as low, intermediate and high risk for T2DM.

The cost of screening one dental patient in the dental setting with AUSDRISK was estimated at $41. To screen the entire cohort of 1,185,382, the estimated cost was $48,600,662. The analysis identified 616,400 dental patients at risk of T2DM. The NNS to identify one dental patient at high risk for T2DM is 1.92, and the cost for identifying one dental patient as high risk for T2DM was determined as $78.85.
Figure 6.5 Diabetes screening entire model
Figure 6.6 Cost effectiveness analysis in the dental setting.

![Diagram showing cost effectiveness analysis in the dental setting]

Table 6.7 Cost-effectiveness analysis in the dental setting

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Cost</th>
<th>Incr Cost</th>
<th>Eff</th>
<th>Incr Eff</th>
<th>Incr C/E</th>
<th>NMB</th>
<th>C/E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excluding dominated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No screening</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>AUSDRISK screening</td>
<td>$48,600,662</td>
<td>$48,600,662</td>
<td>616,400</td>
<td>616,400</td>
<td>$78.84</td>
<td>n/a</td>
<td>$78.84</td>
</tr>
<tr>
<td>All</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No screening</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>n/a</td>
</tr>
<tr>
<td>AUSDRISK screening</td>
<td>$48,600,662</td>
<td>$48,600,662</td>
<td>616,400</td>
<td>616,400</td>
<td>$78.84</td>
<td>n/a</td>
<td>$78.84</td>
</tr>
<tr>
<td>All referencing common baseline</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>No screening</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>n/a</td>
</tr>
<tr>
<td>AUSDRISK screening</td>
<td>$48,600,662</td>
<td>$48,600,662</td>
<td>616,400</td>
<td>616,400</td>
<td>$78.84</td>
<td>n/a</td>
<td>$78.84</td>
</tr>
<tr>
<td>All by Increasing effectiveness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No screening</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>AUSDRISK screening</td>
<td>$48,600,662</td>
<td>616,400</td>
<td></td>
<td>n/a</td>
<td></td>
<td>$78.84</td>
<td></td>
</tr>
</tbody>
</table>

AUSDRISK Australian diabetes risk assessment tool
6.2.2 Cost effectiveness analysis to identify undiagnosed T2DM

The natural history of the disease progression starts with the first screen in the medical setting (cycle 1) to determine the prevalence of undiagnosed pre-diabetes (preclinical, screen-detectable stage) and undiagnosed T2DM (clinical, screen-detectable stage). Prevalence estimates for undiagnosed T2DM and pre-diabetes for the first screening were based on the GGT RFS. With this assumption the prevalence of undiagnosed T2DM and pre-diabetes among the 40 to 74-year-old dental patient was identified as 3.1% (n = 4,108) and 7.6% (n=10,072).

Results of the cost-effectiveness analysis are presented in Figure 6.7 and Table 6.9. Based on this assumption, the cost to screen with the AUSDRISK all the dental cohort and further screen diagnose 21.5% (n= 132,526) of those identified as high risk with FPG in the medical setting is $63,708,626. The total cost calculated to identify one new case of undiagnosed T2DM was $15,508 and the NNS to screen diagnose one dental patient from the entire cohort of 1,185,382 as undiagnosed T2DM is 288.

Figure 6. 7 Screening (dental and medical together) cost and effectiveness
Table 6.8 Cost-effectiveness analysis

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Cost</th>
<th>Incr Cost</th>
<th>Eff</th>
<th>Incr Eff</th>
<th>Incr C/E</th>
<th>NMB</th>
<th>C/E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excluding dominated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No screening (standard care)</td>
<td>0</td>
<td>0</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>Screening</td>
<td>$63,708,626</td>
<td>$63,708,626</td>
<td>4,108</td>
<td>4,108</td>
<td>15,508</td>
<td>n/a</td>
<td>15,508</td>
</tr>
<tr>
<td>All</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No screening (standard care)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>Screening</td>
<td>$63,708,626</td>
<td>$63,708,626</td>
<td>4,108</td>
<td>4,108</td>
<td>15,508</td>
<td>n/a</td>
<td>15,508</td>
</tr>
<tr>
<td>All referencing common baseline</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No screening (standard care)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>n/a</td>
<td>undominated</td>
</tr>
<tr>
<td>Screening</td>
<td>$63,708,626</td>
<td>$63,708,626</td>
<td>4,108</td>
<td>4,108</td>
<td>15,508</td>
<td>n/a</td>
<td>15,508</td>
</tr>
<tr>
<td>All by Increasing effectiveness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No screening (standard care)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>Screening</td>
<td>6,3708,626</td>
<td>4,108</td>
<td>n/a</td>
<td>15,508</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Incr, Incremental; Eff, effectiveness; NMB, net monetary benefit; C/E, cost/effectiveness

6.2.3 Five-year follow-up

6.2.3.1 Incidence of type 2 diabetes mellitus

Incident cases of new T2DM were defined as those dental patients who were normoglycemic or pre-diabetes by IFG at baseline (cycle 1) but had developed T2DM during the five-year follow-up (Figure 6.8, appendix 7.1.5 and 7.1.6). The annual incidence of T2DM among those with normoglycemia and IFG at baseline was 0.8% and 2.2%. In the five-year follow-up, the number of dental patients newly identified as T2DM was 5,704 (4.4%). This indicates that one in every 22.5 dental patients with an AUSDRISK score of ≥12 was identified as at high risk of developing T2DM within a five-year period.

Based on the annual incidence of T2DM, the relative risk was calculated (Table 6.10) for each year to determine the risk of developing T2DM over a period of five years among dental patients with pre-diabetes to those with normal glucose tolerance (NGT). The mean relative risk of developing T2DM over a period of five years was 2.74, (SD 0.017) times higher for
dental patients with pre-diabetes compared to that of NGT. The NNS one positive case of undiagnosed T2DM during each year of follow up in the five-year period is 70.68 (SD = 0.30).

Figure 6. 8 Diabetes incidence by baseline glucose tolerance status

![Diabetes incidence chart]

Table 6.9 T2DM incidence and relative risk over a five-year period

<table>
<thead>
<tr>
<th>Year</th>
<th>IFG</th>
<th>Screen positive</th>
<th>Screen negative</th>
<th>NGT</th>
<th>Screen positive</th>
<th>Screen negative</th>
<th>RR (95% CI)</th>
<th>z Statistic</th>
<th>NNS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>222</td>
<td>9750</td>
<td></td>
<td>947</td>
<td>116215</td>
<td></td>
<td>2.75 (2.3-3.1)</td>
<td>13.7</td>
<td>70.5 (81.7-61.9)</td>
</tr>
<tr>
<td>2</td>
<td>225</td>
<td>9896</td>
<td></td>
<td>930</td>
<td>114124</td>
<td></td>
<td>2.71 (2.3-3.1)</td>
<td>13.5</td>
<td>71.2 (82.8-62.5)</td>
</tr>
<tr>
<td>3</td>
<td>228</td>
<td>10029</td>
<td></td>
<td>913</td>
<td>112069</td>
<td></td>
<td>2.75 (2.3-3.1)</td>
<td>13.8</td>
<td>70.5 (81.8-62.1)</td>
</tr>
<tr>
<td>4</td>
<td>231</td>
<td>10150</td>
<td></td>
<td>897</td>
<td>110052</td>
<td></td>
<td>2.75 (2.3-3.1)</td>
<td>13.8</td>
<td>70.5 (81.7-62.1)</td>
</tr>
<tr>
<td>5</td>
<td>233</td>
<td>10259</td>
<td></td>
<td>880</td>
<td>108071</td>
<td></td>
<td>2.74 (2.3-3.1)</td>
<td>13.8</td>
<td>70.7 (81.9-62.2)</td>
</tr>
</tbody>
</table>

Significance level = P<0.0001, NNS number needed to screen, CI confidence interval, IFG impaired fasting glucose, NGT normal glucose tolerance, RR relative risk

6.2.3.2 Incidence of pre-diabetes

Incident cases of new pre-diabetes were defined as those dental patients who were normoglycemic at baseline (cycle 1) and had developed IFG during the five-year follow-up but not progressed further to T2DM during this period. The annual incidence of IFG among those with normoglycemia at baseline was 0.4%. In the five-year follow-up, the number of dental
patients who were newly diagnosed as pre-diabetes was 2,283. Since IFG is a transient state before progressing to T2DM and my model was hypothetical, it was not possible to give a precise value on the number of dental patients who made two transitions from Normoglycemic to IFG and further progressed to T2DM. However, the annual rate of progression from normal blood glucose status to pre-diabetes during the five-year period in this cohort was 0.38%. This indicates that one in every 52 dental patients was identified as of high risk of developing T2DM within a five-year period.

6.2.3.3 Mortality

The model calculated all-cause mortality according to the glucose tolerance state. All-cause mortality refers to death due to any cause within each health state. AusDiab study mortality data was used for each health state for this assumption. The annual incidence of mortality among the different health states is presented in figure 6.9. Over the five-year follow-up, there were 4623 deaths recorded in this age group. When compared to those with NGT, deaths among those with newly diagnosed T2DM and pre-diabetes were 3.6 times and 1.6 times higher respectively.

6.2.3.4 Survival

Disease-free survival refers to the length of time after primary diagnostic screening in the medical setting that a patient survives without being diagnosed as T2DM. Overall survival refers to the length of time after primary diagnostic screening; the dental patient survives with or without the disease. Figure 6.13 shows the overall and disease-free (T2DM) survival among the cohort. In the base case scenario, 96.9% (n = 128417) of the dental patients identified as at high risk were free of T2DM. At the end of five years, T2DM free survival was 89.6%, and the overall survival among the cohort was 96.5%.
Figure 6. 9 Five-year mortality by baseline glucose tolerance.

NGT normal glucose tolerance; IFG impaired fasting glucose; DM diabetes mellitus

6.2.4 Ten-year follow-up

To identify the risk progression over a period of 10-year, the Markov chain model was extended for an additional five years with a constant annual incidence and disease transition probabilities. Figure 6.11, appendix 7.1.5 and 7.1.6 shows the risk of disease progression over a period of 10 years from the baseline values (cycle 1).

6.2.4.1 Incidence of type 2 diabetes mellitus

The number of dental patient cohort with newly diagnosed T2DM during the ten-year follow-up was 11,068 (8.6%). Of those, 8733 and 2335 had NGT and IFG developed T2DM. This indicates 7.3% and 23.1% of those with NGT and IFG at baseline developed T2DM over the 10-year duration.
6.2.4.2 Incidence of pre-diabetes

The number of dental patients in this cohort who were newly diagnosed with IFG is 4,368. This shows 3.7% of those with NGT developed IFG during the 10-year period indicating an annual rate of progression from NGT to pre-diabetes as 0.36%. One in every 27-dental patient with NGT identified as high risk with the diabetes risk assessment tool will develop pre-diabetes during the 10-year period.

6.2.4.3 Mortality

During the 10-year period, there were 9,542 deaths recorded within the cohorts. Among those 6,552 were in NGT, 1,060 were with IFG and 1,876 were T2DM. Figure 6.12 shows the mortality by percentage among different health states over the 10-year period. The risk of mortality was three and two times higher among those diagnosed with T2DM and IFG compared to those with NGT.
6.2.4.4 Survival

Figure 6.13 shows the overall and disease-free (T2DM) survival among the cohort. In the base case scenario, 96.9% (n = 128417) of dental patients identified as high risk were free of T2DM. At the end of 10 years, T2DM free survival was 82.8%, and the overall survival among the cohort was 92.8%.

Figure 6.12 Total mortality over the 10-year period in different health states
6.2.5 Conclusion

The cost of screening one dental patient with AUSDRISK in the dental setting was estimated at $41 and the entire dental cohort of 1,185,382 between 40 and 74 years in Victoria is $48,600,703. The NNS for one dental patient as high risk for T2DM is 1.9. The cost of identifying one dental patient at high risk for T2DM was determined as $78.85.

The cost to identify one dental patient as T2DM (who was previously undiagnosed) is $15,508. The NNS in the dental setting to diagnose one dental patient as undiagnosed T2DM in the medical setting is 288.

At the end of five-years, 8.7% with NGT progressed away to other health states namely IFG, T2DM or death, among those identified as high risk in the dental setting. There was a 6.5% increase in the number of dental patients with IFG compared to baseline values. The number of dental patients diagnosed with T2DM increased 2.2 times compared to baseline values, and the mortality among those with an AUSDRISK score of ≥12 was 3.5%.

At the end of 10 years, 16.69% of those with NGT at baseline progressed away from the health state to IFG, T2DM or death. There was a 9.2% increase in the number of cohorts with IFG.
compared to baseline values, and the number of people diagnosed with T2DM increased 3.2 times compared to baseline values. Mortality among the entire cohort was 7.2%.

6.3 Discussion

In this chapter, the model results will be compared with the literature on T2DM screening. Further, the theoretical and practical implication of screening to facilitate future policy recommendation will be discussed in the broader contest. To the best of my knowledge, this study is the first of its kind in Australia to screen the entire Victorian adults, between 40- and 74-year adults, eligible for screening with the AUSDRISK diabetes risk assessment tool in the dental setting followed by a diagnostic test in the medical setting to predict undiagnosed T2DM. Further, the disease progression model predicts the risk of T2DM and pre-diabetes over a five- and ten-year period.

6.3.1 Risk assessment questionnaire

To date, only one study reported using the AUSDRISK diabetes risk assessment questionnaire in the dental setting. Considering it was done among the Victorian population the model applied the data to categorise dental patients at low or high risk of T2DM. Having said that, globally, 15 other studies had reported using two step screening approach that include diabetes risk assessment followed by PoC HbA1c or blood glucose investigation in the dental setting (Akyil, Miloglu, Olgun, & Bayrakdar, 2014; AlGhamdi, Merdad, Sonbul, Bukhari, & Elias, 2013; Barasch et al., 2013; Biethman, Pandarakalam, Garcia, Whitener, & Hildebolt, 2017; Bossart et al., 2016; Bould, Scott, Dunne, & Asimakopoulou, 2017; Engstrom, Berne, Gahnberg, & Svardsudd, 2013; Franck, Stolberg, Bilich, & Payne, 2014; Genco et al., 2014; Giblin, Rainchuso, & Rothman, 2016; Hadlaq et al., 2017; Harase et al., 2015; E Lalla, Kunzel, Burkett, Cheng, & Lamster, 2011; Lamster, Cheng, Burkett, & Lalla, 2014; Mulligan, Lipson, & Heaton, 1990). Of them, only five had used the entire list of questions from the validated risk assessment questionnaire to determine dental patients risk of T2DM (Akyil et al., 2014; Bould et al., 2017; Franck et al., 2014; Genco et al., 2014; Giblin et al., 2016). Further, only two of those five used the validated risk assessment questionnaire as a pre-requisite for blood glucose investigation (Bould et al., 2017; Franck et al., 2014). Four (Barasch et al., 2013;
Biethman et al., 2017; Bossart et al., 2016; E. Lalla, Cheng, Kunzel, Burkett, & Lamster, 2013) of the ten studies that did not use the entire list of questions applied just one to four questions from the ADA risk assessment questionnaire in some capacity. The remainder of the studies did not use a validated diabetes risk assessment questionnaire for risk stratification. Instead, they relied on one or more traditional risk factors that met the study requirement for selection to screen.

Reasons for not testing the entire list of questions to determine dental patients risk score was not explicitly stated in any of the studies. However, it is thought the reasons may be due to the reduced number of participants being categorised as high risk when conforming to the risk stratification or it may well be to maximise participants number eligible for blood glucose investigation or HbA1c test. Overall, four validated diabetes risk assessment questionnaire ((ADA type 2 diabetes risk test, the Finnish diabetes risk score, the Australian diabetes risk assessment tool and the Heikes diabetes risk calculator (American Diabetes Association; Chen et al., 2010; Heikes, Eddy, Arondekar, & Schlessinger, 2008; Silventoinen et al., 2005)) were used in the dental setting to predict the risk of T2DM. It includes information on lifestyle, sociodemographic and anthropometric measures to predict and categorise individuals in low medium or high-risk groups. All have a lot in common being simple, non-invasive and agreement on the common risk factors in predicting DM. Despite their closeness, they are not comparable to one other in predicting the future risk of incident DM by the duration of onset.

6.3.2 model outcomes

The model identified a large number (more than four times) of dental patients as high risk with the AUSDRISK, but only 1.6% of all those screened with the AUSDRISK were within the DM range (assuming no loss of GP follow-up) when tested with the FPG. A study conducted in general dental practice in England (Bould et al., 2017) that used the FINDRISC identified 12.3% of the ≥45-year-old dental patients at high risk for T2DM. Among that 4.1 % and 45% were within the DM and pre-diabetes range when screened with the point of care HbA1c. This suggests that one in every 200 dental patients were identified to be within the DM range. The Australian study conducted in the Colac region of Victoria (Colac study)(Rogers, Pawlak, Law, Carroll, & Sharp, 2017) that used the AUSDRISK in the dental setting identified 4.2 times
more number of dental patient as high risk when compared to the FINDRISC. This study used 6% HbA1c as a cut off value for high risk and identified one in every 26.5 patient as high risk for T2DM. But the study fell short of reporting how many of those identified as high risk were within the pre-diabetes or DM range despite using the PoC HbA1c in the two-step screening.

An English study that used the FINDRISC followed by the point of care HbA1c identified 25% more number of dental patients within the DM range. In the AusDiab study, AUSDRISK followed by the FPG identified 1.4% as undiagnosed T2DM. When HbA1c was used for screen diagnosis in one other scenario in the AusDiab study, it identified 0.4% of the ≥40 years study participants as undiagnosed T2DM (Lee et al., 2018). In the GGT RFS study, 2.7% of all those screened with the AUSDRISK followed by the FPG were within the DM range. Although, the GGT RFS identified two and 6.7 times as many people within the DM range compared to the FPG or HbA1c used in the AusDiab study it has some important limitations. Firstly, the GGT RFS was a cross-sectional study by design, unlike the prospective AusDiab study. Secondly, the number of study participants in the 40 to 74-year-old was one fourth to that of the 40 years and older AusDiab study participants. Thirdly, the GGT RFS was carried out to identify the risk of DM in a high-risk region in rural Victoria, unlike the prospective AusDiab study that included representative samples from several randomly selected sites in Australia. In spite of these limitations, the model applied the GGT RFS values for undiagnosed T2DM because the AUSDRISK values of ≥12 in the 40 to 74 years age group correspond well with the model age group and the study was carried out in the Victorian population.

In the AusDaib study, 1.4% of the ≥40 years study participants were identified as undiagnosed T2DM compared to 1.6% in my model. This suggests that the results were in line with the nationally representative population in Australia. Having said that, the model results may still be an overestimation of undiagnosed T2DM in the 40 to 74-year-old Victorian dental patients. The reason for such a belief stems from three crucial consideration. Firstly, The AUSDRISK diabetes risk categorization is based on the findings from the Colac public oral health services (Colac study) in South West Victoria (Rogers et al., 2017). The Colac study has several limitations that may have exaggerated the dental patient risk of T2DM. The Colac region is socio-economically disadvantaged where residents had to travel 100 kilometres to access dental services. Thirty-one percent of the Colac study participants were recruited from the emergency
dental services. The two-step screening approach (AUSDRISK followed by the PoC HbA1c) used in the Colac study failed to report the number of dental patients within the DM or pre-diabetes range, and the AUSDRISK risk categorization based on age is not described. According to the 2011 “index of relative socio-economic disadvantage” Colac is a socioeconomically disadvantaged region within Victoria and Australia as a whole (id - the population experts, 2011). Residents in this region experience 65% lower educational attainment (completed year 12 or equivalent) and 25% higher disability when compared to the Victorian average (Australian Bureau of Statisticcs, 2018). Disadvantaged communities with lower education attainment experience far greater oral and general health needs compared to those in middle income or affluent communities. Despite these limitations, the model applied the AUSDRISK risk category from this study because it is the only available study that used the AUSDRISK in the dental setting. The reason for not reporting dental patients within the DM range in the Colac study may be that the findings did not correspond well with the national estimates of undiagnosed DM as 30%. To overcome this limitation, the model applied FPG values among the 40 to 74 years old GGT RFS participants with the AUSDRISK score of 12 and above.

Secondly, the 3.1% (n=4,104) of the dental patient identified as undiagnosed T2DM is indeed an undeniable misnomer. A vast majority of dental patient categorised as high risk and referred to the GP for screen diagnosis may well have accessed the GP on their own and diagnosed as T2DM. The 2016-2017, Patient experience survey in Victoria reported 82% of the adults in Victoria saw a GP within the previous 12 months (Australian Institute of Health and Welfare, 2018). Therefore, 3,368 of the 4108 dental patients identified as undiagnosed T2DM would have accessed the GP otherwise on their own. However, there is a 30% chance that the DM may have gone undetected based on the estimates for undiagnosed T2DM in Australia (Sainsbury, Shi, Flack, & Colagiuri, 2018). With this assumption, only 2342 (57%) of the 4,108 dental patients should be categorised as new cases of T2DM diagnosed by the GP in a reasonable condition rather than being labelled as undiagnosed T2DM being diagnosed. Going by this assumption only 1,750 (1.3%) of the 132,526-dental patient with an AUSDRISK score of ≥12 should be duly categorised as undiagnosed T2DM.
Other reasons that suggest overestimation of undiagnosed T2DM in the model may be due to the threshold used to categorise high risk. At an AUSDRISK threshold of $\geq 12$, The GGT RFS estimated 39.5% of the Victorian population between 40 and 74 were at risk of DM. While the AusDiab study estimated 21% of the Australian population $\geq 40$ years have an AUSDRISK score of $\geq 15$. At the currently accepted AUSDRISK threshold of $\geq 12$ would translate 964,866 (39.5%) of the 2,442,700 Victorian population in 40 to 74 years as high risk of DM. Despite the high T2DM risk estimate, the number of new cases of T2DM recorded in this age group for Victoria was 9404 in 2017 (This data was sourced from the NDSS – an initiative of the Australian Government administered with the assistance of Diabetes Australia). Translating the NDSS data to the Victorian population the annual incidence rate of T2DM in the 40 to 74-year-old is 0.38%. Taking all these into consideration the model overestimates the risk of T2DM at the currently recommended threshold for high risk. The limitations of AUSDRISK were consistent as evidenced in the retrospective analysis of the GGT RFS and the five-year follow-up of the AusDiab study participants (Lee et al., 2018; Malo et al., 2015).

Several studies had used the risk assessment tool to forecast the odds of developing incident DM by duration or count, in the medical setting. The AUSDRISK predict the risk over a five-year period for the Australian population and the FINDRISC over a ten-year duration for the Finnish population. The ADA takes a more cautious stance by not disseminating the odds of developing incident DM by duration or count. The ADA risk assessment questionnaire and the FINDRISC has a cutoff score of $\geq 5$ and $\geq 15$ for high risk which is different to that of the AUSDRISK. Excluding all those identified as undiagnosed T2DM in the $\geq 40$ years AusDaib study participants, 12.7% with the AUSDRISK score of $\geq 15$ developed T2DM during the five-year period. When the same condition was applied to the 40 to 74-year-old dental patients, 3.9% of those with the with the AUSDRISK score of $\geq 12$ developed T2DM. The AusDiab study identified three times more number of patients with T2DM during the five-year follow-up period. However, such comparison needs to be interpreted with caution in view of the difference in the AUSDRISK cut off values. The GGT RFS identified 52% of the males and 40% of the female’s participants with an AUSDSRISK score of $\geq 12$. In that only 3.4% of the males and 2.2% of the females were within the DM range, despite the fact that the region is well known for the higher prevalence of CVD and risk of DM in Australia.
There is a general consensus in the construct of all the diabetes risk assessment questionnaire that rely on the common risk factors to predict risk, but they did vary inconsiderably. Disease incidence and prevalence in different racial/ethnic groups that best represent the Australian population risk of DM is gambled in the construct of the AUSDRISK. While the ADA risk assessment questionnaire made no explicit reference in this aspect. For example, ethnicity and place of birth were used as risk indicators in the AUSDRISK, but the ADA risk assessment questionnaire and the FINDRISC relies on risk factors that can be readily applied to a more diverse group of population that goes beyond the confines of national or global regions. Although questions such as ethnicity, place of birth and smoking status may help predict the risk of DM, the potential advantage of AUSDRISK covering more diverse but specific risk indicators may very well work against to its downside. For example, diagnostic tests that express good sensitivity typically presents low specificity; often these two parameters are inversely related more like a see-saw.

In the GGT RFS, the sensitivity, specificity and PPV for dysglycemia (this include both pre-diabetes and DM) at an AUSDRISK score of $\geq 12$ was 81%, 57% and 12% (Appendix 7.1.4) (Malo et al., 2015). The diagnostic accuracy values suggest two significant concerns with the AUSDRISK. Firstly, the low specificity implies high false positive where the study participants may not necessarily be at increased risk of DM although the AUSDRISK results may suggest otherwise. Secondly, the PPV pose another significant concern where a low reading suggests that the prevalence of IFG is not high enough to warrant screening. At an AUSDRISK score of $\geq 20$ the sensitivity, specificity and PPV were 25%, 85% and 28%. Very low sensitivity of 25% which is less than a third of that observed at $\geq 12$ imply a large proportion of people with DM is likely to have been missed or gone unnoticed. The AusDiab study identified little difference in the incidence of new cases of T2DM among those with low ($\leq 14$) or high ($\geq 15$) AUSDRISK scores in the five-year follow-up (Lee et al., 2018). In my model, a large proportion of dental patients were identified as high risk with the AUSDRISK, but only 1.6% of all those screened with the AUSDRISK were undiagnosed T2DM. In the five-year follow-up, 3.5% of all the dental patients screened with the AUSDRISK (with no loss of GP follow-up assumption) were diagnosed as T2DM. The annual incidence of T2DM in the 40 to 74-year-old Victorians is as low as 0.38% (calculation based on number of new cases registered between January 1 to December 31 with NDSS) compounded with a low prevalence of IFG of 4.7 (Malo et al., 2015)
suggest that most of the cases identified as IFG at an AUSDRISK score of $\geq 12$ is likely to be not suggestive of DM. Although pre-diabetes is a risk factor for DM, the progression to T2DM is not forthcoming always (Bertram & Vos, 2010). Age of onset often determines the duration of transition to T2DM. For example, a person who is diagnosed as pre-diabetes at the age of 70 is more likely to become DM in the next five to ten-years than someone diagnosed at 40. A systematic review and meta-analysis on the progression of HbA1c from 6.1 to 6.4 identified an incidence of 35.6 per 1,000 person-years (Morris et al., 2013) suggesting 65% of the subjects do not progress to DM in the 10-year period. Although the AUSDRISK is not a diagnostic test per se, the combination of high false positive and low prevalence of IFG in the community makes the usefulness of this tool for identifying undiagnosed T2DM questionable for the Australian population. This suggests that the AUSDRISK is less suitable for wider application in a population with low incidence or prevalence of DM such as Australia as a whole or Victoria in particular. Overall, the model findings suggest that the AUSDRISK screening in the dental setting provided an unreasonable and exaggerated estimate on the risk of T2DM among the 40 to 74-year-old Victorian dental patients. The findings are in line with previous findings where the usefulness of the AUSDRISK at the current recommended a score of $\geq 12$ to determine high risk for DM were not good enough to rely upon for physician referral to screen for undiagnosed T2DM.

### 6.3.3 Diabetes in Australia compared to other regions

Globally, close to half a billion people live with DM, of them, 80% live in low- and middle-income countries. Countries with a higher number of DM also account for the greater number of undiagnosed cases. Approximately, 85% of people with undiagnosed DM live in low- and middle-income countries. The IDF WP region is the most populous, but the prevalence of DM is lower to that of “North America and Caribbean region”, “The Middle East and North African region” and the “South-East Asian region”. The IDF acknowledges considerable disparities in the incidence and prevalence of DM between countries within this region. The 2017, Global Burden of Disease (GBD) data for WP region, WE and the Group of 20 largest, advanced or emerging economies (G20) that represent two third of the world population accounting for 85% of the global gross domestic product was derived from the Institute of Health Metrics and Evaluation (IHME) and presented in appendix 7.1.7 to 7.1.12. The incidence, prevalence and
mortality for T2DM in Australia are among the lowest when compared with countries and territories in WP, WE and G20 nations.

6.3.4 Is diabetes screening in the dental setting cost-effective?

As per the model assumption, one in every 288 and 117 dental patients will be identified as undiagnosed T2DM and pre-diabetes. This suggests that 0.34% of the dental patient screened with the AUSDRISK will be identified as undiagnosed T2DM. The cost to identify one dental patient as high risk with AUSDRISK is $78.85 and the cost incurred to diagnose one case of undiagnosed T2DM is $15,508. The approach for the cost calculation in the model for identifying undiagnosed T2DM was based on one FPG test. This is the most conservative estimate since the diagnosis of DM almost always require a repeat test along with an OGTT. As per the AusDiab study, the cost calculated for one OGTT was $19 (Lee et al., 2018). When the OGTT cost was added on top of the existing cost of $114 to reconfirm the diagnosis in the medical setting, the cost incurred to identify one case of undiagnosed T2DM increased to $16,121. Since the sensitivity and specificity of the OGTT are different from the FPG, not all test positive cases for FPG should necessarily test positive for the OGTT. To minimise uncertainty and avoid any such error in the absence of primary or secondary data cost was calculated for one FPG alone. As such, the cost calculation is an underestimate and the true cost to identify one new case of undiagnosed T2DM initiated through the dental setting is beyond the scope of this thesis, but it is estimated to be no less than $16,121.

A univariate sensitivity analysis was performed at different GP follow-up rate to assess the impact of cost in identifying undiagnosed T2DM. Table 6.11 describes the costs and NNS to identify one new dental patient as undiagnosed T2DM. Since there are no previous studies that used diabetes risk assessment questionnaire in isolation in the dental setting for GP referral, studies that used the two-step screening (risk assessment followed by PoC HbA1c test) was used for the univariate sensitivity analysis. A scenario of no loss of follow-up was included for the purpose of comparison, although the chances for 100% GP follow-up are remote and unachievable. As such, it is vital that the univariate sensitivity analysis need to be interpreted with caution. In the best-case scenario (the most optimistic assumption) where 27% follow-up with the GP, the NNS with AUSDRISK to identify undiagnosed T2DM and pre-diabetes is 230
and 94, at an average cost of $13,098 for each diagnosis. In a modestly worst-case scenario, where 15% of those identified as high-risk follow-up with the GP, the NNS to identify one new case of as undiagnosed T2DM and pre-diabetes is 414 and 169, at an average cost of $20,635 for one new case of undiagnosed T2DM identified. For the sake of argument, if all dental patient identified as high-risk follow-up with the GP one in every 62 and 25 dental patients may be identified as undiagnosed T2DM and pre-diabetes. This suggests that the range in which dentist can anticipate identifying one new case of undiagnosed T2DM is one in every 230 to 414 screened with AUSDRISK. Alternatively, it can be interpreted that the probability of identifying one dental patient as undiagnosed T2DM with AUSDRISK range between 0.24% to 0.43%.

No previous study has estimated the cost to screen with the diabetes risk assessment questionnaire and diagnose dental patients for undiagnosed T2DM initiated through the dental setting. A study conducted among ≥40 years US dental patient using ADA diabetes risk assessment questionnaire followed by PoC HbA1c identified one in every 24 dental patients identified as high risk with the PoC HbA1c were within the T2DM range (Neidell, Lamster, & Shearer, 2017). This study determined a cost of $28 (USD to AUD conversion rate applied at the time of writing this report) for screening in the dental setting and $211 for diagnosis using FPG in the medical setting. The cost calculation for screen diagnosis in the medical setting is not well described in this study. However, it appears blood glucose investigation along with consultation and travel cost was factored in for the physician follow-up, but this was not included in the dental visit. Further, the study failed to disclose the number of dental patients identified as undiagnosed T2DM in the medical setting, upon GP referral. Also, the screening tools and cost calculation in this study is very different from the approach used in my model. As such, the results of this study need to be interpreted with caution because PoC HbA1c screening cannot be relied upon for diagnosis of T2DM. It is noteworthy to mention that only 24 of the 375 (6.4% or one in every 15.6) dental patient identified as dysglycemia with the PoC HbA1c in four different studies turned out to be DM when confirmed with the gold standard in the medical setting (Biethman et al., 2017; Franck et al., 2014; Genco et al., 2014; Herman, Taylor, Jacobson, Burke, & Brown, 2015).
In the AusDiab study, a scenario in which calculation for AUSDRISK screening alone encountered a cost of $37 per individual and the NNS to identify one new case of undiagnosed T2DM was 71. When the calculation was used to cover FPG along with AUSDRISK to identify one new case of undiagnosed T2DM it resulted in a cost of $3,357 (Lee et al., 2018). A retrospective analysis of 2,763 patients records in a GP practice in UK, over a three-year period, to determine the cost for opportunistic screening (that included blood glucose test, staff and administrative cost) resulted in a 2% yield. The NNS to identify one new case of T2DM diagnosed was 51 and the cost to identify one new case of DM was $686 (GBP to AUD conversion rate at the time of writing this report) (Pereira Gray, Evans, Wright, & Langley, 2012). This suggests that AUSDRISK screening in the dental setting followed by a GP referral for blood glucose investigation encountered 4.6 times higher cost when compared to the AusDiab study and a staggering 22.6 (GBP converted to AUD as of today value) times higher cost when compared the English study in the GP setting.

6.3.5 Disability Adjusted Life Years

The DALYs is the approach used by the WHO and the GBD in estimating disease burden. The WHO defines DALYs as “One DALY can be thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability” (World Health Organization, n.d.-b)
Table 6.10 Univariate analysis with different GP follow-up rate

<table>
<thead>
<tr>
<th>Eligible dental cohort</th>
<th>Dental screening (AUSDRISK)</th>
<th>GP follow-up</th>
<th>Medical screening (FPG test)</th>
<th>Cost/person To identify undiagnosed T2DM</th>
<th>NNS to identify one case of undiagnosed T2DM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost/person</td>
<td>Total cost</td>
<td>Identified as high risk</td>
<td>Cost/person***</td>
<td>Undiagnosed T2DM</td>
</tr>
<tr>
<td>1,185,382</td>
<td>$41</td>
<td>$48,600,662</td>
<td>616,400</td>
<td>$114</td>
<td>2,866 (0.24%)</td>
</tr>
<tr>
<td>1,185,382</td>
<td>$41</td>
<td>$48,600,662</td>
<td>616,400</td>
<td>$114</td>
<td>4,108 (0.34%)</td>
</tr>
<tr>
<td>1,185,382</td>
<td>$41</td>
<td>$48,600,662</td>
<td>616,400</td>
<td>$114</td>
<td>5,159 (0.43%)</td>
</tr>
<tr>
<td>1,185,382</td>
<td>$41</td>
<td>$48,600,662</td>
<td>616,400</td>
<td>$114</td>
<td>19,108 (1.61%)</td>
</tr>
</tbody>
</table>

UDT2DM; undiagnosed T2DM, NNS; number needed to screen, FPG; fasting plasma glucose, ¹ (AlGhamdi et al., 2013),² (Bierthman et al., 2017) * model assumption(Genco et al., 2014), **at no loss of GP follow-up from the dental setting, ***cost calculated for one FPG test
DALYs essentially measure something lost rather than gained. Disability weight is used in the calculation of Years of Life lived with Disability (YLD) before we could calculate DALYs. The DW is a weight factor that indicates the severity of the disease on a scale from 0 (perfect health) to 1 (equivalent to death)(World Health Organization, n.d.-a). DW is derived using multiple attributes or disease-specific utility instrument summary scores between 0 to 1 and these scores are used in the calculation of YLD and DALYs for cost-utility analysis for a number of health conditions (Brazier, Deverill, & Green, 1999; Haagsma, Polinder, Cassini, Colzani, & Havelaar, 2014; Murray, Lopez, & Organization, 1996). The 2016 Global Burden of Disease study had calculated DW for 333 diseases (Abajobir et al., 2017).

DALYs can be calculated for any health condition by adding up the Years of Life Lost (YLL) due to premature death and number of YLD. To make it sound simple, one DALY is equivalent to the loss of one healthy life year. YLL and YLD calculation involve a series of steps before summing up the YLL and YLD.

<table>
<thead>
<tr>
<th>Disability Adjusted Life Years = YLL + YLD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years of Life Lost (YLL) = N x L</td>
</tr>
<tr>
<td>Years Lost due to Disability (YLD) = I x DW x L</td>
</tr>
</tbody>
</table>

N = number of deaths, L = standard life expectancy at the age of death in years, I = number of incident cases DW = disability weight, L = average duration of the case until remission or death (years).

To explore if periodontal disease is a significant complication of DM that impact day to day life of an individual, DW derived from the GBD for chronic periodontal disease and complication that arises as a sequela of DM were compared (Appendix 7.1.13). The comparison showed chronic periodontal disease had the least impact in terms of severity with a score of 0.007. It is noteworthy to mention that the GBD does not recognise chronic periodontal disease as a complication of DM. Further, appendix 7.1.14 extrapolated from GBD shows the DALYs for diseases and condition that are postulated to have a bidirectional relationship with DM. One DALY can be viewed as one lost year of "healthy" life. Chronic periodontal disease has a DALYs score of 66 per 100,000. Despite the wider prevalence of
chronic periodontal disease, the DALYs was substantially low implying the impact on life is very minimal.

6.3.6 Who pays for the cost?

In Australia, 75-85% of the cost for screening DM that includes AUSDRISK, FPG, OGTT and HbA1c in the medical setting are covered under the medicare benefit scheme. This cost cover does not apply for DM screening in the dental setting. This raise more concerns as to who pays for the screening cost. Given the additional cost for AUSDRISK screening on top of the dental treatment, it would be fairly reasonable to assume from the patient point of view to have all the T2DM related screening tests done under one roof in the medical setting as this will lessen additional GP visit, transportation and consultation cost. The AUSDRISK is available in paper and online interactive format, it is a user-friendly tool that can be readily used by any individual without the need for a health professional because the risk score is calculated almost instantaneous and readily interpretable. As such, the cost to be borne by the patient for screening in the dental setting is hard to justify. On the other hand, dentists may wish to be paid for their extended service at an acceptable profit margin. This may put the dentist and the patient in an uncompromising paradoxical situation where economics loom on top of the uncertain benefit of AUSDRISK screening.

6.3.7 Relationship between diabetes and periodontal disease

DM and periodontal disease are widely prevalent. Periodontal disease (including gingivitis) is much more common and is known to affect 90% of the population (Pihlstrom, Michalowicz, & Johnson, 2005) and a significant cause of tooth loss among adults. The global prevalence of severe form of periodontitis (periodontal pocket depth of ≥4mm) in adults is 11.2% (Kassebaum et al., 2014). Over the years, several studies had explored the relationship between DM and periodontal disease. Despite the evidence being equivocal its often taken for granted that DM contributes to incident periodontal disease and vice versa in literature.

A Cochrane systematic review identified treatment for periodontal disease among people with DM reduced HbA1c values by 0.29% in a three to four months period. This effect started to
decay during the four months post treatment period until no difference was observed at 6 months. The quality of the evidence in this study was low (Simpson, Needleman, Wild, Moles, & Mills, 2010). A more rigorous systematic review of previous systematic reviews of clinical trials concluded that periodontal treatment had a positive effect on HbA1c levels in people with DM but the effect size was very small and evidence is of low quality (Hasuike, Iguchi, Suzuki, Kawano, & Sato, 2017). One other recent systematic review (Nascimento, Leite, Vestergaard, Scheutz, & López, 2018) of longitudinal studies that had a mean follow-up of 4.8 years identified poorly controlled DM was associated with periodontal onset or progression. However, the study that used the clinical attachment loss in this review was unable to identify DM contributed to periodontal destruction. One of the critical limitations in this review is that it did not control for the possible confounding variables like smoking/tobacco, gender, age, body mass index and socioeconomic status (Horta et al., 2017). Since many of the common risk factors co-exist in both DM and periodontal disease, it can be extremely challenging in determining a cause-effect relationship despite a weak positive association.

Longitudinal observational studies in Japan and Taiwan came with conflicting results. Two of the three studies are more inclined to the evidence that periodontal disease is not related to the increase in the risk of incident T2DM. Ide et al. (2011) in his seven-year follow-up of non-diabetic individuals with moderate and severe periodontal disease identified no significant association to incident T2DM (Ide, Hoshuyama, Wilson, Takahashi, & Higashi, 2011). The study conducted in Taiwan that followed-up 5,885 cohorts between 35 to 44 years for five years identified DM had some effect on periodontal destruction, but the reverse was not found to be true after adjusting for metabolic risk factors. The findings from this study were in line with the seven-year follow-up of Japanese study discussed earlier (Chiu et al., 2015).

On the contrary, Morita et al. (2012) identified a relationship where participants with a pocket depth of $\geq 4$ showed an increase in HbA1c values compared to those with no pocket (code 0) in the five-year follow-up. But the Morita study identified 165 (3%) of the 5,583 participants with HbA1c of less than 6.5% at baseline and shallow or deep pocket ($\geq 4$mm) exhibited HbA1c levels $\geq 6.5$ after a five years follow-up. The Morita et al. study had several limitations where the participants comprised mainly of older males, smokers, ex-smokers, higher alcohol consumption and low uptake of repeat follow-up for periodontal disease and HbA1c
investigation compared to the baseline numbers (Morita et al., 2012). Although when compared to those with code 0 of Community Periodontal Index (CPI), people with shallow and deep pocket (code 3 and 4) had a higher incidence of HbA1c of \(\geq 6.5\) but this still represents a tiny proportion of participants (3%) compared to 97% of those who did not have their HbA1c within the DM range. Such a small difference may well have happened otherwise by chance in any population where common risk factors were not adequately controlled. Further, the study made no reference to how many of the 5583 participants with shallow or deep pocket were within the pre-diabetes range at baseline.

Epidemiological studies have demonstrated two to three-fold increase in the risk of severe periodontal disease among people with DM (George W Taylor, 2001). Some studies suggest a linear relationship between the severity of periodontal disease and deterioration of glycaemia among people with uncontrolled DM (Casanova, Hughes, & Preshaw, 2014; Taylor et al., 1996). While others suggest that the chronic inflammation in periodontal disease can deteriorate glycaemic control which again can further accelerate periodontal destruction (Grossi et al., 1997; Stewart, Wager, Friedlander, & Zadeh, 2001; G. W. Taylor, 2001).

6.3.8 Do adults with periodontal disease seek frequent dental care?

Other than gingival bleeding which is a reversible condition and of minimal consequence, periodontal disease is largely asymptomatic and often goes unnoticed by the patient for several years unless otherwise there is associated tooth mobility due to alveolar bone loss. Often by the time the patient seeks treatment, the supporting structures (periodontium) of the tooth is already in an advanced stage of destruction. Having said that, there may be several reasons for not seeking care for periodontal disease like absence of pain symptoms or associated discomfort that impact day to day routine, socio-economic situation, cost, access, time off from work, smoking/tobacco use that constrict the gingival blood vessels and prevent bleeding, other health condition that takes higher priority over dental needs. If at all they are convinced towards any clinical intervention for periodontal disease upon dentist advise it is usually for aesthetic reasons. Dentist use this opportunity for scaling (superficial cleaning) and root surface debridement (deep cleaning in the crevice between the tooth and gums). Anything beyond scaling is dentist driven need for periodontal treatment.
Dental patients often feel little convinced with deep cleaning or advanced periodontal treatment, and the reason for such a belief is aesthetic. Root surface debridement and other advanced periodontal treatment like flap surgery can bring about the resolution of inflammation and better attachment of healthy periodontium (devoid of periodontal pockets) to the tooth surface. But, resolution of gingival inflammation also reduces the volume of the gingival tissue coverage, and this does not look aesthetically pleasing because the fullness of the gum tissues covering the teeth appears reduced. There is a lot of difference in what patients and dentist perceive as healthy periodontium which is one of the important reasons as to why dental patients are often little convinced with the outcome from advanced periodontal treatment other than replacement of missing teeth with dental implants.

Left alone, without any continued care, the affected tooth will need removal at some stage, but this can vary from a few years to several years. For some, dental needs stop with the removal of the affected tooth, unless otherwise other teeth may require similar treatment, or the patient is more concerned about aesthetics and seeks expensive replacement options that necessitate further visits. It is fairly common practice for the dentist to wait till the tooth goes more mobile (grade 2 or 3 mobility) and offer expensive replacement options than to work towards preserving the periodontium from further deterioration that necessitates continued patient cooperation and commitment. As such, it’s difficult to say if dental patients really seek treatment for periodontal disease of their own or dentist use this opportunity to warn the patient with the adverse consequence of becoming edentulous and convince for periodontal treatment.

### 6.3.9 Is screening for diabetes worth the effort?

Most of the chronic diseases are age-related, as age advances so do the risk of chronic diseases. DM can be linked to an endless list of complication and nearly every organ in the body can be either directly or indirectly affected by DM. It is postulated to have a bidirectional relationship with several conditions other than periodontal disease like CVD, depression, tuberculosis, obstructive sleep apnoea, bronchial asthma, dementia, stress, liver diseases, and several cancers. Although people with DM express more periodontal disease compared to those with NGT, it is not that people without DM do not get periodontal disease and in fact, most of the periodontal disease is present in people without DM. Taking all this finding into consideration,
it may well be that uncontrolled DM can potentially exacerbate periodontal destruction. But this may very well apply to all the diseases and condition that are seen as comorbidity or complication of uncontrolled DM as discussed above. Hypertension is at least three times more common, and the age of onset often precedes the incidence of T2DM. People with uncontrolled T2DM are more likely to express higher cardiovascular problems (most often hypertension start prior to the incidence of T2DM), stroke, renal disease, depression, dementia and many more. As such, it is essential that periodontal disease is not looked at any differently.

A large cluster-randomised trial in the UK, Anglo-Danish-Dutch study of intensive treatment in people with screen-detected DM in primary care (ADDITION-Cambridge) (Simmons et al., 2012) assessed the mortality outcome of stepwise screening in England. The study was unable to demonstrate screening for T2DM was linked to reduction in cardiovascular, T2DM or all-cause mortality. Further, the author went on to discuss that the benefit of screening may be smaller than what it was initially thought (Simmons et al., 2012). Another large multicentre clinical trial in the US and Canada, The ACCORD study that aimed at reducing the cardiovascular morbidity and mortality by intensive treatment in participants with T2DM was unable to demonstrate an appreciable reduction in the cardiovascular events despite lowering the systolic blood pressure to normal values (Cushman, Evans, & Cutler, 2015).

The former administrator of Centres for Medicare & Medicaid Services in the US, Donald Berwick (1985) said “the mere existence of unrecognised cases of illness is, by itself, insufficient reason to screen. Disease has many faces, and the hunt is not benign” (Berwick, 1985).

Any screening activity should be based on sound evidence that early diagnosis can lower the morbidity and mortality levels in the community. In consideration of the adverse consequence of overdiagnosis and debate surrounding the benefits of screening, the National Screening Committee in the UK set out several criteria. One of the important criteria is that any screening activity should be based on evidence that it improves health(National Screening Committee, 2015).
Aldous Huxley wrote, “Medical science has made such tremendous progress that there is hardly a healthy human left.” (as cited by Yudkin, 2014).

6.3.10 Is screening for pre-diabetes worth the effort?

In recent years pre-diabetes has received increasing attention as early identification of this condition provides a window of opportunity to alter the natural history of T2DM. As age advances so do the risk of all chronic diseases like DM, periodontal disease, CVD, arthritis, Alzheimer’s, depression and many more. The prevalence of pre-diabetes is 3 to 4 times higher than DM and do not progress to DM, always. Around 37% of US and 50% of Chinese adult population are prediabetic (Centre for Disease Control and Prevention, 2014; J. S. Yudkin & V. M. Montori, 2014). Estimation of pre-diabetes can be challenging for other reasons too. Firstly, there is a substantial confounding in pre-diabetes estimates. The IDF estimates that 16.2% of women have some form of transient hyperglycaemia during pregnancy of them 85% is due to GDM (International Diabetes Federation, 2017). Secondly, the diagnostic accuracy of FPG and HbA1c for pre-diabetes are uncertain. A systematic review and meta-analysis of screening for pre-diabetes identified inconsistent results with FPG or HbA1c. FPG showed acceptable specificity but poor sensitivity while HbA1c performed poorly on both the diagnostic accuracy parameters (Barry et al., 2017). These limitations compounded with the hormonal changes lead to fluctuations in glycaemic levels and acceleration of periodontal inflammation that can have drastic changes in the periodontal tissues that include false pocketing. A recent systematic review estimated the prevalence of periodontal disease during pregnancy anywhere between 5 and 55% (Daalderop et al., 2018). The Study of Health in Pomerania Trend study (Kowall et al., 2015) identified pre-diabetes, and well-controlled DM was not linked to periodontal disease. The argument that pre-diabetes contributes to periodontal destruction or the vice versa is very shallow. Such an association is of little or no practical significance because pre-diabetes is much more common and not a disease per se.

“There is a tendency to assume that if screening is carried out, all will be well. This is a damaging fallacy. Every proposed screening programme must be rigorously examined against clear criteria....The decision to screen for any condition should be undertaken as a hard-
headed professional exercise rather than a form of ‘feel good’ evangelism.” (Holland & Stewart, 1990).

The notion that dental setting can be a good place for the opportunistic screening of undiagnosed T2DM stems from the assumption that there is a delay in the diagnosis of T2DM from the time of onset and adults with periodontal disease seek dental treatment more frequently compared to those with no periodontal disease. Periodontal disease is often asymptomatic this makes it very different from dental caries where the onset is often an acute or chronic episode of pain of varying intensity once the enamel is breached, that makes people seek dental treatment. Currently, there is no evidence to suggest periodontal disease is an early sign of DM and people at risk of periodontal disease, or dysglycemia seek frequent dental care. Further, if dental setting offers an opportunity for the chance discovery of undiagnosed T2DM, then it makes even more a better case for the GPs, Ophthalmologist, Cardiologist, Neurologist because cardiovascular, ophthalmic and neurological symptoms like hypertension, glaucoma and peripheral neuropathy are early signs of DM.

Hypertension is three times more prevalent than DM, and most of the death among people with DM is due to CVD. Hypertension is a significant risk factor for DM that share the very same common risk factors and complications of DM. In the UK, a meta-analysis of a large cohort study that involved 4.1 million people with no previous history of DM or hypertension identified a 20 mmHg increase in the systolic blood pressure is associated with a 58% higher risk of incident DM and a 10 mmHg of diastolic blood pressure was associated with 52% increased risk of developing DM (Emdin, Anderson, Woodward, & Rahimi, 2015). This may well turn the attention to initiate screening for a much prevalent condition as hypertension that is known to be the forerunner for CVD and a significant risk factor for T2DM.

### 6.3.11 Overdiagnosis

Low prevalence of T2DM and high false positives with AUSDRISK screening contributes to overdiagnosis and waste of time, money and manpower. Some of the foreseeable scenarios include situations where the dentist may wish the patient follow-up with the GP upon referral,
while the patient is little convinced being at increased risk of T2DM when there are no accompanying symptoms that make them feel any ill. Patient compliance for physician referral was identified as a significant concern in a US study when risk assessment questionnaire along with HbA1c was used to identify patient risk in the dental setting. The reasons for nonadherence to GP referral were not clear, but resistance to compliance was identified as a significant barrier (Genco et al., 2014). Request for GP follow-up can make things more awkward or embarrassing for the dentist when most of the FPG tests results are expected to come negative, upon GP advise for a blood glucose investigation, which is the most plausible scenario with AUSDRISK screening, and an assurance from the GP that everything is well with the dental patient. Additionally, physicians may feel little convinced that the AUSDRISK tests were any necessary for their patients and a rebuke for going beyond the confines of the dentist roles and responsibilities in screening T2DM which is essentially a cornerstone of GP practice to recognise risk and diagnose patients for all chronic medical conditions including DM. Genco et al. (2014) reported that the physician refused to perform DM screening, upon referral, in two of his dental patients when the PoC HbA1c readings in the dental setting were above normal values (Genco et al., 2014). Such an adverse scenario can lead to a conflict of interest, a sense of mistrust that can jeopardize dentist patient relationship.

Overdiagnosis can have several other consequences that include emotional, financial, over medication, side effects of drugs for pre-diabetes on an apparently healthy asymptomatic individual (Kale & Korenstein, 2018; J. Yudkin & V. Montori, 2014). The Diabetes Reduction Assessment with Ramipril and Rosiglitazone Medication (DREAM) study (Gerstein et al., 2006) reported Rosiglitazone medication delayed the onset of T2DM in 14 of 100 individuals, over a three-year period. This indicates that the remaining 86 healthy subjects were on the medication that is known to cause heart failure and other cardiovascular risks (J. Yudkin & V. Montori, 2014). T2DM prevention program in a large US study suggests Metformin use in people with pre-diabetes may reduce the chances of developing T2DM by 31% (Diabetes Prevention Program Research Group, 2002; J. Yudkin & V. Montori, 2014). In Australia, a national plan is been called for by several health care organizations to avert the consequence of overdiagnosis and overtreatment (Coady & Calderwood, 2017). The popular British daily, The Guardian, reported that the leading medical body in the UK, Academy of Medical Royal
Colleges, claims the cost incurred to the NHS towards over diagnosis amounts to two billion pounds a year (Campbell, 2014).

The vast majority of people with pre-diabetes do not progress to become T2DM in a 10-year period (Morris et al., 2013). As such, early diagnosis of pre-diabetes and to some extent DM will have minimal impact on the longevity of life. Huo et al. (2015) estimated life expectancy among Australian adults with DM at 50 reduced only by 3.1 to 3.2 years compared to those without DM and this difference reduced to less than a year in the 70-74-year-old’s (Huo et al., 2016). GPs are the first point of contact for any general health issues, and DM is no different, and diagnosis has always been made only in the medical setting. The AIHW along with the medical professional organization like the NMHRC, RACGP and Diabetes Association recommend opportunistic screening for DM and this information is widely disseminated since 2009 in different format within the medical community (Australian Government - Department of Health, 2016; Colagiuri, Davies, Girgis, & Colagiuri, 2009; Diabetes Australia; Royal Australian College of General Practitioners, 2016). In view of this development, any small increase in the number of new cases should not be regarded as an increase in disease level but a reduction in the number of undiagnosed T2DM.

Ageing deteriorates glucose tolerance in a vast majority of people, and DM prevention is all about delaying the onset of T2DM (J. Yudkin & V. Montori, 2014). Lifestyle and pharmacological intervention have proven effective in preventing or delaying the progression towards DM by up to 57% (Gillies et al., 2007). Disease-modifying factors like lifestyle changes in particular, can address part of the solution which again to a large extent depends on patient cooperation and willingness for any meaningful benefit. Further, lifestyle modification program have inherent problems due to poor compliance from participants that had significantly reduced the effectiveness of such program in the past (Castellani, Ianni, Ricca, Mannucci, & Rotella, 2003; Huisman, Maes, De Gucht, Chatrou, & Haak, 2010; Kruegle, 2012; Mauro, Taylor, Wharton, & Sharma, 2008; Miller & Brennan, 2015; Moroshko, Brennan, & O'Brien, 2011; Zuckoff, 2012). If lifestyle changes can produce significant benefits, then why is that 37% of the US and 50% of the Chinese adult population follow these long-established remedies and cut down the risk of DM and hypertension? It is not that people do not know that lifestyle modification will significantly improve their health. But anything
that requires a change from people routine that demands additional time, discipline and effort will always have challenges.

Individual level risk factors like diet, cholesterol, physical activity that are proximally associated with the disease have received much of the attention (Link & Phelan, 1995). With such a short-sighted approach we are missing the wider determinants of health such as socio-economic status, poverty, education, employment, resources, happiness, living condition, marriage and stress which have all been consistently associated with disease and illness. Is this the victim blaming approach and are we not considering the social causation of disease?

6.3.12 Can the disease level in the community be evasive?

Screening and diagnostic tools are constantly evolving, accordingly changes to the classification of diseases. Newer approaches in the detection and recording of oral diseases using brush biopsy to detect pre-cancerous/dysplastic changes, International Caries Classification and Management Systems (ICDAS) for dental caries, Index of Orthodontic Treatment Needs, inclusion of attachment loss to periodontal pocket depth in the adult oral health survey in England and NHANES in the US significantly alter the oral disease incidence and prevalence. For example, the recording of dental caries has gone beyond the simplistic measure of “no obvious decay” and “decay” to a more detailed recording by the newer criteria introduced by ICDAS. (Ismail et al., 2007; Shivakumar, Prasad, & Chandu, 2009). Novel methods of recording dental caries include incipient carious lesion (a reversible condition) in reporting. This can significantly alter the existing disease levels in the community to an artificially inflated value (Agustsdottir et al., 2010; Arangannal, Mahadev, & Jayaprakash, 2016; Braga, Oliveira, Bonini, Bonecker, & Mendes, 2009). Such findings may lead to unnecessary health care resource allocation in addressing a stereotype of an existing condition. This gives a misconception that the disease may well be on the rise.

“Critics such as Payer and Caplan maintain that the routine human condition— unhappiness, bone thinning, stomach aches and boredom—is increasingly being re-defined as disease: ......with falling thresholds resulting in more people considered to be sick. In other cases, drugs
approved for devastating illness, such as clinical depression, are indicated for milder conditions, such as shyness, which is now dubbed ‘social phobia’” (Wolinsky, 2005)

In England, school dental screening was ceased in 2007 due to lack of evidence that it improved dental health, dental or school attendance, or cost saving among those screened positive for dental caries (Milsom, Tickle, & Blinkhorn, 2008). The same argument holds true for DM. The AUSDRISK does not require higher technical skills, and people can use make use of the online version at the comfort of their home. This will avoid any unnecessary expenditure and unwanted examination turning healthy individuals into patients.

6.3.13 Disease mongering approach

It would be incomplete not to mention the role of pharmaceutical, diagnostics and biotech companies in the earlier detection of diseases. In 2014, the global pharmaceutical industry revenue had soured a trillion for the first time and projected to grow at a compounded annual growth rate of 6.3% to reach $1.2 trillion by 2022. This new projection had replaced the earlier prediction of 5% in 2015 (Evaluate Pharma, 2016). Chronic diseases in particular, with no foreseeable cure in the near future for hypertension, DM, Alzheimer’s, depression, arthritis, have immensely propagated the pharmaceutical sector profits by keeping people afloat on medication all their life.

Disease mongering” is the term better used to describe the practice of stretching the diagnostic boundaries of illness in an effort to medicalise a healthy individual (R. Moynihan & Henry, 2006). There is a lot of money in recalibrating a healthy into sick. This would mean a great deal of effort from the pharmaceutical industry to widen the net coverage so that a large proportion of the so-called healthy or borderline healthy fall within the burgeoning brackets of the statistically adjusted diseases. The approach as a whole is somewhat analogous to the age-old strategy of “divide and rule/conquer” adopted by the Roman ruler Julius Caesar, French military commander Napoleon Bonaparte (Hagopian, 2015; Kolling & Hunt, 2015) and several imperial powers. When a large proportion of the healthy population can be divided into independent groups based on age, body mass index, racial profiling and behavioural risk factors
it is easy to sell (conquer) the idea of disease which is a marketing strategy. This dedicated
effort did not go in vain; a new disease was born, Syndrome X now referred to as metabolic
syndrome (Wolinsky, 2005). Although early diagnosis and intervention may seem noble and a
fascinating idea for the benefit of the society, but the overriding interest is to capitalise on the
scope to generate higher revenues. Goldman Sachs, a renowned investment banking and
financial service firm said, “curing disease may not be economically viable” (Luntz, 2018).

Cochrane UK, Senior Fellow in General Practice, questioned if diagnosing pre-diabetes would
offer any benefit? And said, “Pre-diabetes is a classic case of an artificial diagnosis, a form of
disease-mongering that is often now called “overdiagnosis” (Lehman, 2016).

Health care professionals rely on information from scientific literature indexed in medical
journals to weigh diagnostic and treatment options. Research funded by pharmaceutical,
diagnostics and biotech companies are written to favour their products in journals. With this
approach, they have widened their grip on medical journals to market their product (Ross,
2011). The Guardian reported in 2011 that Richard Horton, the chief of a leading open-access
medical journal, The Lancet, said: “journals have devolved into information laundering
operations for the pharmaceutical industry” (Bero L, 2017; Ross, 2011).

The medical community in itself is partly to blame by falling short of recognising the
commercial motives in clinical decisions. To make things worse pharmaceutical companies
form an informal alliance with physicians and patient groups what Ray Moynihan calls it as
emeritus professor Catherine D.DeAngelis was seeking more transparency in the financial
relationship between physicians and drug manufacturers. Pharmaceutical companies engage in
several drug promotion strategy by offering gift, travel and conference sponsorship and
financial rewards for research activities. Although health care professionals deny such practice
have little influence in their clinical decision making, the findings show this was far from real,
physician who met or received monetary benefits from pharmaceutical representatives were
13.2 times more likely to include products in the hospital formulary, when monetary benefits
were provided they were 21.4 more likely to speak at symposium and 9.2 times more likely to perform research (Chren & Landefeld, 1994; Komesaroff & Kerridge, 2002).

A US based diagnostic firm employed a renowned dentist to promote a product that can identify precancerous or dysplastic features in the oral mucosa at an early stage, but the product was found to be no superior to an oral examination by an oral and maxillofacial surgeon. Having known the financial motives, competing interest and rivalry within the health care industry, it is difficult to verify alternating claims were any true because research findings can be easily manipulated to produce desired outcomes. The results of the AUSDRISK screening and the highly error-prone PoC HbA1c screening for T2DM in the dental setting is more likely to fall within the sphere of influence of the stakeholders.

“Within many disease categories informal alliances have emerged, comprising drug company staff, doctors, and consumer groups. Ostensibly engaged in raising public awareness about underdiagnosed and undertreated problems, these alliances tend to promote a view of their particular condition as widespread, serious, and treatable. Because these “disease awareness” campaigns are commonly linked to companies’ marketing strategies, they operate to expand markets for new pharmaceutical products” (Ray Moynihan, Peter, Heath, & Henry, 2002).

6.4 Conclusion

The economic evaluation aims to identify the cost and benefits of opportunistic screening for T2DM initiated through the dental setting. At the AUSDRISK threshold of ≥12 the model identified one in every 1.9 dental patients screened were identified as high risk and the cost to identify one high risk individual was $78.85. Based on the model assumption one in every 288 dental patients screened with the AUSDRISK in the dental setting were identified as undiagnosed T2DM in the medical setting and the cost incurred to identify one new case of undiagnosed T2DM initiated through the dental setting was estimated as $15,508.
In the medical setting, excluding those identified as undiagnosed T2DM, the number of dental patients newly diagnosed as T2DM during the five-years period was 5,704 (4.4%). This indicates that one in every 22.5 dental patients with an AUSDRISK score of $\geq 12$ developed T2DM in the five-year period. In the ten-year follow-up, 8.6% ($n=11,068$) of those with an AUSDRISK score of $\geq 12$ and not identified as undiagnosed T2DM developed T2DM. This indicates one in every 11.6 dental patients identified as high with an AUSDRISK score of $\geq 12$ develops T2DM during the ten-year period.

AUSDRISK is primarily a screening tool to predict the risk of T2DM over a five-year period. The results of the hypothetical model indicate AUSDRISK has poor predictive ability for undiagnosed T2DM or pre-diabetes. The model findings are in line with previous estimates on AUSDTSRK as a screening tool. In view of the low prevalence of the disease in the community, poor patient compliance for GP follow-up compounded with a high false positive rate can potentially lead to unnecessary physician referral besides uncertain benefits. Hence, the cost and time spent on screening with the diabetes risk assessment tool are unjustified. The model findings provided the opportunity for a more comprehensive understanding of several limitations that make screening for T2DM in the Australian or Victorian dental setting, in particular, to be neither cost-effective nor appropriate when compared to screening in the medical setting.

Currently, there is no evidence to support periodontal disease is an early sign of DM or middle-aged adults with undiagnosed dysglycemia seeks frequent dental care, exhibit higher level of periodontal destruction compared to those without periodontal disease. The bidirectional relationship between DM and periodontal disease had remained a subject of controversy. Despite the myriad of confounding factors, very low effect size and clinical relevance, some support the notion that such a relationship may exist. Nevertheless, the cause-effect relationship is largely unsupported and unproven.

In financially constrained health systems around the world, resource allocation will need to be based on favourable evidence that any medical screening in the dental setting can reduce disease levels in the community, demonstrate health benefits at an acceptable cost. Screening
for T2DM with the diabetes risk assessment tool in the Victorian dental setting did not live up to any of this expectation. A two-step opportunistic screening that includes a risk assessment followed by a PoC HbA1c may offer some benefits particularly in the low- and middle-income countries where the prevalence of T2DM, periodontal disease and the risk factors, like poverty, stress, tobacco and alcohol, that predispose to these two conditions are exceptionally high.
6.5 Bibliography


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confidential information
7.1.3 The Australian Type 2 Diabetes Risk Assessment Tool

What is type 2 diabetes?
Type 2 diabetes is a chronic (long-term) disease marked by high levels of sugar in the blood. It occurs when the body does not produce enough insulin (a hormone released by the pancreas) or respond well enough to insulin.
Type 2 diabetes is the most common form of diabetes. There are approximately 1 million people with type 2 diabetes currently. This figure is expected to increase significantly in the coming years.
People with diabetes have a higher risk of developing heart disease, stroke, high blood pressure, circulation problems, lower limb amputations, nerve damage, and damage to the kidneys and eyes.

Risk factors
Many Australians, particularly those over 40, are at risk of developing type 2 diabetes through lifestyle factors such as physical inactivity and poor nutrition. Family history of diabetes and genetics also play a role in type 2 diabetes.

What can you do to lower your risk of developing type 2 diabetes?
Your lifestyle choices can prevent or, at least, delay the onset of type 2 diabetes.
You cannot change risk factors like age and your genetic background. You can do something about being overweight, your waist measurement, how active you are, eating habits, or smoking.
If there is type 2 diabetes in your family, you should be careful not to put on weight. Reducing your waist measurement reduces your risk of type 2 diabetes.
By increasing your physical activity and improving your eating habits you can lower your risk. Eat plenty of vegetables and high fibre cereal products every day and use a small amount of fats and oils. Monounsaturated oils, such as olive or canola oil, are the best choice.
You can have type 2 diabetes and not know it because there may be no obvious symptoms.
1. Your age group
   - Under 35 years: □ 0 points
   - 35 – 44 years: □ 2 points
   - 45 – 54 years: □ 4 points
   - 55 – 64 years: □ 6 points
   - 65 years or over: □ 8 points

2. Your gender
   - Female: □ 0 points
   - Male: □ 3 points

3. Your ethnicity/country of birth:
   3a. Are you of Aboriginal, Torres Strait Islander, Pacific Islander or Maori descent?
      - No: □ 0 points
      - Yes: □ 2 points
   3b. Where were you born?
      - Australia: □ 0 points
      - Asia (including the Indian sub-continent): □ 2 points
      - Middle East, North Africa, Southern Europe: □ 0 points
      - Other: □ 2 points

4. Have either of your parents, or any of your brothers or sisters been diagnosed with diabetes (type 1 or type 2)?
   - No: □ 0 points
   - Yes: □ 3 points

5. Have you ever been found to have high blood glucose (sugar) (for example, in a health examination, during an illness, during pregnancy)?
   - No: □ 0 points
   - Yes: □ 6 points

6. Are you currently taking medication for high blood pressure?
   - No: □ 0 points
   - Yes: □ 2 points

7. Do you currently smoke cigarettes or any other tobacco products on a daily basis?
   - No: □ 0 points
   - Yes: □ 2 points
1. **Your age group**
   
   *If you scored 6-11 points in the AUSRISK you may be at increased risk of type 2 diabetes.* Discuss your score and your individual risk with your doctor. Improving your lifestyle may help reduce your risk of developing type 2 diabetes.

8. **How often do you eat vegetables or fruit?**
   
   Every day ☐ 0 points  Not every day ☐ 1 point

9. **On average, would you say you do at least 2.5 hours of physical activity per week (for example, 30 minutes a day on 5 or more days a week)?**
   
   Yes ☐ 0 points  No ☐ 2 points

10. **Your waist measurement taken below the ribs**
    (usually at the level of the navel, and while standing) Waist measurement (cm)

   **For those of Asian or Aboriginal or Torres Strait Islander descent:**

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<tr>
<th>Men</th>
<th>Women</th>
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<tr>
<td>Less than 90 cm</td>
<td>Less than 80 cm</td>
<td>0</td>
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<td>90 – 100 cm</td>
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   **For all others:**

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<th>Men</th>
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<tr>
<td>Less than 102 cm</td>
<td>Less than 88 cm</td>
<td>0</td>
</tr>
<tr>
<td>102 – 110 cm</td>
<td>88 – 100 cm</td>
<td>4</td>
</tr>
<tr>
<td>More than 110 cm</td>
<td>More than 100 cm</td>
<td>7</td>
</tr>
</tbody>
</table>

   **Add up your points**

   **Your risk of developing type 2 diabetes within 5 years*:**

   ☐ 5 or less: Low risk
   
   Approximately one person in every 100 will develop diabetes.

   ☐ 6-11: Intermediate risk
   
   For scores of 6-8, approximately one person in every 50 will develop diabetes. For scores of 9-11, approximately one person in every 30 will develop diabetes.

   ☐ 12 or more: High risk
   
   For scores of 12-15, approximately one person in every 14 will develop diabetes. For scores of 16-19, approximately one person in every 7 will develop diabetes. For scores of 20 and above, approximately one person in every 3 will develop diabetes.
If you scored 12 points or more in the AUSDRISK you may have undiagnosed type 2 diabetes or be at high risk of developing the disease. See your doctor about having a fasting blood glucose test. Act now to prevent type 2 diabetes.

*The overall score may overestimate the risk of diabetes in those aged less than 25 years.*
### 7.1.4 AUSDRISK at various cut-off values for FPG

FPG ≥ 6.1 mmol/L (dysglycemia)

<table>
<thead>
<tr>
<th>AUSDRISK</th>
<th>Sensitivity %</th>
<th>Specificity %</th>
<th>PPV % (95% CI)</th>
<th>NPV % (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥12</td>
<td>81.3 (70.7 to 89.4)</td>
<td>57.7 (54.6 to 60.7)</td>
<td>12.3 (9.5 to 15.5)</td>
<td>97.7 (96.2 to 98.7)</td>
</tr>
<tr>
<td>≥13</td>
<td>74.7 (63.3 to 84.0)</td>
<td>63.8 (60.8 to 66.7)</td>
<td>13.1 (10.0 to 16.6)</td>
<td>97.2 (95.6 to 98.3)</td>
</tr>
<tr>
<td>≥14</td>
<td>68.0 (56.2 to 78.3)</td>
<td>71.6 (68.7 to 74.3)</td>
<td>14.8 (11.2 to 19.0)</td>
<td>96.8 (95.3 to 98.0)</td>
</tr>
<tr>
<td>≥15</td>
<td>61.3 (49.4 to 72.4)</td>
<td>76.4 (73.7 to 79.0)</td>
<td>15.9 (11.9 to 20.7)</td>
<td>96.4 (94.9 to 97.6)</td>
</tr>
<tr>
<td>≥16</td>
<td>53.3 (41.4 to 64.9)</td>
<td>81.7 (79.1 to 84.0)</td>
<td>17.5 (12.8 to 23.0)</td>
<td>96.0 (94.5 to 97.2)</td>
</tr>
<tr>
<td>≥17</td>
<td>45.3 (33.8 to 57.3)</td>
<td>86.3 (84.1 to 88.4)</td>
<td>19.4 (13.8 to 26.1)</td>
<td>95.6 (94.1 to 96.8)</td>
</tr>
<tr>
<td>≥18</td>
<td>34.7 (24.0 to 46.5)</td>
<td>91.7 (89.9 to 93.4)</td>
<td>23.4 (15.9 to 32.4)</td>
<td>95.1 (93.5 to 96.3)</td>
</tr>
<tr>
<td>≥19</td>
<td>28.0 (18.2 to 39.6)</td>
<td>94.6 (93.0 to 95.9)</td>
<td>27.3 (17.7 to 38.6)</td>
<td>94.7 (93.2 to 96.0)</td>
</tr>
<tr>
<td>≥20</td>
<td>25.3 (16.0 to 36.7)</td>
<td>95.3 (93.9 to 96.5)</td>
<td>28.4 (18.0 to 40.7)</td>
<td>94.6 (93.1 to 95.9)</td>
</tr>
</tbody>
</table>

Data source (Malo et al, 2015) Data are % (95% CI).
7.1.7 T2DM compared with Western Pacific region

T2DM incidence in 2017

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of new cases per 100,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vietnam</td>
<td>367</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>546</td>
</tr>
<tr>
<td>Tonga</td>
<td>666</td>
</tr>
<tr>
<td>South Korea</td>
<td>454</td>
</tr>
<tr>
<td>Solomon Islands</td>
<td>547</td>
</tr>
<tr>
<td>Singapore</td>
<td>315</td>
</tr>
<tr>
<td>Samoa</td>
<td>519</td>
</tr>
<tr>
<td>Philippines</td>
<td>390</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>539</td>
</tr>
<tr>
<td>New Zealand</td>
<td>782</td>
</tr>
<tr>
<td>Marshall Islands</td>
<td>333</td>
</tr>
<tr>
<td>Malaysia</td>
<td>348</td>
</tr>
<tr>
<td>Laos</td>
<td>889</td>
</tr>
<tr>
<td>Kiribati</td>
<td>602</td>
</tr>
<tr>
<td>Japan</td>
<td>795</td>
</tr>
<tr>
<td>Fiji</td>
<td>982</td>
</tr>
<tr>
<td>Micronesia</td>
<td>235</td>
</tr>
<tr>
<td>China</td>
<td>319</td>
</tr>
<tr>
<td>Cambodia</td>
<td>548</td>
</tr>
<tr>
<td>Brunei</td>
<td>265</td>
</tr>
<tr>
<td>Australia</td>
<td>846</td>
</tr>
</tbody>
</table>

T2DM prevalence in 2017

<table>
<thead>
<tr>
<th>Country</th>
<th>Prevalent cases per 100,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vietnam</td>
<td>7295</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>10172</td>
</tr>
<tr>
<td>Tonga</td>
<td>13571</td>
</tr>
<tr>
<td>South Korea</td>
<td>8836</td>
</tr>
<tr>
<td>Solomon Islands</td>
<td>9824</td>
</tr>
<tr>
<td>Singapore</td>
<td>6584</td>
</tr>
<tr>
<td>Samoa</td>
<td>10333</td>
</tr>
<tr>
<td>Philippines</td>
<td>7350</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>9401</td>
</tr>
<tr>
<td>New Zealand</td>
<td>5370</td>
</tr>
<tr>
<td>Marshall Islands</td>
<td>14976</td>
</tr>
<tr>
<td>Malaysia</td>
<td>6937</td>
</tr>
<tr>
<td>Laos</td>
<td>6320</td>
</tr>
<tr>
<td>Kiribati</td>
<td>17432</td>
</tr>
<tr>
<td>Japan</td>
<td>6737</td>
</tr>
<tr>
<td>Fiji</td>
<td>20277</td>
</tr>
<tr>
<td>Micronesia</td>
<td>6262</td>
</tr>
<tr>
<td>China</td>
<td>5988</td>
</tr>
<tr>
<td>Cambodia</td>
<td>8698</td>
</tr>
<tr>
<td>Brunei</td>
<td>5235</td>
</tr>
<tr>
<td>Australia</td>
<td>18312</td>
</tr>
</tbody>
</table>

7.1.8  T2DM compared with Western European region

### 7.1.9 T2DM mortality comparison with WE and WP region

#### Mortality compared with Western European nations in 2017

- Andorra: 5
- Australia: 7
- United Kingdom: 12
- Switzerland: 9
- Sweden: 15
- Spain: 16
- Portugal: 15
- Norway: 9
- Netherlands: 14
- Malta: 8
- Luxembourg: 8
- Italy: 6
- Israel: 8
- Ireland: 8
- Iceland: 9
- Greece: 6
- Germany: 12
- France: 6
- Finland: 6
- Denmark: 11
- Cyprus: 11
- Belgium: 10
- Austria: 20

**Mortality per 100,000**

#### Mortality compared with Western Pacific region in 2017

- Vietnam: 21
- Vanuatu: 45
- Tonga: 108
- South Korea: 13
- Solomon Islands: 69
- Singapore: 2
- Samoa: 55
- Philippines: 33
- Papua New Guinea: 56
- New Zealand: 6
- Marshall Islands: 80
- Malaysia: 7
- Laos: 20
- Kiribati: 1
- Japan: 1
- Fiji: 1
- Micronesia: 94
- China: 6
- Cambodia: 15
- Brunei: 46
- Australia: 7
- American Samoa: 80

**Mortality per 100,000**

---

7.1.10 T2DM incidence and prevalence compared with G20 countries

7.1.11 DALYs for T2DM compared with WE and WP region

DALYs for T2DM compared to WE nations in 2017

DALYS for T2DM compared to WP region in 2017

7.1.12 DALYs for Type 2 Diabetes compared to G-20 nations

7.1.13 Disability Weight compared to periodontal disease

Source: Global Burden of Disease Study 2016
7.1.14 Disease with a bidirectional relationship

Diseases that are hypothesized to have bidirectional relationship with DM

<table>
<thead>
<tr>
<th>Disease</th>
<th>DALYs per 100,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>CKD</td>
<td>209</td>
</tr>
<tr>
<td>Glaucoma</td>
<td>7</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>593</td>
</tr>
<tr>
<td>Liver diseases</td>
<td>531</td>
</tr>
<tr>
<td>Diabetes</td>
<td>814</td>
</tr>
<tr>
<td>Asthma</td>
<td>329</td>
</tr>
<tr>
<td>Alzheimer’s</td>
<td>471</td>
</tr>
<tr>
<td>CVD</td>
<td>5178</td>
</tr>
<tr>
<td>Hypertension</td>
<td>242</td>
</tr>
<tr>
<td>Depression</td>
<td>597</td>
</tr>
<tr>
<td>PD</td>
<td>66</td>
</tr>
</tbody>
</table>

Source: Global Burden of Disease Study, 2016 Questionnaire and Plain Language Statement
Minerva Access is the Institutional Repository of The University of Melbourne

Author/s: Chinnasamy, Alagesan

Title: Screening for Type 2 Diabetes Mellitus initiated through the dental setting: a cost-effectiveness analysis

Date: 2019

Persistent Link: http://hdl.handle.net/11343/228847

File Description: Redacted thesis file

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