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**Implants for the Aged Patient
Biological, Clinical and Sociological Considerations**

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Abstract

Until recently age, particularly old age, was considered a contraindication to the placement of dental implants. However this was based largely on anecdotal dogma rather than empirical information. This review considers the biological, clinical and socioeconomic implications of implants placed in the aged population. Aging has been shown to have an influence on the biological aspects of soft and hard tissue wound healing and tissue remodelling, which may influence the establishment and maintenance of implant integration. However, information to date indicates that age should not be an a priori contraindication for implant placement and there is good evidence to indicate dental implants can be placed successfully in the elderly with good clinical and socioeconomic outcomes.

Biological Considerations for Dental Implant Treatment in the Elderly Patient

The ongoing biological success of implant therapy is based on long term stability of both soft and hard tissue integration. The main biological considerations in treating elderly patients with dental implants is the possibility of compromised wound healing following implant placement, as well as the effect of aging on the long term integrity of osseointegration.

Osseointegration is a complex process that involves a cascade of events that occur at the tissue-implant interface. These involve clot formation and the initial adsorption of serum components immediately following implant placement, an immune-inflammatory response to implant insertion, the migration and attachment of undifferentiated mesenchymal cells onto

the implant surface, their proliferation and differentiation, the formation of extracellular matrix, and finally its mineralization and maturation. Recent studies using a human *in vivo* model have shown that inflammation, skeletogenesis, angiogenesis and neurogenesis are the main biological processes that are involved in osseointegration (44,68). Concurrently, I κ B/NF κ B, wnt and TGF β /morphogenetic protein signalling are prominently regulated during the osseointegration process.

The physiological process of aging itself is also highly complex at the molecular, cellular, and systemic levels, and can affect the multiple aspects of wound healing associated with surgical implant placement. There are no studies that specifically investigate differences in the biological aspects of wound healing around dental implants among patients of different ages. However, the effect of aging on the healing of other soft and hard tissues has been investigated elsewhere in the body, such as the skin and periodontium, as well as long bone fractures. Since many of the wound healing biological processes are common between different parts of the body, with similarities particularly evident in different bone healing scenarios (9,58,67), we can look to this literature for insight into possible biological mechanisms that may be compromised following implant placement.

In this section of our review, the effect of aging on biological mechanisms relevant to the soft and hard tissue wound healing processes associated with dental implant insertion will be assessed in the context of the classically recognized stages of wound healing: 1) Inflammatory phase and 2) New tissue formation; 3) Maturation and remodelling. A summary of these mechanisms is presented in Table 1.

Early (Inflammatory) Stage of Wound Healing

The temporal soft and hard tissue wound healing events following implant placement have been investigated in a dog model over a 12 week period (19,20). In terms of soft tissue morphogenesis of the mucosal attachment to implants, during the 4 days after transmucosal implant placement, large numbers of neutrophils were shown to infiltrate and degrade the coagulum present between the mucosa and the implant. A dense fibrin network established a primitive seal between the wound surface of the flap and the implant. The first signs of epithelial proliferation were not observed until after 1 and 2 weeks of healing with a barrier epithelium being established at this time. Similarly, in terms of bone formation and the establishment of osseointegration, the preparation of a recipient site for a dental implant results in blood vessel disruption and the ensuing blood clot fills the osteotomy site.

Consequently, platelets are activated and release alpha granules into the fibrin-rich extracellular matrix, forming a hemostatic 'blood clot' that functions as a reservoir for signalling molecules including chemoattractants for inflammatory cells. Neutrophils, monocytes, and lymphocytes appear consecutively, and their fibrinolytic activity enable them to migrate into the extracellular matrix of the blood clot (19).

Inflammation is the critical aspect of early wound healing, and hence it is important to note that inflammation has been shown to increase with aging (34,43). Aging is known to promote the release of inflammatory mediators from fibroblasts (16,77), and a prolonged inflammatory phase may delay wound healing (5). In a distraction osteogenesis model, aged mice had increased circulating serum levels of interleukin-6 and tumor necrosis factor- α and an associated 60% reduction in bone formation compared to young mice (128). The reduced bone formation in aged mice could be simulated in young mice treated by the use of the pro-inflammatory cytokine tumor necrosis factor- α , and it could be reversed in old mice by the inhibition of tumor necrosis factor- α signalling (128).

The concept that aging affects systemic inflammation is further supported by bone fracture healing studies using aged chimeric mice produced by ablating the bone marrow with radiation and then reconstituting with marrow from mice of different ages (134). This approach produced aged chimeric mice in which tissue progenitor cells and osteoblasts were host-derived, but inflammatory cells in the callus were derived from younger mice. The chimeric aged mice developed larger fracture calluses and had accelerated remodelling compared to the control aged mice, indicating that the inflammatory cells from young mice enhanced the bone regenerative processes. However, in young chimeric mice, the transplantation of inflammatory cells from aged mice did not inhibit the superior healing observed in these mice (134), suggesting that although systemic inflammation and other factors influence local stem cells, intrinsic differences in stem cell populations are an important determinant of the reduced repair that occurs with aging.

New Tissue Formation (Proliferative Stage)

In terms of soft tissue healing around implants, after 2 weeks of healing, fibroblasts are the dominating cell population in the connective tissue interface, but by 4 weeks, the density of fibroblasts substantially decreases as the connective tissue begins to mature. After 6 - 8 weeks of healing a mature barrier epithelium and fully organized collagen fibers are present, and a fully functional soft tissue seal is established (20). Notably, in a gingival

healing model, a significant delay in wound coverage by epithelial tissue has been observed in older rats (26). In terms of bone formation to establish osseointegration, blood vessels sprout into the blood clot forming 'granulation tissue', and mesenchymal progenitors originating from the bone marrow enter the site, ultimately differentiating into osteoblasts. The formation of woven bone by osteoblasts results in bone formation at the implant interface (20).

There are two aspects of aging which potentially affect new tissue formation during the regenerative phase of healing, namely changes in stem cell populations and changes in the microenvironment (growth factors, extracellular matrix etc.) that alter the biological activity of progenitor cells. Adult progenitor cells are present in virtually all tissues, and their primary role is to regulate tissue homeostasis and regeneration. Stem cell functions decline with age, probably through alterations in self-renewal, differentiation potential, senescence and the arrest of proliferation (59). Depletion and/or senescence of progenitor cells are associated with age-related tissue degeneration as well as the reduced potential for regeneration following injury (106,109). Research in stem cell aging has more recently focused on the role of oxidative stress and impaired cellular antioxidant mechanisms, modifications in the systems that control the repair of damaged DNA, reduction of telomere length, and epigenetic changes induced by histone acetylation and methylation (59). All these events are affected by many different cell-intrinsic and cell-extrinsic pathways that influence not only stem cell function but also other cells present in the stem cell niche (73,95).

Mesenchymal progenitor cells are key to bone regeneration, with bone marrow derived stromal cells) being the key population in the context of dental implant osseointegration. It has been known for some time that the number of mesenchymal progenitors within bone marrow decreases with age (21,38). Furthermore, it has been reported that cell proliferation, migration, and pluripotency are significantly inhibited in stem cells obtained from aged periodontal ligament tissues compared with young individuals (137). Similarly, it has been shown that gingival fibroblasts derived from aged donors displayed a reduction in cell proliferation compared with cells obtained from younger donors (26).

The diminished cell proliferation described in aged cells is largely mediated through telomere shortening and the DNA damage response. The function of telomeres is to act as molecular clocks that keep a record of cell replication (60). Telomere loss through multiple

cell divisions results in critically short telomeres that result in a phenomenon known as replicative senescence (27). A defining aspect of cellular senescence is the inability of cells to progress through the cell cycle. The loss of telomeres is detected as a type of DNA damage, triggering the DNA damage response. A group of DNA damage kinases (ataxia telangiectasia mutated, ataxia- and Rad-related, checkpoint kinase-1, and checkpoint kinase-2 are the main mediators of the DNA damage response, which upon phosphorylation activate several cell cycle proteins, including p53 (27). Phosphorylated p53 protein activates the expression of p21, which binds to and inhibits cyclin-dependent kinase complexes, ultimately altering the proliferative activity of cells (49). Several markers and morphologic features characterize senescent cells, including the absence of the proliferative marker Ki-67, an increase in senescence-associated β -galactosidase activity, and the expression of tumor suppressors and cell cycle inhibitors (p16, ARF, p53, p21, p15, p27, and hypophosphorylated retinoblastoma protein) (94).

The importance of maintaining robust stem cell populations is demonstrated in mice with telomerase gene deletion (109,110). These mice develop senescent stem cell populations and have reduced capacity for tissue maintenance and regeneration (110). In bone, telomerase gene deletion results in accelerated aging and reduced bone mass (109).

The role of aging on the cellular aspects of bone healing continues to be an active field of investigation. For example, recently the early periosteal progenitor cell response was investigated in rigidly fixed murine proximal tibia osteotomies, with a more robust periosteal response observed in young compared with aged mice. (135). Furthermore, the rate of proliferation, expression of cyclin D1, and the amount of matrix formed were significantly elevated in young mice compared to aged mice. In a murine calvaria critical-defect model examining the role of wnt signalling in the relative regenerative potential of bone marrow derived stromal cells from young and aged mice, bone marrow grafts from aged mice resulted in impaired bone healing associated with reduced β -catenin signalling, which was restored following Wnt3a treatment (81). These various studies suggest that aging results in intrinsic differences in the population of regenerative (progenitor) cells that limits the capacity for new tissue formation, which may be reversed by the delivery of deficient molecular cues to the wound site.

Cumulative oxidative stress is another factor that has been shown to induce cell senescence and apoptosis (15,109,111). Bone healing in the elderly may be negatively

impacted by a reduced capacity to neutralize reactive oxygen species of the respiratory chain. Free radicals produced by the respiratory chain may cause oxidative damage to various cellular components that may affect cellular function by cells of the osteogenic lineage (55,76).

Aside from the effect of aging on resident tissue cells, it has been shown that it may also have a negative impact on the growth factors present in serum. Indeed, upon exposure of gingival fibroblasts to serum derived from young and middle-aged rats, superior cell migration was induced by serum from the younger animals (26). This is consistent with a previous report that muscle tissues from aged mice experience a rejuvenating process when they are exposed to a young circulatory system (35).

In the context of the effect of aging on the local environment during bone healing, it has been shown that intramuscular implantation of demineralized bone matrix causes less calcium and lower levels of alkaline phosphatase in older rabbits (122). Furthermore, demineralized bone matrix prepared from younger sources has been reported to be more osteoinductive than preparations from older animals, indicating a possible decrease in morphogenetic proteins and other growth factors (102). Indeed, insulin-like growth factor-1 and transforming growth factor- β concentrations in bone have been shown to decline with age (99,113). The osteogenic capacity of subcutaneously implanted recombinant morphogenetic protein-2 in a rat model was also negatively affected by increasing age (88). The administration of parathyroid hormone, prostaglandin E₂, or calcitrol (1,25-dihydroxycholecalciferol) was able to restore the bone inductive activity of bone morphogenetic protein-2 in aged rats (74). Overall, these ectopic implantation studies imply that the local environment contributes to age-related changes in bone formation.

Aging may affect angiogenesis at several levels, including changes in the production or signaling associated with vascular endothelial growth factor and fibroblast growth factor-2 (56,123). Another study showed that, as compared with 4-week old mice, middle-aged (6 months) and old mice (18 months) exhibit a progressive decrease in the expressions of hypoxia-inducible factor-1 α and matrix metalloproteinase-9 early in fracture repair and have reduced vascularization of fracture callus and decreased bone regeneration (83). More recently, the effect of aging on angiogenesis has been shown to occur in a tissue-specific manner (115).

Tissue Maturation and Remodelling

The long-term success of implant therapy is reliant on the maintenance of a soft tissue seal around the implant, as well as adequate bone support. Appropriate maturation of the wound and subsequent remodelling are essential in achieving these absolute pre-requisites for clinical success, and hence an understanding of the effect of aging on tissue maturation and remodelling is important.

The tissue-remodelling phase of the wound healing process is associated with a change in the collagen composition within the wound. As the wound matures, type III collagen, which is the predominant matrix molecule found in granulation tissue, is ultimately replaced by type I collagen (57). It has been shown that collagen 1A1 gene expression is down regulated in the aged periodontal ligament (96). Furthermore, it has also been reported that decreased transforming growth factor- β signaling and consequent reduced levels of connective tissue growth factor may be responsible for the progressive loss of collagen in aged skin (100).

It has been demonstrated that aging modifies gingival wound healing (26). Furthermore, only young fibroblasts develop actin stress fibers and incorporate α -smooth muscle actin into these structures. Furthermore, aged fibroblasts had a reduced capacity to remodel 3-dimensional collagen matrices compared with young cells (26). These results suggest that aging affects the dynamics of the actin cytoskeleton and collagen reorganization during wound healing, probably disturbing tissue homeostasis and function.

Collagen fibers are significantly modified and reorganized during tissue-remodelling, with matrix metalloproteinase involved in the remodelling of extracellular matrix components as newly formed tissue is re-organized during the maturation stage of gingival wound healing (101). Increased levels of matrix metalloproteases and tissue inhibitors of matrix metalloproteases have been identified in periodontal ligament cells from aged compared to young donors (17). It has been suggested that tissue remodelling and maturation develop with an increased level of proteolytic enzymes in aged subjects, which might negatively alter the mechanical properties of the newly formed tissue (119). The effect of aging on apoptosis is also worth considering because in the final stages of the wound-healing process, activated fibroblasts, macrophages, and endothelial cells undergo apoptosis as an important step in the wound maturation process (42). Since aging modifies apoptotic signaling (52), it has been speculated that the removal of cells from the newly regenerated tissue is compromised in older individuals (119).

Collagen is remodelled through phagocytosis during wound healing (6). Collagen phagocytosis is a complex process that involves the initial degradation of collagen macromolecules by matrix metalloproteases, the binding and internalization of collagen fragments by integrins, and their degradation in intracellular phagolysosomal domains (114). It has been shown that cell aging was associated with an increase in collagen phagocytosis (79). Given that aged periodontal ligaments show a decrease in collagen content (96), it has been speculated that increased collagen phagocytosis may contribute to this altered phenotype.

With regards to bone healing during osseointegration, immature woven bone is remodelled into lamellar bone over time, in a process recapitulating intramembranous bone formation (19). Furthermore, successful osseointegration is reliant on adequate bone support for the implant to withstand masticatory forces over time, and this stability must be considered in the context of a continually remodelling bone support over time.

The effect of aging on cellular and structural changes leads to an imbalance in bone remodelling (30,76). Although not all elderly patients are osteoporotic, it is generally accepted that if we live long enough, we will become osteoporotic. Osteoporosis is the result of progressive catabolic changes, and it is generally accepted that the risk for osteoporosis increases with age (85,107). Changes found in skin collagen also occur in bone collagen with aging and may be a causal counterpart to loss of bone quality in senile osteoporosis (116). In addition, age-related changes of non-calcified collagen in human cortical bone have been reported (132). Non-enzymatic glycation-induced crosslinks of collagen might also be a reason for the reduced biomechanical properties of aged bone, as well as influencing both remodelling and bone regeneration (132,138).

Pre-clinical animal trials, usually utilizing ovariectomized animals, have shown that osteoporosis can have a negative impact on osseointegration as measured by histomorphometric outcomes such as bone-implant contact and bone volume (45,125). Furthermore, the use of osteogenic surface modifications has been shown to improve osseointegration in similar pre-clinical animal models (69). Nevertheless, although some clinical reports suggest that osteoporosis is a risk-factor for implant failure (3), there is limited evidence that osteoporosis may have detrimental effects on bone healing during or following osseointegration (50), and hence it is not possible to make any firm conclusions regarding the effect of osteoporosis in dental implant therapy. Furthermore, it is unclear if

any potential negative clinical effect can be overcome by the use of implants with a microrough (Ra 1 - 2 μ m) surface topography (2).

Clinical outcomes of implants in older patients

Implant outcomes are measured by survival and success (12). The definition of these terms has changed over time. Success originally meant survival and this can make assessment of implant outcomes difficult. Currently, survival is the physical presence of the implant in the mouth, while success is the absence of complications. These complications may be biological, technical and, more recently, aesthetic. Biological complications include bleeding, peri-implant mucositis, peri-implantitis and inflammation from excess cement. Screw loosening, fracture or chipping of crowns or bridges and loss of retention are technical complications. Aesthetic complications can be rated by both the clinician and patient, and include differing appearance to the contralateral natural tooth, recession of mucosal margin and metal of the implant showing. A summary of the clinical outcomes of aging on dental implants is presented in Table 2.

Survival of Implants in the Elderly Patient

Dental implants have high long-term (10 years and longer) survival rates irrespective of system, surface and type of restoration (13,14,25,32,124,136). Simultaneous grafting with implant placement and aesthetic outcomes are similar in the elderly and younger patients (12,22,72). Many of these studies either have not reported on the age of the subjects or the elderly are in very small numbers. Both of these will mask the survival rates in patients over 65 years of age. There can be a high dropout rate among the elderly due to death, infirmity or serious illness that prevents them attending review appointments (72). Interestingly in some reports implant surgery has been undertaken with a high average age, such as 55 years with few post-operative issues (124). A regression analysis of the long-term survival of 388 Straumann TPS[®] implants found that age is not significantly related to implant survival time (13). Implant placement in the elderly is not mentioned to be an issue in terms of poor wound healing or post-operative complications. However, the elderly that attend dental clinics for implant surgery are likely to be healthier and more able to look after themselves.

Few recent studies have focussed on elderly patients alone. Most papers reporting outcomes in the elderly are 15 years and older, often using machined or titanium plasma

sprayed surface implants, which are no longer used (24,53,70,91,112,120,136). In the short term, 1 to 6 years, success rates in elderly patients were at least equal to younger patients under 65 (40). The Toronto studies led by Zarb reported that 4.7% of implants were lost after ten years in subjects aged between 65 and 82 (136). Data from the Brånemark clinic regarding implants placed in edentulous healthy elderly patients, aged 79 years and over, at the time of placement have the same prognosis as younger patients (70). A patient's age was not associated with increased surgical complications and geriatric patients may not be poor surgical candidates (120).

Risk Factors Affecting Implant Outcomes in the Elderly Patient

Traditional risk factors affecting implant outcomes are medical issues, such as smoking and diabetes, previous periodontal disease, residual cement, lack of maintenance and poor oral hygiene or inability to clean (4,104). These also apply to implants in the elderly (33). The prevalence of peri-implant mucositis ranges from 19 to 65% and peri-implantitis 1 to 47% (4,8,41). Many studies include patients over 65 in their analysis and, as with survival and success, age is either not mentioned or not a statistically significant factor.

From a small retrospective study of 35 geriatric patients over 70 years of age, it was reported that implant therapy in patients with controlled systemic disease, (i.e. under the care of an appropriate physician, on appropriate medications and not deteriorating), should not be considered particularly high risk (79). Interestingly smoking is not widely reported in the literature looking at implant risk factors in the elderly. This may be due to low numbers of smokers. Type 2 diabetes is increasing in prevalence and affects many elderly patients. Glycaemic control affects peri-implant health with poorer control related to increased bleeding and greater bone loss in patients aged 59 to 64 years (51). It was suggested that control of periodontal disease is a key element in implant success. More regular recall, use of chlorhexidine mouthwashes and post-operative antibiotics may reduce the incidence of complications.

Many elderly patients have serious medical issues in addition to smoking and diabetes, such as cancer and osteoporosis/osteopenia, and these can affect implant outcomes (103). Head and neck cancers are more common in the elderly and can be treated with radiotherapy (31). Radiotherapy decreases bone vascularity and vitality and a recent systematic review reported a significant increase in the risk of implant failure especially in the maxilla (31). Osteoporosis and osteopenia are declines in bone volume and quality and

are seen in post-menopausal women. These women may be considered at risk for tooth and implant loss, although results are inconsistent (47). After taking into account age, implant position, implant surface, years in function, diabetes, plaque, smoking, periodontitis and peri-implant bone status, Dvorak et al. (47) could find no relation between osteoporosis and peri-implantitis. Bisphosphonates are commonly used in the management of osteoporosis and inhibit osteoclast activity preventing bone resorption and turnover (7). This may impair osseointegration and there is a low risk of bisphosphonate-related osteonecrosis of the jaws with implant placement. A recent meta-analysis reported on almost 1300 patients with over 4500 implants and just under a third in patients taking oral bisphosphonates (7). The use of bisphosphonates did reduce the survival and success rates of dental implants. Eighty-six patients (6.7%) were reported to have developed bisphosphonate-related osteonecrosis of the jaws, which lasted for 16 to 72 months. Implant placement does carry a risk in these patients.

Peri-implant Mucositis and Peri-implantitis

Peri-implant mucositis is a reversible inflammation of the soft tissues around the implant with redness, swelling and bleeding but no bone loss. Peri-implantitis involves bone loss around an integrated fixture. The prevalence of peri-implant mucositis and peri-implantitis varies between studies and depends on the criteria used (8). Many elderly patients are often included in these reports. However, again age may not have been reported and the numbers are often too low to be statistically significant.

The prevalence rates of mucositis and peri-implantitis have been reported to be around 31% and 37% at the patient level and 38% and 23% at the implant level respectively in a Belgian study (87). Subjects older than 65 years and those with a history of periodontitis were more likely to experience mucositis or peri-implantitis. The association was stronger in fully edentulous patients, which is many elderly patients and often those reported in the literature. There was a correlation with rough surfaces and peri-implant disease. Periodontitis prevalence increases with age (104) and will increase the risk of peri-implantitis. The incidence of peri-implant mucositis and peri-implantitis can increase with increased function time in the mouth (90). Whether this is due to the effect of ageing on the immune system and healing or length of exposure remains to be determined (40).

Maintenance of Dental Implants in the Elderly Patient

Regular annual maintenance reduces the incidence of biological complications and enrolment in a maintenance program is necessary to get the best survival and success rates (32,36). This will be difficult for those in aged care or hospitals due to infirmity or serious illness that prevents them attending review appointments. In addition, there are few dentists that undertake treatment in these facilities (39).

Plaque accumulation around implants is related to mucositis (93,105). Implants are not always well cleaned by elderly patients because of impaired vision and lack of dexterity (93). Oral hygiene of elderly in aged-care homes can also be poor especially if the patient is reliant on the staff to provide their oral hygiene (64,75). A study of oral health in nursing homes has shown that less than one-third of residents cleaned their own teeth twice a day, but more than half once a day (63). One-third of residents had some assistance and those with cognitive impairment, such as dementia, required help. When assistance was required only 30% had their teeth cleaned once or twice a week. Educating the elderly is an answer, but they may have trouble with dexterity or holding the brush. Bigger brush handles or powered brushes may help. In addition, those with cognitive impairment may not remember the instructions and, irrespective of age, all oral hygiene advice needs continued reinforcement. A solution is to educate the aged-care staff, but there seems to be a lack of appropriate education and most information comes from journals, books, AV media or in-house training by other staff (65). One-third didn't receive any information at all. Additional barriers are no reinforcement, low priority, fear of causing pain and injury, a perception that oral care does not provide significant benefits, issues with poor patient cooperation, too few staff and a lack of time. There may also be a high rate of staff turnover (39). The use of family members seems to have been overlooked, but they may not be interested in looking after the resident, live too far away or might not be able to afford oral hygiene products.

People with implants will become increasingly common in aged-care facilities and many of the staff may not know that inhabitants have dental implants (75). It has been suggested that consideration should be given to the cleansability of implant restorations and that removable restorations should be favoured for ease of cleaning. The long-term effects of poor oral hygiene on implant survival in the elderly remains to be determined. A study of 35 edentulous patients restored with a mix of fixed and removable full arch restorations, has reported that roughly two thirds had poor oral hygiene and slightly fewer had moderate to

severe inflammation (66). Those who could provide their own daily oral hygiene had better oral hygiene and more inflammation. However, good function was maintained in the majority of the patients and the authors recommended this choice of treatment in elderly patients. Elderly patients with implant-supported overdentures were highly satisfied with their treatment (78). The dentures were easier and quicker to clean than fixed restorations, suggesting that implant-retained dentures may be the preferred choice in the edentulous elderly rather than fixed restorations. The data for single implant retained crowns or fixed bridges do not exist to any great extent.

Peri-implant mucositis responds well to treatment. Peri-implantitis can also respond well to management. However, in a recent review it was noted that in the treatment of peri-implantitis, although many short-term outcomes are favorable, there may be a lack of disease resolution and further progression, recurrence of the disease and implant loss (61). It has been suggested that where there are biological complications, the superstructure or denture attachment could be removed and the implant buried (126).

In summary, treatment of patients over 65 with implants can be considered safe and predictable. Patients' age *per se* does not appear to present a risk factor in implant survival and success. However, poor general health can reduce implant outcomes. Poor oral hygiene is an issue in the elderly and is related to peri-implant inflammation. Regular maintenance is important, but difficult for many elderly to attend due to infirmity or serious illness.

Sociological Considerations of Implants for the Aged Patient

Social considerations of dental implant treatment for the aged patient should not differ considerably from those for any patient. It is recognized that provision of dental implants is complex and requires good communication with the patient to minimize misunderstandings with regard to treatment outcomes, complications and commitment to ongoing care. A summary of sociological considerations for dental implants in the aged patient is presented in Table 3.

Changing Demographics

The prevalence of edentulism has been monitored for decades in many countries with most developed countries demonstrating a substantial decline in edentulism in recent times (37,63,92,117,121,133). Even though there is a clear decline in the number of missing teeth in older patients it is predicted that there will continue to be a need for replacement treatments well into the future (54). These declining rates of edentulism and increasing numbers of natural teeth in the aging population have been described as dentistry achieving an adverse 'consequence of success' (71). Thus, as more teeth are retained into older age more teeth become at risk of developing dental caries and periodontal diseases. As a consequence there is now a trend towards older people with more teeth having greater requirements for dental care and this is leading to an increased burden on the health system

The impact of missing teeth, due to issues with appearance and function, is reported to most commonly affect psychological and social wellbeing (89). Historically missing teeth have been replaced with dentures, but today many people regard dentures poorly and find the thought of wearing dentures disturbing (62). With the advent of implant supported or retained dental prostheses has come a significant change in treatment strategies for edentulous patients. Perhaps the two most significant advances in this field have been the ability to provide improved stability for complete denture wearers, and for the partially edentulous, improved esthetics and function (1).

Patient Satisfaction & Expectations with Implant Retained/Supported Dentures for the fully edentulous patient

Many studies have reported that the general satisfaction rate of edentulous patients with complete dentures ranges between 65-90% (18,29). Nonetheless, there are individuals who, for a variety of reasons, are unable to adapt or tolerate full dentures. Unfortunately, our ability to predict who these patients will be is very unreliable (28). While various soft and hard tissue augmentation procedures have been developed to provide a better foundation for complete dentures, they do not always improve the patients' ability to control and manage their dentures in a comfortable and functional way. However implant-retained dentures have improved these adverse outcomes and in doing so improved the quality of life for those patients who cannot tolerate complete dentures. More recently a systematic review concluded that implant supported dentures resulted in high patient satisfaction with regard to denture comfort, improved chewing efficiency and increase maximum bite force, however an improvement in general quality of life was not always noted (23).

Patient Satisfaction & Expectations with Implant treatment for Partially Edentulous Patients

Once all of the teeth have been lost the only replacement option is full dentures. Whether these will be implant retained or not will depend on functional, financial and clinical parameters. Even though the incidence of full edentulousness is declining the fact remains that there is still a significant proportion of the aging population who will have a need (and demand) for complete denture services.

The issues facing partially edentulous individuals differ from those for fully edentulous patients. For individuals with missing teeth the issues confronting them are largely related to esthetics and function. While many people with missing teeth replace them with removable partial dentures this option is becoming less acceptable, even in the aging population. A recent study investigating the motivation and expectations of partially edentulous patients seeking an implant solution found that an overriding driving force to seek such treatment was to return to “normality”. That is, they sought implant treatment as a means to return their quality of life to a normal status (54). Following treatment a common finding was that the subjects felt the replaced teeth felt like natural teeth and had restored their lost function and or esthetics. Due to the limited sample size it was concluded that further studies were needed to determine the expectations of patients over a broad range of ages and socioeconomic background to enable a better understanding of patients’ attitudes and beliefs towards implants prior to undertaking such treatment.

Economic Issues

Apart from the clinical judgment and technical competence of the clinician providing implant treatment, the patient should be presented with enough information to understand the costs, benefits and potential complications of such treatment. Many of these are difficult to quantify and interpret, but they are of considerable importance to aged patients. One of the most significant of these issues for the patient is financial constraint, which can preclude many from undertaking such treatment. However, interestingly, a study that removed this obstacle and offered mandibular overdenture implant treatment at no cost, reported that 36% of the participants did not accept the offer (129). Those who refused treatment cited fear of

implant surgery and satisfaction with their current complete dentures as reasons for their decision. From this it would seem that cost is not always an overriding issue in the decision making process of whether to proceed with implant related treatment.

Nonetheless, dental implant treatment is generally considered by most patients to be an expensive treatment option. In this context it must be noted that implants are often placed where more conservative, simpler, faster and less costly traditional techniques involving far less risk would benefit the patient to a far greater degree (10). Thus, although other less expensive treatment options to implants exist, the esthetic, functional and emotional benefits gained from dental implant treatment can be significant, albeit difficult to measure.

The financial aspect of implant treatment is often overlooked in reviews considering implant treatment with the major focus being on site assessment, patient fitness for treatment and a willingness and ability to undergo the required surgical and restorative procedures. However, another very important aspect to patient management and successful treatment outcomes is consideration of the future comfort, as well as functional and aesthetic benefits in relation to the associated treatment costs. Clearly, any implant treatment plan needs to take into account the costs of not only the initial capital outlay (involving professional fees, laboratory fees and implant component costs), but also future maintenance and repair costs, and any other potential hidden costs of the service (82,84,86,97).

Thus a patient needs sufficient information to be able to evaluate the cost/benefit of the proposed treatment. This should include an appraisal of the financial obligations, time commitment, opportunity for improved quality of life, discomfort and inconvenience as well as long term maintenance costs. These must be considered both individually and collectively prior to commencement of treatment. If the patient perceives the costs involved outweigh the expected value and outcomes of the treatment they are likely to question whether to proceed. On the other hand, if they believe the costs are justified, then treatment is likely to proceed and they are more likely to appreciate the treatment provided (131).

To date there have been few studies evaluating the cost/benefit or health economic outcomes of dental implant treatments. Most have considered single tooth implant replacement versus traditional fixed three unit fixed dental prosthesis and almost none have considered such issues in the aged or aging patient. Typical findings are that single tooth replacement with an implant is a cost effective treatment compared to the traditional fixed

bridge and that for the replacement of multiple teeth dental implants are associated with higher costs but better health outcomes than other traditional (fixed or removable) forms of multiple tooth replacement (127,139).

Initial studies investigating cost benefit outcomes of implant treatments have used visual analogue scales and patient satisfaction questionnaires (130). In addition to these it has been suggested that quality of life benefits should also be considered (46). Initial studies investigating how implants impact on quality of life used various forms of the Oral Health Impact Profile (118). Recently such instruments have been refined and the 'Quality of Life with Implant-Prostheses' questionnaire for assessing the impact of cemented implant prostheses on oral health-related quality of life has been developed (98). This new questionnaire allows for patient satisfaction, patient well-being and patient quality of life to be assessed.

This type of approach has been extended, in which patient preference for implant treatments before and after treatment was recorded using visual analogue scales (139). This was followed with some further sophisticated modeling including quality-adjusted tooth years (an assessment of the type of restoration and its effect on adjacent teeth) and then using a stochastic cost-effectiveness model the expected costs and quality-adjusted tooth years were analyzed. From these analyses it was concluded that while both implant supported single crowns and fixed dental prostheses resulted in good long term clinical results, from the patients' perspective, the lower costs associated with the single tooth implant option resulted in this treatment being preferred over the traditional fixed dental prosthesis option.

Most recently, a systematic review attempting to determine the degree to which cost of prosthodontics care is considered in relation to good clinical outcomes concluded that measures of cost benefit, cost effectiveness and cost utility are commonly used to address these issues (11). However it was noted that such measures are difficult to do and that further collaboration with experts in health economics is needed to fully understand these complex interrelationships.

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Table 1

Summary of Biological Considerations of Aging for Dental Implants

<i>Early (Inflammatory) Stage of Wound Healing</i>	Aging promotes the release of inflammatory mediators resulting in a prolonged inflammatory phase which may delay soft tissue wound healing. Osseous healing is also affected by age and appears to progress at a slower rate than in younger individuals.	References: 5, 128, 134
<i>New Tissue Formation (Proliferative Stage)</i>	Aging affects new tissue formation during the regenerative phase of healing by changes in stem cell populations and changes in the microenvironment. Stem cell numbers and functions decline with age reducing the potential for regeneration following injury. Diminished cell proliferation described in aged cells is largely mediated through telomere shortening and the DNA damage response. Bone healing in the elderly is also negatively impacted. Aging also affects angiogenesis through changes in the production or signalling associated with many growth factors.	References: 27, 49, 55, 56, 59, 60, 76, 106, 109 115, 123
<i>Tissue Maturation and Remodelling</i>	Long-term success of implant therapy is reliant on the maintenance of a soft tissue seal around the implant, as well as adequate bone support. Aging modifies a number of important processes associated with tissue maturation including gingival wound healing, cell activity, levels of matrix metalloproteases and tissue inhibitors of matrix metalloproteases, apoptosis and collagen turnover. Aging also results in an imbalance in bone remodelling.	References: 17, 26, 30, 42, 52, 76, 79, 96, 119

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Table 2

Summary of Clinical Outcomes of Aging on Dental Implants

<i>Survival of implants in the Elderly Patient</i>	Over the short term (1 to 6 years), success rates in elderly patients (65 years and older) appear to be similar to younger patients A patient’s age was not associated with increased surgical complications and geriatric patients may not be poor surgical candidates.	References: 24, 40, 53, 70, 91, 112, 120, 136.
<i>Peri-implant Mucositis and Peri-implantitis</i>	The prevalence of peri-implant mucositis and peri-implantitis varies between studies and depends on the criteria used. The association of peri-implant mucositis and peri-implantitis appears to be stronger in fully edentulous patients, which is mainly elderly patients. There was a correlation with rough surfaces and peri-implant disease. Factors associated with peri-implant mucositis and peri-implantitis are long standing pre-existing periodontitis and increased function time in the mouth	References: 4, 8, 40, 41, 87, 90, 104

<i>Risk Factors affecting Implant outcomes in the Elderly Patient</i>	Many elderly patients have serious medical issues in addition to smoking and diabetes, such as cancer and osteoporosis/osteopenia, and these can affect implant outcomes. Associated treatments such as radiotherapy and medications such as bisphosphonates can increase the risk of implant failure.	References: 7, 31, 33, 47, 51, 79, 103
<i>Maintenance of Dental Implants in the Elderly Patient</i>	Regular annual maintenance may be difficult for those in aged care or hospitals due to infirmity, serious illness that prevents them attending review appointments and reliance on the staff to provide their oral hygiene. Education of both the elderly and their carers will be essential to maintaining dental implant health this group.	References: 39, 63, 64, 65, 75, 93

Table 3

Summary of Sociological Considerations for Dental Implants in the Aged Patient

<i>Changing Demographics</i>	Despite a substantial decline in edentulism in recent times it is predicted that there will continue to be a need for replacement treatments well into the future. This trend towards older people with more teeth having greater requirements for dental care is leading to an increased burden on the health system. With the	References: 1, 37, 54, 63, 92, 117, 121, 133
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	advent of implant supported or retained dental prostheses has come a significant change in treatment strategies for edentulous patients. Implants now provide an opportunity for improved stability for complete denture wearers, and for the partially edentulous, improved esthetics and function.	
<i>Patient Satisfaction & Expectations with Implant Retained/Supported Dentures for the fully edentulous patient</i>	Implant-retained dentures have improved comfort and function for those patients who cannot tolerate complete dentures. As a result implant supported dentures are associated with high patient satisfaction but an associated improvement in general quality of life is not always noted.	References: 23
<i>Patient Satisfaction & Expectations with Implant treatment for Partially Edentulous Patients</i>	The motivation and expectations of partially edentulous patients seeking an implant solution are a desire to return to “normality”. Although subjects have reported that implants felt like natural teeth and had restored their lost function and or esthetics further studies are needed to determine the expectations of patients over a broad range of ages and socioeconomic background to enable a better understanding of patients’ attitudes and beliefs towards implants prior to undertaking such treatment.	References: 54
<i>Economic Issues</i>	Patients should be presented with enough information to understand the costs, benefits and potential complications of implant treatment. Cost benefit, cost effectiveness and cost utility are commonly used to address these issues (11). To date there have been few studies evaluating the cost/benefit or health economic outcomes of dental implant treatments in the aged or aging patient. Cost benefit outcomes of implant treatments should include quality of life benefits.	References: 11, 46, 82, 84, 86, 97, 98, 118, 131, 139

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