IMPLANT TREATMENT OUTCOMES AT THE UNIVERSITY OF BRITISH COLUMBIA GRADUATE PERIODONTICS CLINIC:
A RETROSPECTIVE ANALYSIS

by

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ABSTRACT

Objectives: Dental implants have predictable outcomes and high survival rates. However, a small but significant subset of patients experience implant failure. A retrospective review of charts at UBC was conducted to determine how patient-, disease-, site-, surgeon- and implant design-centered risk factors affect the survival of implants.

Methods: A review of implants placed between 1989-2006 was completed. Inclusion criteria required a one-year post-placement diagnostic radiograph. Implant failure was defined as the loss or removal of an implant at any time. Bivariate analyses were used to identify variables associated with implant failure. Risk factors with p-values < 0.05 or that were deemed clinically relevant by previous studies were included in stepwise linear multiple regression and logistic regression analyses.

Results: Based on the inclusion criteria, 107 patients and 300 implants were included in the study. Follow-up ranged from 1.00 to 19.79 years (mean 4.08 ± 2.95 years). At follow-up, 92.3% of implants survived and 84.1% of patients did not experience failure. In the failing implant group, 13.1% of patients had one failed implant and 2.8% of patients had two failed implants. The survival rate of replacement implants was 85.71%. Most factors studied had no statistically significant impact on survival. Only simultaneous sinus augmentation and removable prostheses were significantly associated with failure and guided bone regeneration was significantly associated with survival. In the regression analyses, the predictors showing the largest effect on thread exposure were: implant model, jaw (in favor of mandibular implants), and surface (in favor of rough surfaces). The odds ratio for implant failure was 16.87 for osteotome sinus elevation and 0.288 for decreasing implant width.
Conclusions: The survival rate for implants placed at UBC is similar to those reported in the literature. Most variables considered risk factors did not have a statistically significant effect on implant failure. Given the high survival rates of implants, a small sample size does not allow for trends in the data to reach statistical significance, even if a true difference exists.
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1. INTRODUCTION

Implant therapy for partially and completely edentulous patients has become a treatment mainstay in modern dentistry. During the 1970s, parallel studies by Branemark and Schroeder introduced the concept of osseointegrated implants (Romeo et al., 2002). The vast majority of clinical studies completed since that time, with at least 5-year follow up, clearly indicate the dental implants have predictable outcomes and high survival rates (Schou et al., 2004). Despite the reported successes, a small but significant subset of patients do experience implant failure (Moy et al., 2005). The identification of risk factors for implant failure is key to informed patient consent and education, treatment planning and improvements in implant design (Moy et al., 2005). The following report outlines numerous patient-, disease-, site- and implant design-centered factors that have been studied in terms of their impact on the success of implant therapy. The effect of the level of training of the surgeon placing the implant fixture on implant survival is also discussed. A retrospective review of patient charts at the University of British Columbia graduate periodontics clinic was conducted to determine how such risk factors have affected the survival of implants placed in this educational setting.
2. REVIEW OF THE LITERATURE

2.1 Patient-centered risk factors

2.1.1 Age

Patient-centered factors are particularly interesting in how they relate to implant success. One factor that has been long studied is the effect of increasing age on implant success rates. As Brocard et al. (2000) explains, anatomic or histologic variations in different age groups may contribute to differences in success rates (Brocard et al., 2000). In particular, the loss of bone mineral with increasing age may account for such differences, especially in women (Cuenin et al., 1997). Bone remodeling appears to be less efficient in older populations and older individuals are more likely to be completely edentulous which has been linked to lower success with implant treatment (Brocard et al., 2000).

Moy et al. (2005) published a retrospective cohort study based on data from 1,140 patients treated over 21 years by the same surgeon using various implant systems (Moy et al., 2005). They reported that advanced age doubled the risk for implant failure; patients older than 60 years of age were twice as likely to have adverse outcomes (Moy et al., 2005). Brocard et al. (2000) published a prospective, multicentre report on 1,022 ITI implants placed between 1991 and 1999 and followed for seven years (Brocard et al., 2000). Younger patient groups (<40 years and 40-60 years) had success rates at or above the global mean success rate for the study, while the success rate for the older group (>60 years) was significantly lower (Brocard et al., 2000).
Four hundred and sixty-four patients with 1852 Branemark implants placed between 1979 and 1999 were followed for at least six months in Deluca and Zarb’s 2006 paper (DeLuca et al., 2006a). No differences were found between age groups and it was concluded that age was an insignificant variable in early implant failures (DeLuca et al., 2006a). In a much smaller study by Dao et al. (1993) the highest implant failure rates were actually reported in the youngest age group (Dao et al., 1993). In another small cohort study, implants placed in geriatric patients had an overall 99% success rate, which is comparable or better to reported success rates in the general population (Grant and Kraut, 2007). Lemmerman and Lemmerman (2005) published a retrospective study involving 1,003 implants of various designs placed between 1987 and 2002 and followed until 2003 (Lemmerman and Lemmerman, 2005). Once again, he concluded that success was unaffected by patient age (Lemmerman and Lemmerman, 2005).

Shirota et al. (1993) studied the effect of aging on osseointegration of implants in rats (Shirota et al., 1993). In the young rats, new trabecular bone formed around the implants, with rapid contact at the bone-implant interface (Shirota et al., 1993). In contrast, older rats demonstrated less bony growth and less bone to implant contact, suggesting that the rate and volume of bone formation around implants decreases with age (Shirota et al., 1993). A similar study also found that older rats had the lowest percent bone-to-implant contact, thickness of bone contact and area of bone surrounding the implant (Takeshita et al., 1997).

Clearly, evidence exists that age influences bone formation around dental implants. Whether this translates to lower success rates for implant therapy seems controversial. Improvements in implant design, particularly in terms of surface
roughness, seems to have improved success of treatment to a degree that the effects of factors such as age are small, or even negligible. Older age groups may include: a greater number medically compromised individuals (including those with osteoporosis, type II diabetes or head and neck irradiation), a larger proportion of patients with periodontitis or a history of the disease, and a higher number of patients with substantial loss of alveolar bone (potentially requiring more complex surgical and prosthetic treatment plans). Age may simply be implicated due to its close association to these other factors that have the potential to increase implant failure. Older age should not be considered a contraindication for implant treatment. Patients should be aware that there is evidence of less efficient bone formation around implants but that the evidence that this leads to decreased implant success rates is not strong.

2.1.2 Gender

The possible effect of patient gender on implant treatment outcomes has been extensively studied in the literature. A number of large studies with long-term follow-ups, as well as numerous review papers have concluded that gender has no effect on implant success (Blanes et al., 2007; Dao et al., 1993; DeLuca et al., 2006a; Lemmerman and Lemmerman, 2005; Levin et al., 2006; Mombelli and Cionca, 2006; Moy et al., 2005). One specific exception involves post-menopausal women who have been found to have lower success rates, particularly in the maxillary arch (August et al., 2001; Moy et al., 2005). This is closely related to bone density and osteoporosis and will be more thoroughly discussed in those sections of this review.
2.1.3 Smoking status

The detrimental effect of smoking on wound healing and periodontal disease has been well established (Baig and Rajan, 2007). Smoking impedes the function of polymorphonuclear leukocytes and macrophages in a number of ways (Bain, 2003). It also contributes to low tissue oxygenation, causes systemic release of epinephrine and norepinephrine, decreases collagen deposition, increases platelet aggregation and blood viscosity, etc. (Moy et al., 2005). Long-term smokers also have lower bone mineral content than non-smokers (Haas et al., 1996). Despite the documented effects of smoking on post-surgical healing, it wasn’t until 1992 that Jones and Triplett first associated smoking with implant failure (Jones and Triplett, 1992).

A large retrospective evaluation of 2,194 Branemark implants by Bain and Moy found that smoking was the most significant risk factor for implant failure in their population (Bain and Moy, 1993). The overall failure rate in smokers was 11.3% compared to 4.76% in non-smokers (Bain and Moy, 1993). When poor bone quality was considered (posterior maxilla), smokers experiences a 17.9% failure rate, in contrast to the 7.3% failure rate in non-smokers (Bain and Moy, 1993). A 1994 report by DeBryn and Collaert demonstrated similar results: a 9% failure rate in smokers versus a 1% failure rate in non-smokers (De Bruyn and Collaert, 1994). Baelum and Ellegard studied periodontally compromised patients and found that smokers were 2.6 times more likely to have explanted implants than non-smokers (Baelum and Ellegard, 2004). Moy et al. (2005) conducted a retrospective cohort study of 1,140 patients over 21 years (Moy et al., 2005). They reported that smoking was a significant predictor of implant failure, with a relative risk of 1.56 (Moy et al., 2005). Studies and reviews that echo the findings of the
above authors are numerous (Aykent et al., 2007; DeLuca et al., 2006b; Hinode et al., 2006; Karoussis et al., 2003; Mombelli and Cionca, 2006; Olson et al., 2000a; Wallace 2000; Widmark et al., 2001).

Bain and Moy (1993) also found differences between moderate and heavy smokers, suggesting a possible dose-dependent effect on implant failure (Bain and Moy, 1993). Lindquist et al. (1996) found greater marginal bone loss around implants in heavy smokers than those with low cigarette consumption (Lindquist et al., 1996).

A majority of failures in smokers appear to occur after the second-stage surgery when implants are uncovered and can be adversely affected by toxic products in cigarette smoke, much like periodontal tissues are affected (Baig and Rajan, 2007; DeLuca et al., 2006a). Gorman et al. (1994) and Lambert et al. (2000) found the majority of failures occurred within the first year, but after the implants were exposed (Gorman et al., 1994; Lambert et al., 2000). It seems that smoking is not associated with an inability to attain osseointegration but rather, an inability to maintain it (DeLuca et al., 2006a). It has also been shown that smoking has a greater effect on maxillary implants than mandibular implants, which is likely related to the poor bone quality associated with the maxillary arch (Baig and Rajan, 2007; Haas et al., 1996).

In contrast, numerous more recent reports have found no significant differences between smokers and non-smokers in terms of implant survival (Bain 2002; Blanes et al., 2007; Brocard et al., 2000; Kumar et al., 2002; Levin et al., 2007; Peleg et al., 2006a; Schwartz-Arad et al., 2002; Schwartz-Arad et al., 2008). It has been argued that roughened surfaces may increase implant success rates to a point where the effect of smoking is negated (Kumar et al., 2002). They speculate that smoking simply does not
play a significant role in osseointegration and survival when surface-modified implants are used (Kumar et al., 2002). This view has been highly contested and the evidence from both sides is compelling. In fact, Hinode et al. (2006) questioned the results of Bain et al.’s 2002 meta-analysis (Bain 2002; Hinode et al., 2006). The 2002 review found no significant differences between implant success rates in smokers and non-smokers but Hinode claims that if the data is evaluated using a synthesized odds ratio a significant risk of implant failure exists for smokers (OR=2.17) (Hinode et al., 2006).

Even if advances in implant design can negate effects of smoking on implant failure, it appears as though smokers continue to experience more complications associated with their treatment. Smoking has been found to adversely affect the health of peri-implant tissue (Aykent et al., 2007; Haas et al., 1996). Peri-implant pocket depth, bleeding indices and bone levels were found to be significantly worse in smokers than non-smokers, particularly in the maxilla (Aykent et al., 2007; Haas et al., 1996). The incidence of peri-implantitis is also elevated in smokers (Baig and Rajan, 2007; Heitz-Mayfield and Lang, 2004). Lindquist et al. (1997) reported increased marginal bone loss around implants in smokers (Lindquist et al., 1997). Deluca et al. (2006) confirmed these findings and Blanes et al. (2007) found a similar trend, although the difference between smokers and non-smokers was not statistically significant (Blanes et al., 2007; DeLuca et al., 2006b).

It has been shown that the risk of implant failure or complications can be reduced to that of a non-smoker if the habit is ceased (Lambert et al., 2000). In 1996, Bain published results indicating that if patients are placed on a smoking cessation protocol one week prior to implant placement, the implant success rates are not significantly
different from non-smokers (Bain 1996). Deluca et al. (2006) found that the effect of smoking on wound healing could be reversed with a 1-2 week smoke-free pre-surgical period (DeLuca et al., 2006a).

Smoking should not be considered an absolute contraindication for treatment (DeLuca et al., 2006b; Moy et al., 2005). The evidence supporting altered wound healing in smokers is difficult to ignore but whether or not this translates to increased implant failure rates is less clear. Smokers should be advised of the possible increased risk for implant failure and complications and a smoking cessation protocol should be recommended prior to fixture placement.

2.2 Disease-centered risk factors

Systemic disease

The effect of systemic pathology on implant osseointegration and maintenance is of particular interest to clinicians who would benefit from the ability to accurately predict a patient’s individual risk. The evidence appears varied: it has been reported that healthy patients have higher implant success rates than those with systemic disease (Brocard et al., 2000), while others publish opposing conclusions (Moy et al., 2005). It can be agreed that controlled systemic disease should not be considered a contraindication for treatment (Brocard et al., 2000). For the purposes of this review, we will concentrate on two of the most extensively researched conditions: diabetes and osteoporosis.
2.2.1 Osteoporosis

Osteoporosis is defined as a bone mineral density level of 2.5 standard deviations or more below the mean of a young population (Beikler and Flemmig, 2003). Three main types of primary osteoporosis exist: post-menopausal, age-related and idiopathic (Mombelli et al., 2006). Secondary osteoporosis can be caused by a variety of factors (diabetes, alcoholism, COPD, anticonvulsant drugs, etc.) (Beikler and Flemmig, 2003). It is assumed that the decrease in bone density associated with osteoporosis affects the mandible and maxilla as it does other bones (Humphries 1989), but this remains unconfirmed in the literature (Beikler and Flemmig, 2003). It is also assumed that impaired bone metabolism associated with osteoporosis may affect osseointegration of implants (Beikler and Flemmig, 2003). Trabecular bone is much more affected by such metabolic changes than cortical bone, making areas such as the posterior maxilla more likely to be severely affected by the disease (Beikler and Flemmig, 2003). However, osteoporotic fractures usually heal readily, suggesting that the repair process in these patients likely remains adequate for implant integration (Dao et al., 1993).

This remodeling process does not appear to differ from that seen in healthy patients, as demonstrated by numerous histologic studies of implants retrieved from osteoporotic jaws (de Melo et al., 2008; Shibli et al., 2008a; Shibli et al., 2008b). These studies showed bone-to-implant contact and bone maturity comparable to that found in healthy subjects (de Melo et al., 2008; Shibli et al., 2008a; Shibli et al., 2008b). In osteoporotic rabbits, bone formation was delayed, trabecular volume and mineral apposition reduced, but considerable bony contact occurred with time (Lugero et al., 2000; Mori et al., 1997).
Clinical studies have delivered conflicting results. Many reports, like Friberg et al. (2001) have shown success rates in osteoporotic women comparable to healthy populations (Friberg et al., 2001; Mombelli et al., 2006). Evidence also exists that implants are highly successful in patients with osteoporosis induced by corticosteroids or other endocrinopathies (Cranin et al., 1991; Friberg 1994; Steiner and Ramp, 1990). Others have found reduced success rates in osteoporotic patients. Blomqvist (1998) found that there was a significantly reduced success rate following maxillary sinus augmentation and implant placement in patients with reduced bone mass density as compared with age- and sex-matched control patients (Blomqvist 1998). August et al. (2001) found that there was an increased failure rate for implants placed in the maxilla in postmenopausal women without estrogen supplementation compared to pre-menopausal women (August et al., 2001).

Moy et al. (2005) describes that in severe cases of osteoporosis it may be difficult to obtain good primary implant stability due to a decrease in trabecular bone mass (Moy et al., 2005). It is advisable that the amount of implant surface area available for osseointegration should be maximized in these patients (rough surfaces, wide platform, etc.) (Moy et al., 2005).

Osteoporosis does not rule out implant placement, but the difference in bone metabolism and possible increased failure risk should be explained to affected patients. Careful assessment of nutrition and systemic health should be completed, and calcium and vitamin D supplementation ensured in the pre-operative period (Beikler and Flemmig, 2003). Patients should be advised to quit smoking, since it is an important risk factor for osteoporosis (Beikler and Flemmig, 2003). Where there is insufficient bone for
implant placement, augmentation should be considered prior to placement (Beikler and Flemmig, 2003). The surgeon can also consider extending the healing period before loading, and using implant designs that ensure optimal bone-implant contact (Beikler and Flemmig, 2003).

2.2.2 Diabetes

Diabetes can be classified into two types. Type I diabetes is an autoimmune disease affecting the beta cells of the pancreas, leading to insufficient insulin production (Mombelli et al., 2006). Type II diabetes is the most common form in the adult population and is associated with obesity (Kahn and Flier, 2000). It is seen as a resistance to insulin and an inability to produce compensatory insulin (Mombelli et al., 2006). Systemic complications are varied and can include: retinopathy, nephropathy, neuropathy, micro and macro-vascular disease, and altered wound healing (Beikler and Flemmig, 2003). In terms of oral health - xerostomia, periodontitis and caries have been linked to this disease (Mombelli et al., 2006). Microvascular disease of the gingival tissue may compromise blood supply and contribute to delayed wound healing and an elevated risk for infection (Shernoff et al., 1994). Many aspects of wound healing are profoundly affected by tissue hyperglycemia, including neutrophils and leukocyte function, chemotaxis and phagocytosis (Goodson and Hunt, 1986).

In Shernoff et al’s 1994 study and Olson’s 5-year follow up of 89 type II diabetes undergoing implant therapy, the survival rate for fixture and prosthesis was approximately 90% (Shernoff et al., 1994). They concluded that the percentage of diabetic patients experiencing failures seemed relatively high, but the percentage fell within normal range for published studies on healthy patients (Olson et al., 2000b;
Shernoff et al., 1994). They also found that fasting plasma glucose, HbA1c values and smoking history were not statistically significant predictors of implant failure (Olson et al., 2000b; Shernoff et al., 1994). Mombelli et al. reviewed six studies, which included diabetic patients in their study population (Mombelli et al., 2006). He found there was no unequivocal tendency towards higher failure rates in diabetics (Mombelli et al., 2006). However, the largest reviewed study was Moy’s 2005 21-year retrospective cohort publication, which included 48 diabetic patients (Moy et al., 2005) They found a statistically significant increase in the relative risk for implant failure in diabetics (RR=2.75) (Moy et al., 2005). Their results demonstrated that even well controlled diabetics were at greater risk for implant failure compared to healthy controls (success rate of 68.75% vs. 93.46%) (Moy et al., 2005).

In a better designed but smaller study (n=15 diabetic patients), patients were matched to two control subjects in terms of age, gender, location of implants, duration of edentulism, type of prosthesis, etc. (Accursi, 1973). No increased risk of implant failure or prosthodontic complications were found in diabetic patients compared to their matched controls (Accursi, 1973). In a retrospective review of 215 implants in 40 diabetic patients, Fiorellini et al. found that the survival rate of dental implants in controlled diabetics is lower than that of the general population, but the results are reasonable (Fiorellini et al., 2000). Of the studies that found an increase in implant failure, it was generally associated with uncovering of implants and the early phase of loading (Beikler and Flemmig, 2003). Such failures may be attributed to a diminished immune response and reduced bone turnover due to microvascular disease (Olson et al., 2000b).
Studies involving diabetic animal models have shown that bone-to-implant contact is significantly reduced with this disease (Fiorellini et al., 1999; Nevins et al., 1998). Bone density was also found to be slightly lower around implants in diabetic patients, but was comparable to controls in insulin-controlled animals (Nevins et al., 1998). It appears as though the healing process is impaired in uncontrolled diabetic animals but osseointegration can still occur. Good initial contact seems to optimize this process and areas with abundant cortical bone appear less affected (McCracken et al., 2000). The biological pathways through which diabetes may affect osseointegration is presently poorly described in the literature (Beikler and Flemmig, 2003).

Beikler and Flemmig outlines some special considerations for diabetic patients undergoing implant therapy in his 2003 review as follows: a) ensure optimal glycemic control in the pre- and post-operative periods, b) the practitioner should be experienced in managing possible peri- and post-operative complications (ex: hypoglycemic crisis during surgery), c) antibiotic therapy should be prescribed, with the first dose given pre-operatively, and d) chlorhexidine use is recommended peri- and post-operatively (Beikler and Flemmig, 2003).

The evidence for patients with diabetes to experience higher implant failure rates is equivocal at present (Mombelli et al., 2006). Animal studies have shown that osseointegration is impaired in subjects with poor glycemic control (Beikler and Flemmig, 2003). Patients should be aware of the current evidence on this topic and precautions should be taken to ensure their disease is well controlled and their risk of post-operative infection is as low as possible.
2.2.3 Periodontal disease

A variety of studies support the theory that existing periodontal pockets around teeth can act as reservoirs for periodontal pathogens that can rapidly colonize tissues around implants (Leonhardt et al., 1993; Papaioannou et al., 1996; Sbordone et al., 1999). It seems reasonable to assume that a patient who is periodontitis-susceptible and who does not receive proper treatment can experience a similar risk for attachment loss at implants and teeth (Hardt et al., 2002). In fact, it has been shown that one year after implant placement, overall periodontal conditions were correlated with the conditions of the tissues around implants (Brägger et al., 1997). Implants harboring Actinobacillus actinomycetemcomitans, Prevotella intermedia or Porphyromonas gingivalis had deeper probing depths and more severe signs of inflammation than implants free of such pathogens (Karoussis et al., 2003).

Currently there are a number of review papers that thoroughly discuss implant therapy in periodontally susceptible patients, including: Van der Weijden et al. (2005), Karoussis et al. (2007) and Schou et al. (2008) (Karoussis et al., 2007; Schou et al., 2004; Van der Weijden et al., 2005). There exist two clinical studies that examine implant therapy in healthy patients and those with periodontitis in terms of implant survival and incidence of biological complications. The Karoussis et al. (2003) publication included treated periodontitis patients and healthy controls (Karoussis et al., 2003). In the periodontitis group, the teeth being replaced by dental implants were lost due to periodontal disease (Karoussis et al., 2003). In the healthy group, teeth were lost due to other reasons (caries, fractures, trauma, etc.) (Karoussis et al., 2003). Patients were offered supportive therapy every 3-6 months and were recruited for a clinical and
radiographic examination 10 years after implant placement (Karoussis et al., 2003). Implants replacing teeth lost due to chronic periodontitis had lower survival rates than those lost due to other reasons (90.5% vs. 96.5%) (Karoussis et al., 2003). This higher susceptibility for implant loss became evident only after 6 years of service (Karoussis et al., 2003).

Based on their definition of peri-implantitis (PD ≥5mm and BOP+), 28.6% of implants in the periodontitis group and 5.8% of implants in the healthy group experienced such complications (Karoussis et al., 2003). Based on their success criteria (PD ≤5mm, BOP -and bone loss <0.2mm annually), success rates of 52.4% and 79.1% of implants replacing teeth lost due to periodontitis and for implants replacing teeth lost due to other reasons, were reported (Karoussis et al., 2003). The authors theorize that, based on the long time period before failure and the high incidence of peri-implantitis, eventually loss may be due to repeated episodes of peri-implantitis over several years (Karoussis et al., 2003).

In a retrospective study by Hardt et al. (2002), patients were divided into groups according to their age-related bone loss score (ArB-score) (Hardt et al., 2002). This score is calculated by dividing the percentage bone loss by the patient’s age multiplied by the number of teeth remaining (Hardt et al., 2002). The two extreme quartiles of the population were considered either the periodontitis group (upper quartile) or the non-periodontitis group (lower-quartile) (Hardt et al., 2002). Once again, implant failure rates were higher in the periodontitis group (8.0% vs. 3.3%) (Hardt et al., 2002). In addition, there was also a statistically significant relationship between the ArB-score and peri-implant bone level change from abutment connection to 5 years later (Hardt et al., 2002).
Other studies have reported similar results. Brocard et al. (2000) found that periodontally maintained patients had significantly lower success rates compared to the global success rate (a difference of 9%) (Brocard et al., 2000). Short-term results in periodontitis patients appear to be very high, with drops in success during the 5-10 year period (Schou et al., 2004). Similarly, the occurrence of peri-implantitis seems to increase as the duration of the study increases (Schou et al., 2004). A study by Polizzi et al. (2000) examining the placement of implants into extraction sockets found that the success of the implant over 5 years was unaffected by the reason for tooth loss (Polizzi et al., 2000). In contrast, Grunder et al. (1999) found more implant failures when periodontitis was cited as the reason for tooth loss (Grunder et al., 1999). Novaes et al. (2003) studied bone-to-implant contact in periodontal infected sites in dogs (Novaes et al., 2003). They found that osseointegration of the implants was not different in sites with induced periodontitis compared to healthy sites (Novaes et al., 2003). This may be another indication that increased failures are not related to healing, but perhaps to infection of the peri-implant tissues over time (Karoussis et al., 2007).

Most recently, Safii et al. (2009) completed a systematic review and meta-analysis on the risk of implant failure and marginal bone loss around implants in patients with a history of periodontal disease (Safii et al., 2009). They concluded that the odds ratio for implant survival was significantly in favor of periodontally healthy patients (OR=3.02) and implants placed in those with periodontitis experienced more peri-implant bone loss than those without a history of periodontitis (standard mean difference =0.61mm) (Safii et al., 2009). All accepted studies (n=5) showed more favorable implant survival in those without history of periodontitis, but none showed that the difference was
statistically significant (Safii et al., 2009). Four of the included studies found there was more marginal loss around implants in those with a history of the disease and two of these found that the difference was significant (Safii et al., 2009). They concluded that there is currently a “moderate” level of evidence to indicate that periodontitis subjects are more susceptible to implant failure and marginal bone loss (Safii et al., 2009).

Oral implants may be successfully placed and maintained in patients with a history of periodontal disease (Karoussis et al., 2003; Schou et al., 2004). Although these studies report lower success rates in those with periodontitis compared to healthy patients, the success rates lie within an acceptable range for the general population (>90%) and the differences are often not statistically significant (Karoussis et al., 2007; Schou et al., 2004). However, patients with a history of periodontitis should be aware that lower survival and success rates, as well as higher incidences of peri-implantitis and peri-implant bone loss have been reported in this population (Karoussis et al., 2003; Schou et al., 2004; Van der Weijden et al., 2005). Since complications and implant loss are likely related to periodontal pathogens, treatment of periodontal disease and continued maintenance are essential to ensure healthy periodontal and peri-implant tissues (Van der Weijden et al., 2005). It is also important to consider that smoking may be a significant confounder is not always reported in these studies (Van der Weijden et al., 2005).

2.3 Implant design-centered risk factors

2.3.1 Implant dimensions

In posterior areas, where the height of alveolar bone above the inferior alveolar nerve canal (mandible) or below the maxillary sinus (maxilla) is often limited, the use of “short” (<10 mm) dental implants is a significant clinical benefit. This limits the need for
extensive bone augmentation or sinus lifting, pre-surgical tomography, (Morand and Irinakis, 2007) reduces surgical risk, discomfort, time and overall cost of treatment (Misch et al., 2006; Montes et al., 2007; Morand and Irinakis, 2007). Short preparations pose less risk to overheating of bone and are useful when small interarch distance or angled/dilacerated roots are present (Misch et al., 2006). When machined implants were commonly used, clinicians sought to place the longest possible implant to maximize the surface area for osseointegration (Morand and Irinakis, 2007). The advent of “rough” surfaces on implants has led to significantly better long-term results and the difference in surface area compared to machined surface can help compensate for less length in the implant fixture (Morand and Irinakis, 2007).

Misch et al. (2006) reviewed the literature from 1991-2003 to examine failure rates associated with implants <10 mm in length (Misch et al., 2006). The average success reported in the literature at this time was 85.3%, representing 2,837 implants (Misch et al., 2006). Failures of short implants generally occurred after prosthetic loading and surgical success did not vary with implant length (Misch et al., 2006). In his own 2006 retrospective evaluation of 745 implants, he found that implant length was not a factor in survival or success over 6 years. He considered splinted implants with no cantilever load, mutually protected or canine-guided occlusion and implant design that optimizes bone-implant contact as factors for success with short implants (Misch et al., 2006).

A number of other studies were examined for this review, with mixed results. DeLuca et al. (1999) followed 1852 Branemark implants placed over 20 years and concluded that a significantly greater number of early failures occurred in implants ≤10
mm compared to longer implants (>10 mm) (DeLuca et al., 2006a). A 3-year prospective report by Grunder et al. (1999) found that 80% of 7 mm long implants failed (Grunder et al., 1999). Lekholm et al. (1999) studied 461 Branemark implants over 10 years and reported that shorter standard-diameter implants were lost significantly more often than longer ones (Lekholm et al., 1999). All of the above studies used machined-surface implants.

Romeo et al. (2004) studied 250 patients with a variety of implant-supported prosthesis (single-tooth prostheses, cantilever prostheses, fixed partial dentures or removable partial dentures) for 3.85 years (Romeo et al., 2004). Implant failure was not significantly influenced by implant length or diameter (Romeo et al., 2004). A retrospective evaluation of 1,387 single tooth implants over 6 years by Levin et al. (2006) found that implant survival was not related to implant dimensions (Levin et al., 2006). Blanes et al. (2007) completed a 10-year review of 192 posterior implants and concluded that length did not influence implant survival or peri-implant bone loss (Blanes et al., 2007). A multicentre report on 1,022 ITI implants followed over 7 years by Brocard et al. (2000) divided implants into groups according to their length and found no difference in survival between groups (Brocard et al., 2000). It appears as though reports which include more rough surface implants, found that length did not influence success while publications involving machined surfaces did find that shorter implants fared worse than their longer counterparts (Misch et al., 2006; Morand and Irinakis, 2007).

In terms of biomechanics, osteointegrated bone-implant interfaces distribute most prosthetic load to the crestal portion of the implant body, with little stress transferred to the apical portion (Misch et al., 2006). This may indicate that implant length is not a
primary factor in load distribution (Misch et al., 2006). To compensate for shorter length, a surgeon may consider a wide-diameter implant (ex: 5 mm) (Morand et al., 2007). A 5 mm wide x 6 mm long implant has the same surface areas as a 3.75 mm wide x 10 mm long implant (Morand and Irinakis, 2007). In fact, width appears to be a more critical factor than length in terms of stress distribution (Petrie and Williams, 2005). Increasing implant diameter results in a 3.5-fold reduction in crestal strain, whereas increasing length leads to a 1.65-fold reduction (Petrie and Williams, 2005).

Reports of increased failures with short implants may be due to: increased crown height (which acts as a vertical cantilever), excessive bite forces, and/or poor bone density (since they are most often placed in posterior regions) (Misch et al., 2006). To compensate for such risks, cantilevers should be avoided, occlusion adjusted to avoid any lateral movement, implants splinted and implant surface chosen to optimize osseointegration (Misch et al., 2006). Reduced mesio-distal dimension of the prosthesis and flattening of the cuspal inclines can also contribute to a more favorable load distribution (Morand and Irinakis, 2007). Morand and Irinakis (2007) suggest using a 2-stage approach with short implants, avoiding free-end situations without a second implant for splinting, and compensating with wider diameter implants to increase success rates, particularly in areas of poorer bone quality (Morand and Irinakis, 2007).

2.3.2 Surface of Implant

The quality of the implant surface influences wound healing at the implantation site and, in turn, osseointegration of the implant (Sykaras et al., 2000). Roughened surfaces demonstrate a number of advantages over machined surfaces, including: increased area for bone-implant contact to offer increased mechanical stability at
insertion, retention of the blood clot after placement, and stimulation of the wound healing process (Morand and Irinakis, 2007). Plasma spray coating is a common way to alter the surface microtexture of implants (Sykaras et al., 2000). It can be used to apply titanium or hydroxyapatite (HA) onto metallic cores (Sykaras et al., 2000). Blasting with particles of varying sizes to create pits and depressions is another method of altering an implant’s surface; aluminum oxide or titanium oxide are commonly used (Sykaras et al., 2000). Chemical (acid) etching to erode the surface of an implant has also been used to alter surface topography (Sykaras et al., 2000). Some companies have used a combination of the above methods to achieve an optimal surface texture. For example, Struamann’s SLA surface uses a combination of sandblasting with large grit particles and acid etching with hydrochloric-sulfuric acid (Sykaras et al., 2000). At present, all methods are commonly used, with the exception of the HA-coated implants, which have been associated with high rates of peri-implant infections and low long-term success rates (Aykent et al., 2007).

Small micropits present on roughened surfaces may influence biologic pathways at the bone-implant interface since the pits are similar in size to cells and large molecules (Kasemo and Lausmaa, 1994). Larger micropits likely serve a mechanical function in stress transfer (Kasemo and Lausmaa, 1994). Roughened surfaces have actually been reported to increase the attachment of osteoblasts and gingival cells onto the implant (Sykaras et al., 2000). Studies on the effect of surface roughness on the ability of osteoblasts to produce a mineralizing matrix found that machined, titanium oxide grit-blasted, and plasma-sprayed titanium surfaces displayed unique patterns of matrix
formation, demonstrating that a surface-dependent physicochemical and biochemical conditioning of implant surfaces takes place (Cooper et al., 1999).

The increase in surface area may be the most valuable factor of altered surface topographies, since the opportunity for osseointegration at the bone-implant interface is greatly increased. Such an increase in area may compensate for the use of shorter or narrow diameter implants in areas where conventional implants are impossible to place (Morand and Irinakis, 2007).

Numerous experimental studies, including Bernard et al. (2003) confirmed that textured implants have increased bone contact and better fixation measured by torque removal (Aykent et al., 2007; Bernard et al., 2003; Carlsson et al., 1988; Feighan et al., 1995; Sykaras et al., 2000). In a human histologic study, machined and grit-blasted microimplants were placed in 27 patients (Ivanoff et al., 2001). Blasted implants had 37% bone-to-implant contact after six months, compared to 9% contact on the machined implants (Ivanoff et al., 2001). The findings in clinical studies appear to concur, with significantly higher success rates with rough implants compared to those with machined surfaces (Bain 2002; Hinode et al., 2006; Misch et al., 2006).

The advances in surface topography has revolutionized the field of dental implantology and, as previously mentioned, may decrease or negate the effects of many of the patient and disease-centered risk factors discussed.

2.4 Implant site-centered risk factors

2.4.1 Previous or simultaneous sinus augmentation

As previously mentioned, implant placement in the posterior maxilla has unique challenges and limitations. Resorption of the alveolar process, pneumatization of the
maxillary sinuses, and poor bone quality can complicate implant therapy (Sorní et al., 2005). Techniques proposed to overcome these limitations include: bone grafting, placement of implants in anatomical abutments and, most commonly, grafting the floor of the maxillary sinus (Sorní et al., 2005). This technique was first published by Boyne and James in 1980 and has been widely used and modified since it allows for the placement of implants of conventional length in grafted sinuses (Wallace and Froum, 2003). Numerous studies have confirmed high success rates for implants placed after sinus elevation and the topic can be best explored through systemic reviews by Wallace and Froum (2003), Sorní et al. (2006), Esposito et al. (2008) and Aghaloo and Moy (2008), just to name a few (Aghaloo and Moy, 2007; Esposito et al., 2006; Sorní et al., 2005; Wallace and Froum, 2003). This augmentation procedure has been well documented and the long-term success/survival (>5 years) of implants placed compares favorably to rates reported for implants placed in ungrafted areas of the maxilla.

Wallace and Froum’s meta-regression analysis of 43 studies found that survival of implants placed in augmented sinuses ranged from 61.7% to 100%, with an average survival of 91.8% (Wallace and Froum, 2003). Sorní et al. reported near identical figures in terms of survival rates (Sorní et al., 2005). Wallace and Froum, among others, found that rough surface implants had higher survival rates than machined-surface implants in grafted sinuses (95.2% vs. 82.4%) (Del Fabbro et al., 2004; Del Fabbro et al., 2008a; Pjetursson et al., 2008; Wallace and Froum, 2003). Implants survived better when particulate grafts were (92.3%) used instead of block grafts (83.3%) and grafts were more successful when resorbable membranes were placed over lateral windows (100% with a barrier membrane, 92.6% without) (Wallace and Froum, 2003).
Contrary to what was previously thought, the use of autogenous bone in sinus grafting does not appear to improve implant and graft survival (Wallace and Froum, 2003). A study by Hallman et al. actually found higher survival rates in sinuses grafted with a xenograft (Bio-Oss®, Osteohealth) compared than those grafted with autogenous bone or a 20/80 xenograft/autograft mix (Hallman et al., 2002). Aghaloo et al. (2007) reviewed 5,128 implants and also reported higher success with Bio-Oss® vs. autogenous bone (95.6% vs. 92.0%). In a recent Cochrane review by Esposito et al. (2008), it was also suggested that bone substitutes such as Bio-Oss® should replace autogenous bone for sinus lift procedures (Esposito et al., 2008). That said, it appears as though Pjetursson et al. (2008) was the first systematic review to examine the effect of different bone materials for implants with rough surfaces (Pjetursson et al., 2008). Historically, machined implants have been used much more often in combination with autogenous bone, while rough surface implants have been used with bone substitutes (Del Fabbro et al., 2008a). When the type of graft used was considered only for rough implants all grafting materials showed similar annual failure rates (1.13% for bone substitutes, 1.1% for combination and 1.27% for autogenous) (Pjetursson et al., 2008).

Immediately placed implants appear to compare favorably to those placed in a delayed fashion, with survival rates of 89.7% and 89.6%, respectively (Wallace and Froum, 2003). This may be because they require more native bone to be present for placement and likely have good primary stability (Del Fabbro et al., 2008a). Poorest results correspond to cases where machined surface implants are used, initial alveolar crest heights are small (<3 mm) and block grafts are used (Pjetursson et al., 2008; Sorni et al., 2005; Wallace and Froum, 2003).
A number of studies have reported that smoking is detrimental to the survival of implants in grafted sinuses (Peleg et al., 2006b). Kan et al. (1999) reported implant success rates 17.4% lower in smokers compared to non-smokers (Kan et al., 1999). Olson reported a similar discrepancy between smokers and non-smokers in his 2002 study with implant failure rates of 12.7% in smokers compared to 4.8% of non-smokers (Olson et al., 2000a). Peleg et al. (2006) conducted a study on 2,132 implants simultaneously placed in grafted maxillary sinuses. Despite the fact that smokers also had significantly less alveolar ridge height than non-smokers, there was no statistically significant difference in the success rates between the two groups (Peleg et al., 2006a). The high success rates found in both smokers and non-smokers was attributed to the use of long, microtextured implants which allow for increased surface area for osseointegration, and that patients were asked to abstain from smoking for 10 days after the surgery (Peleg et al., 2006a).

2.4.2 Previous or simultaneous guided bone regeneration

Guided bone regeneration is based on the concept that, by applying a barrier membrane, bone neogenesis could be induced on top of a flat bone surface, into a created wound space (Christensen et al., 2003). GBR enables the clinician to augment the width of deficient alveolar ridges, cover fenestrations or dehishences around implants, and allow immediate placement of implants in osseous defects or large extraction sites (Simion et al., 2001). The concept of GBR has been extensively studied and reviewed. All review articles and clinical studies considered for this review agree that implant success/survival in regenerated bone is comparable to success/survival rates in native bone (Aghaloo and Moy, 2007; Blanco et al., 2005; Brocard et al., 2000; Christensen et
al.}, 2003; De Boever and De Boever, 2005; Esposito et al., 2006; Fiorellini. 2003; Fugazzotto, 2005; Hallman et al., 2002; Juodzbalys et al., 2007; Simion et al., 2001). A variety of materials have been used and studied including autogenous bone, xenograft materials, etc. A discussion of the different materials and their advantages and disadvantages is beyond the scope of this review.

2.4.3 Location in the arch and bone density

Many studies suggest that implants have higher survival and success rates in the mandible than the maxilla, particularly when the mandible is compared to the posterior maxilla (Turkyilmaz and McGlumphy, 2008). This is largely attributed to the differences in bone density between the mandible and maxilla and between anterior and posterior sites (Turkyilmaz and McGlumphy, 2008). Lekholm and Zarb proposed a bone quality classification (scale of 1 to 4) in 1985, which was based on a subjective assessment by the clinician (Lekholm and Zarb, 1985). The reproducibility and objectivity of this index has since been questioned (Turkyilmaz and McGlumphy, 2008). Computerized tomography (CT) may be the most objective and reliable method to analyze bone; Hounsfield units determined by the software program can give an estimation of bone density (D1 bone, >1250 HU; D2 bone, 850-1250 HU; D3 bone, 350-850 HU; D4 bone, 150-350 HU, D5 bone , >150 HU) (Turkyilmaz and McGlumphy, 2008).

Based on CT imaging, the bone density recordings for the different regions of the jaws were: anterior mandible – 846 ± 234 HU, posterior mandible – 526 ± 107 HU, anterior maxilla - 591 ± 176 HU, posterior maxilla - 403 ± 95 HU (Turkyilmaz and McGlumphy, 2008). These are comparable to what has been reported in other publications (Norton and Gamble, 2001; Shapurian et al., 2006). In the Turkyilmaz and
McGlumphy (2008) study, bone density measures were correlated to insertion torque, and both were associated with improved implant survival (Turkyilmaz and McGlumphy 2008).

Many studies concluded that implants placed in areas of increased bone density had better success and survival rates; mandibular implants fared better than maxillary implants and anterior implants fared better than posterior fixtures (DeLuca et al., 2006a; Grunder et al., 1999; Hinode et al., 2006; Lekholm et al., 1999; Moy et al., 2005; Polizzi et al., 2000; Romeo et al., 2002). That said, with the advent of rough surface implants, survival rates appear to have improved to the point where the differences in implant survival in the different regions are quite small and not statistically significant (Aykent et al., 2007; Ferrigno et al., 2002; Kumar et al., 2002; Morand and Irinakis, 2007; Romeo et al., 2004).

The concept of bone density may be most important when discussing the degree of primary stability available and deciding on the timing of implant loading and the type of prosthesis and occlusion (Misch et al., 2006). In general, it seems appropriate to maximize the surface area for osseointegration by choosing rough-surface implants with the largest dimensions possible given the amount of bone present and the prosthetic plan (Morand and Irinakis, 2007). This is likely most important in areas where bone density is sub-optimal, like the posterior maxilla, and where there is some evidence of lower implant survival and success rates (Morand and Irinakis, 2007).

2.5 Level of training of the surgeon

Little has been published regarding the clinical outcomes of implant therapy in relation to surgical experience of the clinician. Increasingly, dental implants are being
placed by general practitioners with varying levels of surgical experience and implant training.

The first paper to evaluate the effect of surgical experience on early implant failures was a prospective study by Lambert et al. (1997). 2641 implants placed in 30 centers were followed (Lambert et al., 1997). Implants placed by inexperienced surgeons (those having placed less than 50 implants) failed twice as often as those placed by experienced surgeons (those having placed more than 50 implants) (Lambert et al., 1997). The greatest difference was found in the first nine cases, with later cases failing significantly less often (Lambert et al., 1997). In the first nine cases, the failure rate for inexperienced surgeons was 5.9%, compared to 2.4% for those with more experience (Lambert et al., 1997). They concluded that there is a definite learning curve associated with the placement of dental implants (Lambert et al., 1997).

DeLuca et al. (2006) followed 464 patients with 1852 implants over a 20-year period and found that surgical skill proved important in terms of implant success (DeLuca et al., 2006a). They did not include information on the clinician’s experience but found that, if groups according to early implant failure rates, surgeons in the high failure rate group (>8% failures) had a 2.71 times greater failure rate than those in the low failure group (≤8% failures) (DeLuca et al., 2006a). Walton’s 2001 overdenture study found that inexperienced surgeons were more likely to place implants diverged from each other in the frontal plane and with a facial or lingual inclination (Walton et al., 2001).

Conversely, Kohavi et al. (2004) published a retrospective study on 93 implant patients treated in a university training program (Kohavi et al., 2004). They concluded
that clinical experience was not an influencing variable on implant survival over 36 months (Kohavi et al., 2004). This may be partly explained by the surgical and prosthodontic collaboration between faculty and trainees that likely takes place in such a training program (Melo et al., 2006). Melo et al. (2006) studied implant survival rates in an oral and maxillofacial surgery program (Melo et al., 2006). One hundred and seventy-eight implants were placed in 56 patients by residents in different levels of training (Melo et al., 2006). There was no significant difference in implant survival rates when level of training was considered (Melo et al., 2006). In fact, implant survival rates were highest in the first two years of training compared to the third and fourth years (Melo et al., 2006). This likely reflects the level of complexity of cases given to residents as they progress through the program (Melo et al., 2006).

Infection, surgical trauma, impaired healing and premature loading are common causes of early implant failure and it is conceivable that these may be more common with less experienced clinicians (Melo et al., 2006). The evidence regarding clinician experience appears equivocal. Basic surgical principles should always be considered and extensive implant training is advised, particularly before complex treatment plans are executed (Melo et al., 2006). In general, it appears as though good outcome are achievable by surgeons in training (Melo et al., 2006).
3. AIM

The aim of the present study was to investigate implant survival rates and predictors for implant failure in a university teaching facility. A university setting enabled a comparison of the survivability of different implant systems under reasonably standardized conditions (charting systems, follow-up protocol, etc.). In addition, investigations of the clinical outcomes of implants placed in training programs is of great interest in view of other reports stating that prior surgical experience may be significant to implant survival (Kohavi et al., 2004). Such an investigation will also provide an invaluable database of information for the graduate periodontology program. It may enable identification of areas where case documentation can be improved or treatment planning modified. This study will also serve as a basis for addition of new cases and expansion of the study in the future.

The following hypotheses were tested:

i) Implant survival at the UBC periodontology clinic is lower than that reported in randomized control trials, cohort and case studies in the published literature due to the clinician’s inexperience.

ii) A history of smoking and periodontal disease negatively affects implant treatment outcomes.

iii) Patient age, gender and history of systemic disease (diabetes or osteoporosis) do not have a significant impact on implant survival.
iv) Implants placed in the mandibular arch have better survival rates than those placed in the maxillary arch and those placed in the anterior of either jaw fare better than those placed in the posterior.

v) Previous or simultaneous bone augmentation, the clinician’s assessment of bone quality at the time of surgery, implant model, taper, width, length and connection type do not significantly impact implant survival.

vi) Rough surface implants survive better and have less marginal bone loss than smooth surface implants.

vii) Implants placed by inexperienced surgeons fail more often than those placed by more experienced clinicians in a training program.
4. MATERIALS AND METHODS

A retrospective chart review of patients treated in the University of British Columbia Graduate Periodontics program between January 1, 1989 and December 31, 2006 was conducted. The sample cohort had heterogeneous risk factors and the inclusion criteria were as follows: 1) patients had one or more dental implant(s) placed by a resident or staff member of the graduate periodontics program; 2) records of a radiographic and clinical follow up visit at least one year post-implant placement were available; 3) the implant threads were clearly discernable in the radiographs taken at implant placement and follow up. Exclusion criteria included incomplete or unavailable patients records.

Implants from two manufacturers were used in this study (Branemark/Nobel Biocare, Yorba Linda, CA; and ITI/Straumann, Waldernburg, Switzerland). Throughout the study period, patient demographic data, surgical and follow up information was collected through standardized examination forms (health history questionnaire, periodontal charting, surgical summary sheet, implant surgery form, post-operative summary sheet, implant failure guarantee form) as seen in appendices A-E. At follow up appointments, implant osseointegration was evaluated radiographically and clinically through various criteria, including: absence of signs or symptoms of pain, infection, neuropathy, mobility and absence of a peri-implant radiolucency.

Study variables to be evaluated as risk factors for implant failure included: demographic (age, gender, medical status, smoking status), anatomic (bone quantity, bone quality, implant site), reconstructive (previous or simultaneous guided bone regeneration, previous or simultaneous sinus augmentation, types of materials used for
augmentation procedures), implant-specific (brand, model, surface, length, width), prosthodontic (type of provisional and permanent restorations, prosthodontic complications), peri-operative chemotherapy (type, dose and frequency of antibiotics, analgesics, steroids and chlorhexidine), surgical (level of training of the clinician, post-operative complications) and timing (immediate, early and delayed placement and loading) variables. Patients were classified as current, former or never smokers based on what was reported on their health questionnaire and/or the implant screening form.

For a complete list of data collected, refer to appendix F. The same data was also collected for any implant placed after an implant failure (replacement implants).

Demographic, clinical, surgical and follow up data was entered into a computer database (Microsoft Excel 2004; Microsoft Corporation, Redmond, WA). As in several other retrospective investigations (Del Fabbro et al., 2008a; Hämmerle et al., 2002; Melo et al., 2006; Woo et al., 2004), our first outcome variable was implant failure, as in removal or exfoliation of an implant for any reason. Survival time was the duration of time (in months) from placement to removal or the date of the most recent follow up for implants that had not been removed. The second outcome variable was implant thread exposure over time (marginal bone loss), which was analyzed by subtracting the number of threads exposed at the time of implant placement by the number of threads exposed at the time of the most recent follow up.

Most published reports on implant success use several criteria to determine success vs. failure which include: no mobility of the implant, no peri-implant radiolucency on radiographic examination, less than 0.1-0.2 mm of annual radiographic bone loss after the first year, absence of signs and symptoms such as pain, infection,
neuropathies or paresthesia, etc. (Albrektsson et al., 1986; Albrektsson and Zarb, 1993; Kohavi et al., 2004; Misch et al., 2008). The use of success as an outcome variable was not possible due to the limited follow up data available. The follow up exams at UBC do not routinely consist of removal of any fixed splinted implant-supported restorations, and hence, do not allow for a true assessment of the mobility of each individual implant. Only radiographs in which implant threads are visible were considered in the present study. However, since the radiographs were taken by different clinicians using different radiographic equipment (digital radiography replaced film at UBC in 2006) and no stents were used, accurate comparisons between radiographs taken at placement at follow up were not possible. Also, due to the poor angulation of many radiographs, the lack of standardization in the radiographic methodology, and the many different models of implants used, an accurate calculation in millimeters of bone loss was also difficult. Any post-operative complications were assessed using only the chart notes, as patients were not re-examined for this study. Many of these challenges are typical of a retrospective study. Due to the limitations of this design, it would be inappropriate to make conclusions regarding implant “success”.

Descriptive statistics were used for all study variables. Survival rates were calculated at both the implant and patient level. Bivariate analyses were used to identify risk factors associated with implant survival. Risk factors with p-values < 0.05 or predictors that were deemed clinically relevant or important based on previous implant studies were included in logistic regression analysis and in a stepwise linear multiple regression analysis. The outcome variables for these analyses were: implant failure and threads exposed over time. Multicollinearity was tested and the tolerance values of the
predictors were assessed. Tolerance is an estimate of the colinearity of predictors, or how closely two predictors are related to one another (Peat and Barton, 2005). A tolerance value approaching zero indicates colinearity; the predictor shares its effects with other predictors (Peat and Barton, 2005). A tolerance value of one means that the effect of the tested predictor is completely unrelated with the other independent predictors (Miles, 2001).

All statistical analysis was completed using the SPSS program (SPSS Inc, Chicago, IL, version 17.0).
5. RESULTS

One-hundred and eighty-six patient charts were available for review in the current UBC chart filing system and the charting archives for patients who are no longer actively being seen at the university. Radiographs taken prior to July 1, 2006 were in a film format and found in the patient charts. All radiographs taken after this date were in a digital format and examined using the Romexis software system (Planmeca Oy; Helsinki, Finland).

Seventy-nine of the available charts had incomplete records and were not included in the study. The large majority of these charts did not have a radiograph taken at the implant follow up appointment, or if it was taken, the radiograph was not considered diagnostic (implant threads were not visible due to poor angulation) \(n= 64\). Forty-three of these charts were part of a previous overdenture study where it appears as though the follow up protocol involved a clinical exam without radiographs. Since the inclusion criteria requires a diagnostic follow up radiograph at least one-year after implant placement, these charts were excluded. One patient chart had no radiograph from the time of implant placement (the baseline record to measure peri-implant bone loss) and six charts had no radiographs at all. Six charts had no surgical records and two patients had implants placed by surgeons not part of the graduate periodontology program. All of these charts were excluded from the study (Table 1).
Table 1. Reasons for case exclusion

<table>
<thead>
<tr>
<th>Reason for exclusion</th>
<th>Number of charts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of diagnostic follow up radiograph</td>
<td>64</td>
</tr>
<tr>
<td>Lack of radiograph at the time of placement</td>
<td>1</td>
</tr>
<tr>
<td>Lack of radiographs</td>
<td>6</td>
</tr>
<tr>
<td>Lack of surgical records</td>
<td>6</td>
</tr>
<tr>
<td>Implants placed by surgeons not affiliated with the graduate periodontics clinic</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>79</strong></td>
</tr>
</tbody>
</table>

5.1 Patient-level analysis

5.1.1 Distribution of implants

107 patients with 300 implants were included in the present review. Implants were placed between 1989 and 2006 in the UBC graduate periodontics clinic. The majority of patients had more than one implant placed, with a large proportion of patients with two implants, often in the lower mandible. 19.6% of patients had one implant placed, 48.6% of patients had two implants placed, while 31.8% of patients had three or more implants placed (Fig 1).
5.1.2 Implant follow up

Table 2. Follow up time after implant therapy in years.

<table>
<thead>
<tr>
<th>Time between stage 1 surgery and follow up</th>
<th>Minimum (years)</th>
<th>Maximum (years)</th>
<th>Mean ± Std Dev (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time between restoration and follow up</td>
<td>0.51</td>
<td>18.77</td>
<td>3.46 ± 3.17</td>
</tr>
</tbody>
</table>

The mean follow up period ranged from 1.00 to 19.79 years. The mean time (± SD) between implant placement and the most recent implant follow-up examination was 4.08 (± 2.95) years. The mean time between the placement of the restoration and the most
recent implant follow-up exam was 3.46 (+/− 3.17) years. This follow up period ranged from 0.51 to 18.77 years (Table 2).

5.1.3 Implant survival

Fig 2. Percentages of patients experiencing one or more failed implants.

84.1% of patients did not experience implant failure, 13.1% of patients had one failed implant and 2.8% of patients had two failed implants. No patients had more than two failed implants (Fig 2).
5.1.4 Demographic factors

Age

Fig 3. Number of implants placed and number of failed implants in each age group.

Patients in the study ranged in age from 23.53 to 90.48 years, with a mean age (± SD) of 59.04 (± 11.61) years at the time of implant placement. Patients were categorized into three age groups: under 40 years, 40-60 years and more than 60 years of age. 8.91% of patients were under 40 years of age, 37.62% of patients were between 40 and 59 years and 53.46% of patients were over 60 years of age. The percentages of patients in each age group with no implant failures were 77.78%, 78.95% and 88.89% respectively (Fig 3). There was no significant difference in survival rates between the different age groups (p=0.376).
Gender

Of the 107 included patients, 52 were males and 55 were females. 88.89% of female patients and 80.39% of male patients had no implant failures. There was no statistically significant gender difference in survival of implants (p=0.282).

Systemic disease

The presence of systemic disease also had no effect on implant survival (p=0.230). Similarly, when some systemic diseases were examined individually, there was no statistically significant effect of the different diseases on implant failure (diabetes p=0.253; osteoporosis p=0.606).

5.1.5 Smoking status

![Image showing implant survival and failure in never, former, and current smokers.]

Fig 4. Implant survival and failure in never, former and current smokers.
Fig 5. Implant survival and failure in never or former smokers compared to current smokers.

73.1% of patients had never smoked, 13.5% were former smokers and 13.5% of patients were currently smoking at the time of implant placement. There was no statistically significant difference in implant survival between the smoking groups (p=0.454). However, there was a trend for current smokers to have more implant failures than never or former smokers (Fig 4). Eleven out of 76 never smokers experienced implant failure, while 2/14 former smokers and 3/14 current smokers lost implants. Even when the never and former groups were combined (to increase the sample size), there was no statistically significant difference between never/former smokers and current smokers (p=0.368) (Fig 5).
5.2 Implant level analysis

At the implant level, 92.3% of implants survived to follow up. 7.7% of implants failed over the mean 4.08 ± 2.95 years follow up time. On average, implants failed after 44.22 ± 46.32 weeks. The minimum time from implant placement to failure or removal was two weeks, and the maximum time from placement to failure was 209.29 weeks.

5.2.1 Implant design

Implant brand

Fig 6. Number of implant failures related to model or brand of implant.

Of the 300 implants included, 244 were Branemark or Nobel Biocare implants and 50 were Straumann implants. 22 of the Nobel implants failed (90.98% survived),
while one of the Straumann implants was lost (98.0% survived) (Fig 6). There was no statistically significant difference between survival rates of these two systems (p=0.070).

All of the Straumann implants were rough surface implants, while 33.06% of the Branemark/Nobel implants placed were smooth surface implants, which may explain the trend for Straumann implants to have fewer failures. However, when rough and smooth surface Branemark/Nobel implants were compared, there was no significant difference in implant survival percentages – 9.71% vs. 10.47% respectively (p=0.519). Of the implants included in the study, the earliest Straumann implant was placed in 2002, while Branemark/Nobel implants have been placed since 1997. Since Straumann implants are a relatively new addition to the grad perio program, these implants have shorter follow ups.
Implant surface

Fig 7. The effect of surface roughness on implant survival.

The effect of surface roughness was compared for both implant systems and no significant difference in implant survival was seen between rough and smooth surface implants (p=0.362) (Fig 7). The survival rate for machined surface implants (n=99) was 90.9% and the rate for rough surfaced implants (n= 101) was 92.8%.
**Implant dimensions - width**

Fig 8. Implant survival based on implant width.

Implants were grouped according to width: narrow (≤3.9 mm, n=119), regular (4.0 – 4.9 mm, n=156) and wide (≥5 mm, n=25) platforms (appendix G, fig. 30). Wide implants had a 4.0% failure rate, regular platform implants had a 5.1% failure rate and narrow implants had an 11.8% failure rate (Fig 8). The differences between these failure rates were not significant (p=0.095).
Implant dimensions – length

Fig 9. Effect of implant length on implant survival.

Implants were also grouped according to length: short (<10 mm, n=37) and long (≥10 mm, n=263) (appendix G, fig. 31 and 32). 12.33% of the implants were short and 87.67% were considered long. The survival rate was 94.6% for short implants and 92.0% for long ones (Fig 9). Survival was not significantly different between groups (p=0.441).

If 10 mm implants were considered as “short”, 42.0% of implants included were long, while 58.0% were short. The survival rate for long implants was 92.0%, and the same rate was 92.9% for short implants. Similar to the above, length did not have a significant effect on implant survival (p=0.476).
**Other design features**

Whether the implant was straight or tapered had no effect on implant survival (p=0.259). The type of connection (external vs. internal hex) also did not affect implant survival (p=0.334).

**5.2.2 Previous periodontal disease**

The effect of a deep probing depth or furcation involvement adjacent to an implant site was also examined. Those with adjacent probing depths of >3 mm (n= 29) and/or an adjacent tooth with a Hamp class I (n=15) or II (n= 9) furcation involvement did not have significantly more implant failures (p=0.612, p= 0.917).

Fig 10. Reason for tooth loss prior to implant placement.
Tooth loss was categorized into three groups: tooth loss due to periodontal disease, tooth loss due to reasons other than periodontal disease, and tooth loss due to unknown reasons. Those specified as “unknown” had no clear indication in the patient’s chart as to why the tooth/teeth was/were lost or the patient’s presented as edentulous and did not report why the teeth were lost. Caries, tooth fracture, congenitally missing teeth, retained deciduous teeth, trauma and persistent endodontic problems were considered “non-periodontal” reasons for tooth loss and accounted for 36.0% of tooth loss (n=36). Periodontitis accounted for 17.0% of tooth loss (n=17) and 47.0% of loss was for unknown or uncharted reasons (n=47) (Fig 10).

![Graph showing implant survival related to the reason for tooth loss prior to implant placement.](image)

Fig 11. Implant survival related to the reason for tooth loss prior to implant placement.
Although the percentage failure for implants replacing teeth lost due to periodontitis was higher than the percentage failure of implants replacing teeth lost due to other reasons, this difference did not reach statistical significance ($p=0.127$) (Fig 11). Even when the group who lost teeth for unknown or uncharted reasons were excluded, there was still no significant effect of tooth loss for periodontal reasons on implant failure ($p=0.462$).

5.2.3 Pre- or peri-operative bone augmentation

Socket preservation

The effect of bone augmentation prior to or at the time of implant placement on implant survival was determined. Fifteen socket preservation cases were included in the study, with one reported failure. Socket preservation had no significant effect on implant survival/failure ($p=0.678$).
Fig 12. The effect of guided bone regeneration (both prior to and simultaneously with implant placement) on implant survival.

Guided bone regeneration (GBR) was completed prior to implant placement in 53 cases (17.67%), with only one reported failure (survival = 98.1%) (Fig 12). GBR had a nearly significant positive effect on implant survival (p=0.091). GBR was completed concurrently with implant placement in 18 cases (6.0%), with no implant failures. The effect of simultaneous GBR on implant survival was not significant (p=0.377). When both GBR procedures were combined, it appears as though bone augmentation has a significantly positive effect on implant survival (p=0.021, n= 71). This is likely because the larger sample size allows for the trend to reach statistical significance.
Pre- or peri-operative sinus augmentation

Fig 13. Effect of sinus augmentation prior to implant placement (lateral window technique) on implant survival.

Similarly, the effect of sinus augmentation prior to or simultaneously with implant placement on implant survival was investigated. Nine cases with lateral window sinus lifts prior to implant placement were included, with no implant failures. Sinus augmentation prior to implant placement did not have a statistically significant effect on implant survival (p=0.477) (Fig 13).
Fig 14. Effect of simultaneous (osteotome technique) sinus augmentation on implant survival.

Osteotome sinus lifts, completed using a modified Summer’s technique (Summers 1994), in conjunction with implant placement were completed in 19 included cases, with five implant failures (a 26.3% failure rate) (Fig 14). Simultaneous sinus lifts were significantly associated with implant failures (p=0.010).
When the analyses of both types of sinus augmentation were combined, there was still a significant association with implant failure (p=0.05).

### 5.2.4 Assessment of implant site at time of fixture placement

**Primary stability**

![Graph showing the effect of torque on implant survival.](image)

**Fig 15.** Effect of torque on implant survival.

The relationship between implant survival and the amount of torque at implant insertion was studied. The mean insertion torque for implants that survived to the most recent follow up was $32.19 \pm 9.75$ N·cm. The mean insertion torque ($\pm$ SD) for failed implants was $36.67 (\pm 4.08)$ N·cm (Fig 15). Lower torque was significantly associated with implant survival (p=0.049) (95%CI: -8.937; -.018).
Subjective assessment of the implant site

The standardized charting for implant placement includes a section to record the clinician’s impression of the amount of bone resorption at the implant site, the vascularity and quality of the bone, as well as the degree of primary stability of the implant. Each of these criteria is subjectively graded on a scale of 1 to 4; one being the most resorption, least vascular, poorest quality and poorest primary stability. The clinicians classified 70.57% of cases as having moderate bone resorption, 50.69% of cases had good bone quality, 76.22% were rated as having good bone vascularity and 76.74% were deemed to have excellent primary stability. None of the above variables were significantly related to implant survival or failure (p=0.851, p=0.299, p=0.453 and p=0.481 respectively).
5.2.5 Implant site

Jaw

Fig 16. Survival of implants based on the jaw in which the implant was placed.

Implant survival in the maxilla was compared to survival in the mandible. The implant failure rate was 6.15% in the maxilla (n=130) and 8.82% in the mandible (n=170) (Fig 16). This difference was not significant (p=0.262).
**Region of the jaw**

Fig 17. Implant survival related to the region of the jaw in which the implant was placed.

Similarly, implant survival and failure rates were compared for implants placed in the anterior regions of the jaw (canine or incisor sites) and implants placed in posterior areas (premolar and molar sites). The implant failure rate for anterior implants (n=164) was 8.54%. The implant failure rate for posterior implants was 6.62% (n=136) (Fig 17). This difference was not significant (p=0.345).
Fig 18. Implant survival related to region of placement in the maxillary arch.

The implant failure rate for the anterior maxilla was 5.26% while the failure rate for implants placed in the posterior maxilla was 6.85% (Fig 18). This difference was not significant (p=0.503).
Fig 19. Implant survival related to region of placement in the mandibular arch.

The implant failure rate for implants placed in the anterior mandible was 10.28%, while the failure rate for those in the posterior mandible was 6.35% (Fig 19). The difference was not significant (p=0.282).
### 5.2.6 Post-operative chemotherapy

Table 3. Post-operative chemotherapy - antibiotics

<table>
<thead>
<tr>
<th>Antibiotic</th>
<th>% of cases for which it was prescribed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amoxicillin</td>
<td>73.4%</td>
</tr>
<tr>
<td>Doxycycline</td>
<td>3.1%</td>
</tr>
<tr>
<td>Clindamycin</td>
<td>7.1%</td>
</tr>
<tr>
<td>Amoxicillin and Metronidazole</td>
<td>0.7%</td>
</tr>
<tr>
<td>Other</td>
<td>5.8%</td>
</tr>
<tr>
<td>None prescribed</td>
<td>9.9%</td>
</tr>
</tbody>
</table>

Table 4. Post-operative chemotherapy - analgesics

<table>
<thead>
<tr>
<th>Analgesic</th>
<th>% of cases for which it was prescribed or recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ibuprofen</td>
<td>59.4%</td>
</tr>
<tr>
<td>Tylenol #3</td>
<td>24.8%</td>
</tr>
<tr>
<td>Acetaminophen</td>
<td>7.7%</td>
</tr>
<tr>
<td>Any over the counter analgesic</td>
<td>2.8%</td>
</tr>
<tr>
<td>Toradol</td>
<td>3.1%</td>
</tr>
<tr>
<td>Ketorolac</td>
<td>0.7%</td>
</tr>
<tr>
<td>Other</td>
<td>1.5%</td>
</tr>
</tbody>
</table>
Table 5. Post-operative chemotherapy – other agents

<table>
<thead>
<tr>
<th>Other</th>
<th>% of cases for which it was prescribed or recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorhexidine</td>
<td>75.3%</td>
</tr>
<tr>
<td>Salt water rinses</td>
<td>5.3%</td>
</tr>
<tr>
<td>Dexamethasone</td>
<td>26.7%</td>
</tr>
</tbody>
</table>

Post-operative prescription medications or recommended non-prescription medications were given out at the discretion of each resident or clinician and the supervising instructor. The above tables show the percentages of patients prescribed each agent.

5.2.7 Post-operative complications

Table 6. Incidence of post-operative complications.

<table>
<thead>
<tr>
<th>Post operative complication</th>
<th>Incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bleeding</td>
<td>1.9%</td>
</tr>
<tr>
<td>Infection</td>
<td>5.7%</td>
</tr>
<tr>
<td>Temporary paresthesia</td>
<td>0.67%</td>
</tr>
<tr>
<td>Permanent paresthesia</td>
<td>0.67%</td>
</tr>
<tr>
<td>No complications</td>
<td>91.06%</td>
</tr>
</tbody>
</table>

Table 6 lists the incidences of post-operative bleeding (for which the patient was seen at the clinic after surgery), infection (for which the patient was prescribed antibiotics after the initial course of post-operative antibiotics), temporary and permanent paresthesia (as reported by the patient post-operatively). A single case of paresthesia was
deemed “permanent” since the patient reported paresthesia immediately post-operatively and at every subsequent recall examination.

5.2.8 Implant restoration

Distribution of implant supported restorations

Fig 20. Distribution of different types of permanent restorations on implants.

In this study, 39.0% of implants were restored with removable overdentures (n=117), 29.0% were restored with splinted crowns (n=89), 15% with single crowns (n=44), 10% with fixed partial dentures (n=29) and 7% with fixed hybrid overdentures (n=21) (Fig 20).
Fig 21. Effect of the type of permanent restoration on implant survival.

The survival rate was 89.81% for implants restored with removable overdentures and 98.79% for implants restored with fixed restorations (Fig 21). Removable implant restorations were significantly associated with implant failure (p=0.001) compared to fixed restorations (fixed full-arch hybrid dentures, splinted crowns or single crowns).
Prosthodontic maintenance of implant-supported restorations

Fig 22. Percentage of patients experiencing prosthodontic complications post-implant placement and restoration.

68.3% of patients experienced one or more prosthodontic complications after implant placement and restoration (Fig 22). These included: esthetic problems, loosening of the abutment, issues with occlusion requiring laboratory work to adjust or re-make the prosthesis, a deficient margin that requires replacement of the restoration, fractured denture, denture retention issues, broken bars, etc.

In terms of post-implant surgical procedures, 9.2% of implants had connective tissue grafting around the implant after placement.
Fig 23. Percentage of patients experiencing prosthetic complications with fixed and removable appliances.

Of the 68.3% of patients with reported prosthetic complications, 49.7% were associated with removable overdenture restorations and 18.7% were associated with fixed implant restorations (Fig 23).
5.2.9 Level of training of the clinician

Fig 24. Number of implants that survived and failed related to the level of training of the clinician.
Fig 25. The percentage of implant failures placed by clinicians at different training levels.
Fig 26. Percentage of patients without implant failure based on the level of training of their treating clinician.

We also investigated if the level of training of the clinician (ie. the year of the program of the clinician at the time of implant placement) impacted the survivability of the implants. Of the patients treated by clinicians in their first year of training (n= 17), 94.12% did not experience implant failure. Among those patients treated by surgeons in their second year of training (n= 40), 88.54% did not experience implant failure. 97.62% of patients treated by third year residents had all of their implants survive to follow up (21 patients were treated by third year residents). 93.18% of patients treated by staff members (n= 22) had no implant failures (Fig 24-26). These differences were not statistically different. (p=0.525).

<table>
<thead>
<tr>
<th>Year of the program</th>
<th>Implant survival %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st year</td>
<td>94.12%</td>
</tr>
<tr>
<td>2nd year</td>
<td>88.54%</td>
</tr>
<tr>
<td>3rd year</td>
<td>97.62%</td>
</tr>
<tr>
<td>staff member</td>
<td>93.18%</td>
</tr>
</tbody>
</table>
5.2.10 Replacement implants

Fourteen implants placed after an implant failure at that site (accounting for 63.4% of failures) had an adequate follow up period to be considered for this study. The survival rate of these implants were 85.71%.

5.2.11 Peri-implant bone loss

Fig 27. Number of threads exposed over time related to implant model.

The number of threads exposed over time was used as a measure of peri-implant bone loss. Horizontal bone loss around the implants was a common finding and the number of threads without surrounding bone was assessed for each implant using the
follow up radiograph. The number of threads exposed at the time of implant placement was subtracted from the number of threads exposed at the most recent follow up. The difference, threads exposed over time, was used as the second outcome measure for stepwise linear multiple regression analysis.

43.56% of Branemark/Nobel implants (n= 88) and 85.11% (n= 40) of Straumann implants had no progression of exposed threads at follow up. Of the Straumann implants, 8.51% had one exposed thread (n= 4), 4.26% had two exposed threads (n= 2) and 2.13% (n= 1) had three exposed threads (appendix H, Fig. 33 and 34). No Straumann implants had more than three threads exposed. Of the Branemark/Nobel implants, 24.26% had one thread exposed (n= 49), 14.85% had two exposed threads (n= 30), 10.40% had three exposed threads (n= 21), 4.95% four threads (n= 10) and 1.98% had five threads exposed (n= 4) (Fig 27). Straumann implants had significantly fewer exposed threads than Nobel implants (p=0.000).
Fig 28. Number of threads exposed over time based on surface roughness.

56.57% of rough surface implants and 35.71% of machined surface implants had no radiographic thread exposure over time. 20.57% of rough and 22.85% of smooth surface implants had one exposed thread. Exposure of two threads was seen in 13.71% of rough and 11.43% of smooth implants. Three threads were exposed on the radiographs in 7.43% of rough implants and 12.86% of smooth surface ones. 1.71% of rough implants and 11.43% of machined implants had four exposed threads, while 5.71% of machined implants and no rough surface implants had five exposed threads (Fig 28). As a general trend, rough surface implants had significantly less radiographic thread exposure over time than their smooth surface counterparts (p=0.000).
5.3 Regression analyses

Two types of regression analysis were completed for this report. Stepwise linear multiple regression analysis was completed with the number of exposed threads over time as the dependent outcome variable. Logistic regression analysis was completed with implant failure as the dependent variable.

In terms of the stepwise linear multiple regression analysis, the predictors (variables) entered included: region of the jaw of placement (posterior vs. anterior), GBR (prior or simultaneous), implant model, implant length, sinus augmentation (prior or simultaneous), implant width, jaw of placement (maxilla vs. mandible) and surface type. Based on the tolerance values, the assumption for the independence of predictors was fulfilled (all tolerance values >0.750). The overall model for the thread exposure outcome was highly statistically significant (p=0.000) and the aforementioned predictors explained 13.3% of the variation in thread exposure.

Beta values (standardized regression coefficients) were used to compare the effect of the predictors. Such coefficients measure the change in the dependent variable that results from a one-standard-deviation change in the independent variables; zero being no effect and one being maximum effect (Schroeder 1986). The predictors showing the largest statistically significant effects were: implant model (β= 0.222 and p=0.001), in favor of Straumann implants, jaw in which the implant was placed (β= 0.213 and p=0.005), in favor of mandibular implants and surface type (β= 0.206 and p=0.011), rough surface being better than machined surface.

A second analysis was done with fewer predictors (only those that were significant or approached significance in the bivariate analyses were included): implant
model, surface type, jaw and sinus augmentation. These predictors explained 13.8% of the variance of thread exposure. The assumption for the independence of the predictors was fulfilled because all of the tolerance values exceeded 0.750. The β values were 0.227 for implant model (p=0.000), 0.260 for surface type (p=0.000), 0.188 for the jaw (p=0.007), and 0.134 for sinus augmentation (p=0.037) (those without sinus augmentation had fewer exposed threads).

Logistic regression analysis was employed with the following predictors: GBR, sinus augmentation, implant width, implant length, jaw, position (anterior vs. posterior), model type and surface type. Only sinus augmentation (p= 0.008) and implant width (p=0.018) were significant predictors of implant failure/survival. Odds ratios (OR) were used to assess the risk of implant failure if a certain predictor is present. The OR is a relative measure of risk and demonstrates how much more likely it is that someone exposed to a risk factor under study (e.g. sinus augmentation) will develop the outcome as compared to someone who is not exposed to it (Westergren et al 2001). The OR for implant failure was 11.00 in favor of implants placed without sinus augmentation and 0.29 in favor of increasing implant width (Table 7).

Table 7. Variables reaching or approaching statistical significance in logistic regression analysis and the corresponding odds ratios.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Odds ratio</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>GBR (prior or simultaneous)</td>
<td>0.150</td>
<td>0.079</td>
</tr>
<tr>
<td>Sinus augmentation (prior or simultaneous)</td>
<td>11.002</td>
<td>0.008</td>
</tr>
<tr>
<td>Implant width</td>
<td>0.288</td>
<td>0.018</td>
</tr>
</tbody>
</table>
When only simultaneous sinus lifts were included in the model, both sinus augmentation and implant surface were significantly associated with implant failure (p=0.003 and p=0.023, respectively). The OR for surface was 0.30 (in favor of rough surface implants) and the OR for sinus augmentation was even higher than the previous model, 16.87.
6. DISCUSSION

Due to incomplete pre-operative, surgical and/or radiographic records, a large portion of the available charts (42.47%) was excluded from the study. The majority of these charts were excluded due to inadequate radiographic follow up, i.e. radiographs were either not taken at follow up or the implant threads and peri-implant bone levels were not clearly visible due to poor angulation. Ensuring a diagnostic radiograph of an implant can be challenging, particularly in situations where adjacent and/or opposing teeth are not present to stabilize the film holder (e.g. completely edentulous patients).

Since this is a retrospective study of implants placed over a long time period, there was no standard protocol for taking radiographs of the implants. Stents were not fabricated to ensure similar angulations at each follow-up and the radiographic technology changed from film to digital in 2006. This lack of consistency made it difficult to compare radiographs over time. For this reason, thread exposure was used as a relatively stable reference point from which to measure peri-implant bone loss over time. Implant survival was considered the first outcome variable; thread exposure was considered the second outcome measure.

6.1 Patient-level analysis

6.1.1 Distribution of implants

When implants were first introduced in the UBC grad program in the late 1990s, the majority of cases involved two implant-supported overdentures. In this study, 48.6% of patients had two implants placed, and 39% of the implants placed were restored with removable overdentures. With time, the implant clinic has evolved. By the mid-2000s,
Residents were placing implants in all regions of both jaws, using extensive autogenous and non-autogenous bone augmentation procedures (socket preservation, guided bone regeneration and sinus augmentation), and completing full-mouth reconstruction cases.

Therefore, the increasing difficulty of the cases accepted at the university may offset the expected increase in implant survival that came with advances in implant design and surface characteristics in the early 2000s. For example, if the clinic continued to accept relatively simple, two-implant overdenture cases (in which implants are likely placed in dense bone) (Misch et al., 2006; Morand and Irinakis, 2007) one would expect that the survival of implants would have improved with the introduction of rough surface implants. In reality, as the implant surface characteristics of implants improved over time, UBC residents began placing more implants in poorer quality bone (i.e. posterior maxilla) (Morand and Irinakis, 2007) with more complex pre- or peri-operative bone augmentation procedures and more challenging prosthodontic rehabilitation and maintenance.

6.1.2 Implant follow up

The mean follow up time for the implants was 4.08 ± 2.95 years, which is relatively short compared to many of the large retrospective and prospective implant studies available to date (Berglundh et al., 2002; DeLuca et al., 2006a; DeLuca et al., 2006b; Eliasson et al., 2006; Ferrigno et al., 2002; Hardt et al., 2002; Lekholm et al., 1999; Levin et al., 2006; Romeo et al., 2004). In the present study, the shorter follow up time was accepted to increase the sample size and ensure the inclusion of newer, rough surface implants and those placed in conjunction with more complex surgical procedures.
(autogenous grafting, sinus augmentation, etc.) that were not practiced at UBC ten years ago.

That said, the maximum follow up time was 19.79 years since implant placement, indicating that we do have over 10 year follow ups for a portion of the sample. The inclusion criterion of a one-year follow up post-implant placement is comparable to many other published studies (De Boever and De Boever, 2005; Kohavi et al., 2004). The sample size does compare favorably to other publications as well, particularly retrospective reports from university training programs (Hardt et al., 2002; Kohavi et al., 2004; Melo et al., 2006). Hardt et al.’s 2002 retrospective study included 97 patients and 346 implants and had a 5-year follow up (Hardt et al., 2002). Similarly, Kohavi et al.’s 2004 study followed 303 implants over an average of 36 months and Melo et al.’s retrospective oral surgery residency-based report followed 54 patients (175 implants) over 6 months (Kohavi et al., 2004; Melo et al., 2006).

6.1.3 Implant survival

At the patient level, 84.1% of patients experienced no implant failures. At the implant level, we found a 92.3% implant survival rate over the mean four years follow-up. These survival rates fall into the range of what is generally found in implant literature (Brocard et al., 2000; Buser et al., 1997; DeLuca et al., 2006a; Ferrigno et al., 2002; Grunder et al., 1999; Lekholm et al., 1999; Levin et al., 2006; Melo et al., 2006; Moy et al., 2005; Romeo et al., 2004; Schwartz-Arad et al., 2008).
6.1.4 Demographic factors

Age

There were no significant differences in implant survival based on patient age in this study. This does not concur with the findings of Moy et al. (2005) who found that advanced age doubles the risk for implant failure (Moy et al., 2005). In fact, the trend in this study was that patients in the youngest age group (>40 years) had the highest failure rate and that the oldest group (>60 years) had the highest survival rate (those between 40 and 59 years of age fell between the two other groups). Many patients in the oldest age group were two-implant overdenture cases with implants placed in the lower mandible, where reported success rates are highest (Misch et al., 2006). It is more likely that younger patients had implants placed in areas where bone is less dense, or where the implant supported restorations were opposed by natural teeth. This is similar to Dao et al.’s 1993 study, where the highest implant failure rates were found in the youngest age group. (Dao et al., 1993). As in this study, many other reports have shown that age does not have a significant impact on implant survival (DeLuca et al., 2006a; Grant et al., 2008; Lemmerman and Lemmerman, 2005).

Gender

In a similar way, although female patients had a higher implant survival rate than male patients in this study, the difference was not statistically significant. This is in agreement with a number of review papers and primary research reports in recent years. (Blanes et al., 2007; Dao et al., 1993; DeLuca et al., 2006a; Lemmerman and Lemmerman, 2005; Levin et al., 2007; Mombelli and Cionca., 2006; Moy et al., 2005).
**Systemic disease**

In this study, the presence of a systemic disease, such as osteoporosis or diabetes, was not significantly associated with implant failure. This may be because so few patient charts reported systemic disease in the patient’s health history section. Of the 107 patients included, only eight had a reported history of diabetes, 24 reported hypertension, 16 arthritis and three indicated they suffered from osteoporosis. Of these, those with the smallest sample sizes (diabetes and osteoporosis) are most likely to be associated with implant failure – diabetes because it impacts wound healing, and osteoporosis because it affects bone mineral density and, possibly, osseointegration. Even if a difference between groups existed, the sample sizes were likely too small to allow for statistical significance.

Many studies and reviews, like this one, have shown that implants placed in patients with osteoporosis are similarly successful to those placed in non-osteoporotic patients (Cranin et al., 1991; Friberg, 1994; Friberg et al., 2001; Mombelli and Cionca, 2006; Steiner and Ramp, 1990). Mombelli and Cionca’s 2006 review paper analyzed data from 17 papers and found that the evidence for an association between osteoporosis and implant failure was low (Mombelli and Cionca, 2006). Moreover, bone-to-implant contact and bone maturity around implants is also comparable (de Melo et al., 2008; Shibli et al., 2008a; Shibli et al., 2008b).

In this study, diabetic patients were no more susceptible to experiencing implant failure than non-diabetics. This is unlike Moy et al.’s 2005 retrospective study (largely machined surfaced implants), which stated a relative risk of 2.75 for implant failure in diabetics (even if they are well controlled) (Moy et al., 2005). Others have agreed with Moy’s conclusions (Fiorellini et al., 2000; Nevins et al., 1998).
Conversely, there is compelling evidence that implants are as successful in controlled diabetics as they are in non-diabetic patients (Mombelli and Cionca, 2006; Olson et al., 2000b; Peleg et al., 2003; Shernoff et al., 1994). As discussed above, if there was a true difference in implant survival between diabetics and non-diabetics in this study, the sample size was likely too small to show a statistically significant difference. In addition, the level of diabetic control at the time of placement or throughout the follow-up period could not be determined, since there is limited data of this kind in the patient chart. If this study was to be done prospectively and we had a large sample of diabetic patients, control could be monitored with periodic assessment of glycosylated hemoglobin (HbA1c) levels throughout the study.

6.1.5 Smoking status

Smoking has been linked to increased implant failures in numerous reports (Aykent et al., 2007; Baelum and Ellegard, 2004; Bain and Moy, 1993; De Bruyn, 1994; DeLuca et al., 2006a; Hinode et al., 2006; Karoussis et al., 2003; Mombelli and Cionca, 2006; Moy et al., 2005; Olson et al., 2000a; Wallace, 2000; Widmark et al., 2001). Some, particularly those published in the 1990s, demonstrated a large (over 2x) difference in survival rates between smokers and non-smokers (Baelum and Ellegard, 2004; Bain and Moy, 1993; De Bruyn et al., 1994). However, more recent studies have did not find a significant difference in implant survival between smokers and non-smokers (Bain, 2002; Blanes et al., 2007; Brocard et al., 2000; Kumar et al., 2002; Levin et al., 2007; Peleg et al., 2006a; Schwartz-Arad et al., 2002; Schwartz-Arad et al., 2008). Advances in surface topography of the implant appear to have increase survival rates to the point where the effect of smoking is negligible (Kumar et al., 2002). In this study, there was a trend for
current smokers to have more implant failures than never or former smokers, but this was not significant. This relationship may not be statistically significant due to the small sample size, or because a majority of the implants placed (68.55%) were modern, rough surface implants which are usually associated with higher survival rates (Morand and Irinakis, 2007).

6.2 Implant level analysis

6.2.1 Implant design

Implant brand

There was a difference in survival rates between the implant systems used at UBC, in favour of the Straumann ITI system, but this difference was not statistically significant. Similar findings were reported in Meijer et al.’s 2009 overdenture study, which stated that ITI implants had a higher, but not significantly so, survival rate compared to Nobel Biocare implants (100% vs. 98%) (Meijer et al., 2009).

At UBC, many factors may have impacted the high implant survival in ITI cases. Firstly, all of the Straumann implants placed were rough surface implants, whereas 33.06% of Nobel implants had a machined surface. That said, there was no significant difference in implant survival between rough and smooth Nobel implants. Secondly, Straumann implants were introduced into the grad perio program in 2002, therefore we have shorter follow up times and less opportunity for long term failures to be recorded in the study. Thirdly and perhaps most significantly, Straumann implants have traditionally been placed only with visiting instructors and these cases tended to be less complex since the instructor wasn’t available for extensive treatment planning prior to the surgical date. In this way, those ITI implants that have been placed may be biased for success since
they were rough surface implants with relatively short follow ups and they were likely placed in relatively simple clinical cases. That said, a large systematic review of the survival rates of implant supported fixed partial dentures published in 2004 found that Branemark Nobel Biocare implants were the only type to have below average survival rates, while all other brands (including ITI) had survival rates above the study average (Pjetursson et al., 2004).

In the available implant literature, both systems show high implant survival rates. For the Straumann/ITI system, Buser et al.’s multicentre study of 2359 implants found that 96.7% of implants survived at 8 years (Buser et al., 1997). Romeo et al.’s 2002 paper followed 187 implants restored with single crowns over 7 years and reported a 96.77% survival rate (Romeo et al., 2002). He then published a 7-year study of 759 implants restored with various removable and fixed appliances and found that survival rates ranged from 94.4-100% for prostheses supported only by implants (Romeo et al., 2004). Similar high survival rates have been reported in many other studies, including this one (100% survived) (Ferrigno et al., 2001 – 95.9%, Brocard et al., 2000 – 92.2%, Blanes et al., 2007 – 97.9%) (Blanes et al., 2007; Brocard et al., 2000; Ferrigno et al., 2002).

In terms of the Branemark/Nobel implant system, high survival rates have also been reported. Eliasson’s 2006 study on 2- and 3-implant supported prosthesis followed over 9 years, reported survival rates from 96.8-98.4% (Eliasson et al., 2006). In Friberg and Jemt’s 2009 report, implant failure rates varied from 0.9-2.9% (Friberg and Jemt, 2009). Ekelund et al. reported a 98.9% 20-year survival rate for Branemark implants in 2003 (Ekelund et al., 2003). In another multicentre study, 96.6% of implants placed in the maxilla and 100% of those placed in the mandible survived 5 years (Henry et al.,
High implant survival rates with this brand of implant have been demonstrated in many other published reports (DeLuca et al., 2006a; Lekholm et al., 2006; Roos-Jansaker et al., 2006; Turkyilmaz et al., 2007). The mean implant survival rate of 92.3% over a mean of 4 years in the present study is comparable to the rates reported in the above publications.

**Implant surface**

When machined and rough surface implants were considered separately, the survival rates were 90.9% and 92.8%, respectively. These rates were not significantly different in the bivariate analysis. The survival rates for machined surface implants in this study were higher than many of the classic studies, but our follow up period was much shorter and our criteria for success was less stringent (Attard and Zarb, 2004).

Many studies have come to similar conclusions – survival rates are not significantly different between smooth and rough surface implants. Friberg and Jemt had two groups: a mixed group with 110 machined and 68 rough implants, and a rough only group with 212 TiUnite implants (Friberg and Jemt, 2009). Implants were followed for 5 years. One machined (0.9%) and two rough (2.9%) implants failed in the mixed group, and three rough (1.6%) implants failed in the rough-only group (Friberg and Jemt, 2009). They concluded that the survival rates for both implant types were favorable and not different from each other, as did Hallman et al. (2005) (Friberg and Jemt, 2009; Hallman et al., 2005). Similarly, in Al-Nawas et al. (2007)’s study, they also found no significant differences in survival between rough and machined implants, although those with rough surfaces had an advantage in poorer quality bone (Al-Nawas et al., 2007).
In our multivariate analysis, when a number of variables were controlled for (GBR, implant length and width, location in the jaw, implant model and simultaneous sinus augmentation), machined surface implants were significantly associated with implant failure, with an effect size of 0.30. Much of the available research agrees that rough implants do seem to have the most favorable survival rates. Khang *et al.* (2001) found cumulative success rates of 95.0% for acid-etched implants and 86.7% for machined implants (Khang *et al.*, 2001). As in Al-Nawas study, the performance difference was greatest in poor quality bone like the posterior maxilla (96.8% for acid etched and 84.8% for machined) (Al-Nawas *et al.*, 2007; Khang *et al.*, 2001). Machined implants were not as successful as rough implants in soft bone in Stach and Kohles’ 2003 report as well (Stach and Kohles 2003). In Del Fabbro *et al.*’s systematic review of immediately loaded implants, rough surfaces had higher survival rates than machined in all types of reconstructions (Del Fabbro *et al.*, 2008b). Similarly, machined implants were found to fail twice as often as rough implants (4.6% versus 2.3%) in a retrospective study of 1925 implants placed over 22 years (Wagenberg and Froum, 2006). The small sample size in this study may prevent a true difference (2%) to be seen as statistically significant in the bivariate analysis, but this difference became apparent when other variables were controlled in the regression analysis.

**Implant dimensions**

In the present study, there was also a trend towards increasing implant failure rates with decreasing implant width (4.0% wide; n=1 failed implant, 5.1% regular; n= 8 failed implants, 11.8% narrow; n= 13 failed implants), but these differences were not statistically significant. The effect of implant length was also studied and short implants
were not statistically more likely to fail (7.1%) than long implants (8.0%). The surface area is so extensive on rough implant surfaces compared to machined surface implants, the length and width may be less critical to improve surface area for osseointegration, provided primary stability is possible (Morand and Irinakis, 2007). Many papers conclude that short implants are just as successful as long ones (Blanes et al., 2007; Brocard et al., 2000; Grant et al., 2009; Levin et al., 2006; Misch et al., 2006; Morand and Irinakis, 2007; Romeo et al., 2004). This is in contrast to other studies evaluating machined implants, which found that longer implants were superior to shorter ones (DeLuca et al., 2006a; Grant et al., 2009; Grunder et al., 1999; Lekholm et al., 1999; Renouard and Nisand, 2006).

Width does not appear to significantly impact implant survival either (Levin et al., 2006; Morand and Irinakis, 2007; Renouard and Nisand, 2006; Romeo et al., 2004). Where a longer implant is not possible it seems prudent to attempt to place a wider one, to maintain as much surface area for osseointegration and primary stability as possible. Increasing the diameter of the implant improves surface areas more than twice as much as increasing the length (Petrie and Williams, 2005). Since it appears as though implant length and width are not major determinants of survival, the implant dimensions should be dictated primarily by the surrounding anatomic structures, the available bone, the type of bone and the prosthetic space. As a general rule, the longest and widest implant that can be properly and esthetically restored should be considered (Morand and Irinakis, 2007).
6.2.2 Previous periodontal disease

The effect of a history of periodontal disease on implant survival was also studied. The only available indicator of disease (a rather crude measure) was the reason for tooth loss prior to implant placement. The sample was divided into groups: teeth lost due to periodontal disease, teeth lost for non-periodontal reasons, and teeth lost for unknown or uncharted reasons. A small portion of the sample (17.0%) had lost teeth due to periodontitis, but a much larger portion (47.0%) did not have the reasons for loss accurately reported in the chart. Although there was a trend for those with teeth lost due to periodontitis to also have implants fail (23.53% versus 5.56%), this relationship was not statistically significant. If a true effect exists, one needs to have a more accurate measure of disease history and a larger sample size for it to be elucidated.

In addition, the effect of a periodontal pocket or furcation involvement on a tooth adjacent to the implant site was investigated. Implants adjacent to such teeth did not suffer significantly more failures. Again, if an effect exists, the small sample size may not allow the trend to reach statistical significance. In this study only 29 implants were associated with adjacent pocket depths of greater than 3 mm and 24 were placed adjacent to furcation involvements. Furthermore, if only deep pockets ($n= 8$ for $PD \geq 5 \text{ mm}$) or severe furcation involvements ($n= 9$ for Class II involvements) (which could theoretically pose the greatest risk) are considered, the sample size would be further compromised.

In Karoussis et al.’s 2003 clinical study, despite regular supportive therapy, patients who lost teeth due to periodontitis had higher long-term failure rates than those who lost teeth for other reasons (9.5% versus 3.5%). Those with a history of the disease also had a much higher incidence of peri-implantitis. Similarly, Hardt et al. (2002)
published a study where patients were grouped based on age-related bone loss score. Again, the implant failure rate was higher in the periodontitis group (8.0% versus 3.3%) (Hardt et al., 2002). Similar findings were reported in many other papers, including a recent systematic review (Brocard et al., 2000; Grunder et al., 1999; Safii et al., 2009; Schou et al., 2004).

### 6.2.3 Pre- or peri-operative bone augmentation

A large part of implant dentistry today involves creating bone where it has been resorbed in order to place an implant of ideal dimensions in the best possible position for prosthodontic rehabilitation. The techniques used to achieve this bone augmentation include socket preservation, guided bone regeneration with particulate or block bone grafts, and sinus augmentation with osteotomes (at the time of implant placement) or with the lateral window technique (several months prior to implant placement). All of these techniques are commonly used in the graduate periodontics program at UBC, but many recent cases have not been included because they did not meet the cut-off of 1-year post-placement follow up time at the data collection phase of this study.

**Socket preservation**

Socket preservation did not have a significant effect on implant survival. Although the utility of socket preservation has been questioned (Fickl et al., 2008), most researchers agree that placing implants in grafted bone does not impact their survivability (Fugazzotto, 2005; Kohal et al., 1998). Many studies, including those done on animals, have found that socket preservation can better preserve the dimensions of the alveolar ridge post-extraction (Araujo and Lindhe, 2009; Cardaropoli and Cardaropoli, 2008;
Irinakis, 2006; Lekovic et al., 1998). Resorption of the alveolar crest without socket preservation can make implant placement more challenging, since the width of the ridge can decrease by 50%, with 2/3 of this loss occurring in the first three months (Schropp et al., 2003). However, the most critical factor for preservation of ridge dimensions appears to be atraumatic extraction of the tooth (Fickl et al., 2008; Irinakis, 2006).

**Guided bone regeneration**

Guided bone regeneration prior to implant placement had a nearly significant effect on implant survival (98.1%, p=0.091, n=58). When the bone graft was done at the time of implant placement, the effect on survival was not significant (p=0.377, n=18). 40.39% of the guided bone regeneration that was completed prior to implant placement was done with a xenograft material (Bio-Oss®) and a resorbable membrane (Bio-Guide or Neomem™). 51.92% of cases were grafted with autogenous bone, either from the iliac crest by referral to an oral surgeon, or via intraoral graft done in the graduate clinic at UBC. A small percentage, 7.69% of cases used another source of grafting material – either an allograft (Dynagraft™) or hydroxyapatite with a resorbable membrane. 5.77% of all cases used a non-resorbable membrane (GORE-TEX®) in conjunction with the bone grafting material.

As discussed in the introduction section of this paper, many studies support that implants placed into grafted bone have comparable survival and success rates to implants placed in native bone (Aghaloo and Moy, 2007; Blanco et al., 2005; Brocard et al., 2000; Christensen et al., 2003; De Boever and De Boever, 2005; Esposito et al., 2006; Fiorellini et al., 2003; Fugazzotto, 2005; Hallman et al., 2002; Juodzbalys et al., 2007; Simion et al., 2001). When both GBR procedures were considered together, there was a
significantly positive effect of bone augmentation on implant survival. The reason for this is unknown and difficult to explain. This trend may be due to the fact that GBR was adopted into the program in the mid-2000s, at the same time as advances in implant surface topography were also taking place. A large proportion of implants placed with GBR were likely rough surface implants. GBR may also indicate that the case was well planned and that fixtures were not placed into bone whose dimensions were not ideal for implant placement or at angulations that were less than ideal for the future restorations.

**Sinus augmentation**

In terms of sinus augmentation, all of the included cases that had a lateral window sinus lift prior to implant placement were completed with Bio-Oss®, a xenograft material and Bio-Guide, a resorbable membrane over the window. None of the implants placed after these sinus lifts failed, i.e. the augmentation did not significantly impact implant survival. This is in agreement with many studies, which indicate that implants placed in augmented sinuses have survival and success rates similar to implants placed in the posterior maxilla without sinus augmentation (Aghaloo and Moy, 2007; Esposito et al., 2006; Sorni et al., 2005; Wallace and Froum, 2003). These findings also parallel what we discussed about GBR; augmented bone appears to carry comparable success rates to native bone.

On the other hand, osteotome sinus lifts were significantly associated with more implant failures (5 out of 14 implants placed with this technique failed). In fact, the odds ratio for osteotome lifts and implant failure was 16.87. This finding is in contrast to the high success rates for this technique in the available dental literature (Fermergard and Astrand, 2008; Ferrigno et al., 2006; Pjetursson et al., 2009; Tan et al., 2008). Pjetursson
et al. (2009) looked at 252 Straumann implants placed over 5 years. The cumulative survival rate for the osteotome-installed implants was 97.4% over an average of 3.2 years (Pjetursson et al., 2009). A recent meta-analysis found an estimated annual failure rate of 2.48% and an estimated overall survival rate of 92.8% for implants placed with this method (Tan et al., 2008). These results are quite different from the 26.34% failure rate in the present study; it is difficult to explain why cases in this study included more failures. This may be related to practitioner inexperience or that it is a technique not often practiced in the clinic. One can argue that it is a technique sensitive surgery that requires skill and experience, but the same can be said for the lateral window sinus augmentation technique, for which UBC has no failures in this report.

All of the failures occurred between 2005 and 2006, were grafted with BioOss® and were completed by three different surgeons at different levels of training. With the exception of one case with 4mm of residual bone, all had more than the recommended 6mm of bone for primary implant stability (Wallace and Froum, 2003). Four of the five failures were early while one occurred after restoration of the implant. In searching for reasons behind these failures, it became evident (personal information provided by the supervising surgeon) that a cluster of cases was completed with a more conservative surgical protocol. After the primary osteotomy site was prepared, osteotomes were used with 2 mm (instead of 0.5-1 mm) of residual bone height at the sinus floor. This was done to reduce the likelihood of sinus perforations by inexperienced surgeons. The result may have been excessive trauma to the surrounding bone from extreme force used while attempting to fracture the sinus floor for an extended duration of time, which ultimately lead to an increased failure rate. Clinic protocol as since been modified.
When both techniques were combined, sinus lifts in general were significantly associated with implant failure. This is likely because there were more osteotome lifts in the sample, which had a large impact on survival and skewed the results towards failure.

6.2.4 Assessment of the implant site at the time of fixture placement

**Primary stability**

The relationship between implant torque at the time of placement and implants survival was evaluated. Lower torque was significantly associated with implant survival. One cannot generalize from this finding, since a large majority of the included cases did not have a torque recording in the chart. Only 80 out of the 300 implants (26.67%) had a torque measurement recorded. In some studies, higher torque has been thought to be associated with better implant survival and better bone density, provided it is within a range that is biologically compatible with maintenance of crestal bone vitality (Ottoni et al., 2005; Turkyilmaz and McGlumphy, 2008). One study found that, after 3 years, 280 successful implants had a mean bone density of $645 \pm 240$ HU and mean insertion torque of $37.2 \pm 7$ Ncm while 20 failed implants had lower bone density ($267 \pm 47$ HU) and lower primary stability ($21.8 \pm 4$ Ncm) (Turkyilmaz and McGlumphy, 2008). Another study found that the risk of implant failure decreased by 20% for every 9.8 Ncm added to the insertion torque (Ottoni et al., 2005). In other reports, insertion torque did not impact on long-term implant survivability (Al-Nawas et al., 2006; Degidi et al., 2006).

The difference in mean torque between failing and surviving implants was only 4.5 Ncm. Given that the torque wrench used at UBC (Nobel BioCare) is labeled with a scale in 10 - 15 Ncm increments, a reading is likely an estimated value between two lines on the scale. The mean difference between groups is smaller than one increment on the
scale and may reflect our inability to measure the torque precisely. There is also a large amount of variability in torque values for implants in both groups. It would be unfair to draw any conclusions from such a small difference in mean torque given the small number of cases with charted torque values and the high degree of variability.

**Subjective assessment of the implant site**

Higher failure rates have been associated with implants placed in bone that the clinician observes to have poor mineralization or limited resistance to drilling (Turkyilmaz and McGlumphy, 2008). According to the results of this study, the clinician’s assessment of bone quality, degree of resorption and vascularity at the time of surgery was not significantly associated with implant survival. An equal number of failed and survived implants were also deemed to have “excellent” primary stability by the surgeon.

In a similar study, a surgeon’s assessment of bone quality at the site of implant placement was recorded for 2,867 fixtures and retrospectively analyzed 3 years later. Implants placed in “good-quality” bone (as assessed subjectively at the time of placement) had significantly better survival than those placed in “moderate-quality” or “poor quality” bone (Holahan et al., 2009). Since this is a completely subjective measure, it is presumed that the accuracy of the assessment may depend on the clinical experience of the surgeon. The clinical experience of the periodontology residents is likely far less than that of the surgeon in this study. This was the only other study found to assess the accuracy of the surgeon’s surgical assessment on long-term survivability of fixtures.
6.2.5 Implant site

Jaw and region of placement

The difference in success rates as it relates to jaw and implant position is often attributed to bone quality (Turkyilmaz and McGlumphy, 2008). Generally anterior sites have better bone density than posterior sites, and the mandible is more dense than the maxilla (Misch et al., 2006; Morand and Irinakis, 2007; Turkyilmaz and McGlumphy, 2008). Poor bone quality has been strongly linked to higher failure rates in implants, particularly for those with smooth surfaces (Morand and Irinakis, 2007).

The present study did not show a significant difference in survival rates for implants placed in the maxilla or mandible, although there was a trend for those in the mandible to fail more often. There was also no significant difference between implant survival rates in anterior versus posterior sites, but there was a trend that favoured posterior implants. Both of these trends oppose what is commonly found in the implant literature (mandibular and anterior implants are generally considered most successful) (DeLuca et al., 2006a; Grunder et al., 1999; Hinode et al., 2006; Lekholm et al., 1999; Moy et al., 2005; Romeo et al., 2002), but it is important to remember that there was no significant difference in either case. Many studies do agree that, since the introduction of rough-surface implants, differences in success rates between jaws or bone types are small and often not statistically significant or clinically relevant. (Aykent et al., 2007; Brocard et al., 2000; Kumar et al., 2002; Polizzi et al., 2000; Romeo et al., 2004)

When jaws were considered separately, implants in the posterior maxilla tended to fail more often than implants placed in the anterior maxilla, but the difference was not significantly different. There was also no significant difference in survival rates for
mandibular implants, but anterior implants tended to have higher failure rates. This finding may be because the sample is largely skewed for mandibular overdenture cases, many of which were placed in the early stages of the implant program when implants had machined surfaces. Many publications report better survival in the anterior regions of both jaws, (Ferrigno et al., 2002; Moy et al., 2005) while others, like ours, found no significant differences (Brocard et al., 2000; Polizzi et al., 2000).

6.2.6 Post-operative chemotherapy

With very few exceptions, antibiotics were given to patients at UBC after implant placement. In almost three-quarters of the cases amoxicillin, a moderate-spectrum, bacteriolytic β-lactam antibiotic, was prescribed. Chlorhexidine, a chemical antiseptic rinse, was also prescribed in three-quarters of cases. Despite the prescription of post-operative antibiotics and oral rinses, infections were associated with 5.7% of implants placed in the grad program.

A Cochrane review was completed to determine if antibiotics at the time of implant placement prevent complications post-surgery (Balevi, 2008). Two randomized control trials with follow-ups of at least 3 months were included (Balevi, 2008). A meta-analysis showed that there was a significantly higher number of patients experiencing implant failures in the group not receiving antibiotics (Balevi, 2008). The number needed to treat to avoid one implant failure due to infection was 25, based on an implant failure rate of 6% for those not taking antibiotics (Balevi, 2008). This study recommends a loading does of antibiotic at the time of implant surgery but makes no conclusions about the benefit of post-operative antibiotics (Balevi, 2008).
6.2.7 Post operative complications

In general, most dental surgery procedures are considered Class 2 by the American College of Surgeons Committee on Control of Surgical infections (Class 1 being the cleanest and least likely to become infected and Class 4 being “dirty” or infected surgery sites). These are known to carry a post-operative infection rate of 10% to 15%, but with proper surgical technique and prophylactic antibiotics, the incidence of infection may be reduced to 1% (Resnik and Misch, 2008). Obviously, the infection rate in this study is higher than 1%. We have to keep in mind that this rate was considered on an implant basis and not a patient or case basis – if two implants placed in the same surgery site became infected it was viewed as two separate events, and not one case of infection.

The protocol at the university requires that extensive patient draping, instrument sterilization, hand scrubbing, sterile gowns and gloves for students and staff as well as proper disinfection procedures for the equipment are completed for each surgery. Residents in training completed the majority of surgeries included in this report and the duration of the surgery (the time the flap is open) is likely much longer than it would be with a more experienced clinician. The duration of surgery is considered the second most critical factor (after wound contamination) for causing post-operative infections (Resnik and Misch, 2008). Operations that last less than one hour have an infection rate of 1.3% compared to 3-hour long surgeries that carry a risk of 4.0% (Resnik and Misch, 2008). It has been reported that the rate of infection doubles with each additional hour (Resnik and Misch, 2008).
The incidence of bleeding problems in this study was 1.9%. This is based on information in the daily record that the patient complained of bleeding problems during the healing phase, or that the patient presented with an uncontrolled bleed to the clinic. The findings may not be accurate because they depend solely on accuracy in charting, there is no way to appreciate how significant the bleeding problems were and patients may have sought treatment elsewhere (another dentist, hospital emergency room, etc). We also have only superficial information about any bleeding disorders the patients may have, and therefore we cannot draw any conclusions about why certain cases had bleeding issues while most others did not.

The incidence of both temporary and permanent paresthesia was 0.67%. This translates into one patient who experienced temporary paresthesia after implant placement in 1998 and one patient who experienced permanent paresthesia after implants were placed in 2000. Both patients had implants placed in the anterior mandible. Due to the timing of placement, neither of these cases had any 3-dimensional imaging prior to implant placement, which is now routine at UBC. Of the implants included in this study since the introduction of 3-D imaging in this clinic, no paresthesia has been reported. Computerized tomography (CT) scans are more accurate for detecting anatomic structures in the region of implant placement and should be used when traditional films do not provide clarity of nerve position (Greenstein and Tarnow, 2006).

Our rate of temporary paresthesia is similar to that reported by Vazquez et al. (2008) who found that 0.8% of patients with implants placed in the mandible had temporary sensory disturbances that resolved spontaneously (Vazquez et al., 2008). Of the 2584 implants placed, they had no reported cases of permanent paresthesia despite the
fact that all cases were planned with panoramic radiographs (Vazquez et al., 2008). In a much earlier study, 266 patients with implants placed in the mandible were given a questionnaire (Ellies, 1992). 80% responded and 37% reported altered sensation after implant surgery with long term changes in 13% of patients (Ellies, 1992). In Bartling et al.’s (1999) study, 8.5% of patients with mandibular implants experienced altered sensation post-operatively but none had permanent nerve damage (CT scans were only used when the mandibular nerve wasn’t clear on the panoramic radiograph) (Bartling et al., 1999). In another study, 24% of patients had neurosensory disturbances after implant placement in the anterior mandible, but less than 1% had any paresthesia 1 year after surgery (Walton, 2000). From these reports, it appears that temporary sensory disturbances are quite common after mandibular implant placement but permanent damage is rare.

6.2.8 Implant restoration

Distribution of implant-supported restorations

A large portion of implants in this study was restored with removable overdentures (39.0%), while 29.0% of the implants were restored with splinted crowns, 15.0% with single crowns, 10.0% with fixed partial dentures and 7.0% with fixed full-arch hybrid dentures. The sample is skewed for removable denture cases because when implants were first introduced at UBC, the vast majority of accepted cases were two-implant mandibular overdentures. There was a close to 10% difference in survival rates between implants restored with removable prostheses (89.9% survival) and those restored with fixed prostheses (98.8%). Aykent et al. (2007) also found that implants restored with
removable prostheses fared worse than those with fixed restorations (90.2% vs. 95.2% over 1-12 years) (Aykent et al., 2007).

**Prosthodontic complications**

Over two-thirds of patients experienced at least one prosthodontic complication during the follow up time. Almost three-quarters of the reported complications were associated with removable prostheses. Not only were implants more likely to fail in overdenture cases, but the patients were also more likely to experience prosthodontic issues during follow up. Kaufmann et al. reported frequent technical complications with dentures, mostly related to the anchorage systems to the implants (Kaufmann et al., 2009). These complications were more frequently observed in the first year after delivery of the prosthesis (Kaufmann et al., 2009; Kiener et al., 2001). In 2002, a study by Chaffee et al. followed 58 patients with implant supported removable overdentures over 36 months (Chaffee et al., 2002). Of the 58 patients, 6 required no adjustments, while the remaining 52 patients required 327 return visits (194 of these were unscheduled) for prosthesis or abutment adjustments (Chaffee et al., 2002).

Undergraduate students have restored many of the overdenture cases at UBC, whereas the fixed implant-supported restorations were completed exclusively by prosthodontists. This may account, in part, for the higher number of post-placement prosthodontic complications for removable dentures who were often restored by relatively inexperienced students. Also, Walton et al. (2001) described that inexperienced surgeons (much like the periodontology residents at UBC) had a greater tendency to place implants at less-than-ideal angulations (Walton et al., 2001). This study showed a
significantly greater number of denture repairs were required when the lingual inclination of implants was greater than or equal to 6mm (Walton et al., 2001).

6.2.9 Level of training of the clinician

Although not significant, there was a trend for implants placed by residents in their second year of training to have lower survival rates than those placed by first or third year residents, or staff members. In fact, almost half of all failed implants (46.67%) were placed by students in their second year of the program. The high implant survival rate found with those in their first year of training (94.12%) may be because these residents were likely assigned the most simple implant cases (adequate dimensions of existing bone, generous distance between implant position and any anatomic structures, implants placed in highly dense bone, etc.). Second year students were likely assigned more challenging cases while they continued to develop their surgical skills, which may explain the relatively low implant survival rate (88.54%). Third year residents and staff have already undergone extensive clinical and didactic training in implant dentistry, and thus the implants they placed demonstrated relatively high survival rates (97.62% and 93.18%). Staff may have lower success rates than the third year residents because they likely took on the most difficult cases.

Some studies have found that clinician experience and/or training does impact implant survival (DeLuca et al., 2006a; Lambert et al., 1997). One study found that implants placed by inexperienced surgeons were twice as likely to fail, especially if the case was one of their first nine cases (Lambert et al., 1997). In a recent publication by Eliasson et al. (2009), 109 patients had implants placed and 13 patients had fixtures placed by inexperienced surgeons (Eliasson et al., 2009). All three patients who
experienced failures were treated by the small group of inexperienced surgeons (Eliasson et al., 2009).

The lack of a statistically significant difference between implants placed by students at various levels in their training in this study may be related to the close supervision of all residents by an experienced clinician, which may help to lessen the learning curve. Like this investigation, Kohavi et al. (2004) and Melo et al. (2006) also studied university training programs and found that the level of experience did not significantly effect implant survival (Kohavi et al., 2004; Melo et al., 2006). Melo et al. explained the trends in their study based on the level of complexity of the cases given the residents in that program (Melo et al., 2006).

6.2.10 Replacement implants

Should an implant fail, it is important to know if the survival of a replacement implant is comparable to the published survival rates for implants in general. Mardinger et al. (2008) studied 120 patients with implant failures who chose to have replacement implants and 74 patients with implant failures who chose not to have new implants (Mardinger et al., 2008). They found that the major factor that impacted the patient’s decision to replace the implant was the amount of bone loss at the implant site (Mardinger et al., 2008). The tendency to choose reimplantation correlated with the amount of bone loss and the need for augmentation (Mardinger et al., 2008). Reasons patients gave for avoiding reimplantation included: the additional cost (27% of patients), fear of pain (17.7%), fear of second failure (16.2%), proximity to anatomic structures (16.2%), no prosthetic needs for a new implant (12.1%) and medical status (10.8%) (Mardinger et al., 2008).
Currently, very few reports mention the survival rates of replacement implants (Mardinger et al., 2008). One study examined 79 replacement implants and followed them for 7 to 78 months (Machtei et al., 2008). The overall survival rate for was 83.5%, which is lower than reported by most studies for implants placed in pristine sites (Machtei et al., 2008). Grossmann and Levin (2009) also reported low survival rates for replacement implants (71% over 6 to 46 months) (Grossmann and Levin, 2007). In Alsaadi’s (2006) report, 29 machined surface implants were replaced by other machined surface implants and six of these failed (79.4% survival rate) (Alsaadi et al., 2006). On the other hand, when 19 failed smooth-surface implants were replaced with rough implants only one implant failed and when 10 rough implants were replaced with the same surface, none failed (Alsaadi et al., 2006).

The replacement implant survival rate of 85.71% compares favorably to the above-mentioned reports. This relatively high survival rate may be associated with the very small sample size (n=14). There is still a lack of substantial evidence regarding failed implant replacement. Many studies advocate meticulous removal of all granulation tissue around the implant site and the use of wider implants with improved surface texture to ensure the best long-term treatment outcome (Mardinger et al., 2008).

6.2.11 Peri-implant bone loss

Almost twice as many Branemark/Nobel BioCare implants had thread exposure over time compared to Straumann implants. Of all of the predictors in the multivariate analysis, implant model had the largest significant effect on thread exposure (β=0.22). A recent meta-analysis did find that Straumann implants had significantly less marginal bone loss than Branemark/Nobel implants; the pooled mean marginal loss was 0.48 mm
and 0.75 mm respectively, over five years (Laurell and Lundgren, 2009). It is difficult to use thread exposure as a comparison for horizontal bone loss with these two systems since the implant designs are very different (appendix H, fig 33). For Straumann implants, the distance from the lower edge of the smooth neck (the point at which most soft tissue level implants are submerged) to the first thread is 1.25-2.25 mm. In the Branemark/Nobel system, the distance from the point of usual submersion (the edge of the smooth collar in Select implants, the top of the fixture in Groovy and Mk implants) to the first thread is between 0.3 and 1.5 mm (depending on the design). It is important to emphasize that, due to the difference in design, more marginal bone loss has to occur around a Straumann implant to expose the first thread.

Another reason this comparison may be unfair is because so few Straumann implants were placed relative to the number of Branemark/Nobel implants. Until recently, Straumann implants were placed only under the supervision of a visiting instructor, who was not generally available for treatment planning prior to surgery. For this reason, the sample is likely skewed towards more simple cases, as residents tend to reserve the most difficult cases to be done with the instructor with whom they planned it.

The level of thread exposure for Branemark/Nobel implants was high when compared to other published reports. In a 2000 investigation of 4971 implants, marginal bone loss exceeding the first three threads occurred in 1.8% of implants (mean follow up time, 5.1 years) (Snauwaert et al., 2000). In this study, 5.0% of Branemark/Nobel had four threads exposed and 2.0% had five exposed. In another publication limited to machined surface Branemark implants, only 183 out of 3,462 implants had marginal loss of \( \geq 3 \) mm from the fixture/abutment interface with most loss occurring in the first year.
after placement (Pikner et al., 2009). It is difficult to explain why the Branemark implants were associated with more peri-implant bone loss than what is generally found in the literature. The lack of any standardization of radiographic measures in this study makes the value of our marginal bone loss measures questionable. If marginal bone stability is related to the preparation of the bone at the time of surgery, it is plausible that surgical factors may be implicated in this increased loss (residents likely have the flap open longer, may be more liable to overheat the bone than more experienced clinicians).

6.3 Regression analyses

Regression analysis is a technique for modeling the relationship between two or more variables (Miles, 2001). Stepwise linear multiple regression analysis was completed for thread exposure, while logistic regression analysis was completed for the dichotomous primary outcome variable – implant failure.

Implant model had a statistically significant effect on thread exposure, in that Straumann implants were less susceptible to having threads exposed over time. As previously discussed, this maybe largely due to the difference in implant design and case selection between Nobel and Straumann (appendix H, fig. 33). Mandibular implants were found to have less thread exposure than maxillary implants and rough surface implants had less marginal bone loss than their smooth counterparts. These findings are consistent with the low failure rates of mandibular and rough surface implants commonly published (Del Fabbro et al., 2008b; DeLuca et al., 2006a; Grunder et al., 1999; Hinode et al., 2006; Khang and Flier, 2001; Lekholm et al., 1999; Moy et al., 2005; Romeo et al., 2002; Stach and Kohles, 2003). Significant differences were not found when examining surface texture and jaw bone in the bivariate analyses but a clear effect on thread
exposure could be seen after controlling for confounding variables. When fewer predictors were considered in the regression analysis, sinus augmentation was also associated with increased thread exposure.

In terms of implant failure, only sinus augmentation and implant width were found to have significant effects after logistic regression analysis. The odds ratio for implant failure was 11.00 for those with sinus augmentation (16.87 if only simultaneous lifts were considered) and 0.288 for those with narrower implants. This clearly indicates that sinus augmentation was the most significant predictor of implant failure in the present study. As discussed previously, this finding is likely skewed by the relatively high implant failure rate for implants placed with simultaneous osteotome lifts. This is contradictory to the high success rates for this technique in the current literature (Fermergard and Astrand, 2008; Ferrigno et al., 2006; Pjetursson et al., 2009; Tan et al., 2008).

6.4 Study limitations

Many of the drawbacks of this type of retrospective chart review have been discussed in previous sections of this paper. A summary is presented below:

a) Small sample size

b) Large number of excluded cases

c) Retrospective design

d) Important data not always available

e) Relies on accuracy of chart records

f) Unable to prove cause and effect

g) Different types and designs of implants placed
h) Lack of randomization and blinding

Given the high survival rates of implants (including those placed in this program), a small sample size does not allow for trends in the data to reach statistical significance, even if a true difference exists. An analysis of the baseline characteristics of the excluded cases (age and gender) demonstrated that there were no significant differences in these characteristics between the study patients and the excluded patients (p=0.152 and p=0.224).

6.5 Conclusions

The following conclusions can be made in the context of this investigation:

• Implants placed at the UBC graduate periodontics clinic between 1989 and 2006 had a survival rate of 92.3%, which compares favorably to rates reported in the literature.

• 84.1% of patients treated in this clinic had no implant failures.

• 13.1% of patients had one failed implant, 2.8% of patients had two failed implants, and no patients had more than two implant failures.

• The survival rate for replacement implants was 85.71%.

• Most variables considered risk factors did not have a statistically significant impact on implant survival.

• In the bivariate analysis, only sinus augmentation (particularly indirect, simultaneous elevations) was significantly associated with implant failure and guided bone regeneration was significantly associated with implant survival.
• In the regression analyses, the predictors showing the largest effect on thread exposure were: implant model, jaw (in favor of mandibular implants) and surface (in favor of rough surface implants).

• The odds ratio for implant failure was 0.30 for machined surface implants and 0.29 for decreasing implant width.

• The odds ratio for implant failure was 16.87 when an indirect osteotome lift was employed. Overly conservative approaches to osteotome sinus lifts should be avoided.

• Lateral window sinus lifts were not associated with any implant failures.

• Given the high survival rates of implants, a small sample size does not allow for trends in the data to reach statistical significant, even if a true association exists.

6.6 Future directions

In order to more efficiently expand this investigation over time, a two-page form was developed to record all of the necessary investigation for each implant case (appendix I). The first form is to be completed at the time of implant planning and placement. The second is to be completed at the time of implant restoration and after every follow up at least one year after placement. This study can then be revisited in several years with a larger sample size and longer follow up to validate if any of the observed trends are significant. Currently, the university protocol includes a radiographic follow up each year after implant restoration for five years. This protocol should be strictly enforced. In addition, it would be valuable to follow all implants placed every 2-3 years after the first five years post-operative. Continued evolution of the graduate
program to include more difficult cases and innovations in dental implant and grafting materials will provide for interesting comparisons in the future.
REFERENCES


APPENDICES

APPENDIX A: Periodontal charting
APPENDIX B: Surgical summary

University of British Columbia
Faculty of Dentistry
Department of Clinical Dental Sciences

Chart No. ________

PERIODONTAL SURGERY DOCUMENTATION

Date 05/03 Area(s) of Surgery (circle) UR, UAnt, UL, LL, LAnt, LR

Type(s) of Surgery Planned
1) ________ ________ Premedication: Type ________ Amt ________
   Implant 12,13.
   Given ________ minutes before start

2) ________ ________ B.P. ________ ________ Pulse ________ ________ Resp. Rate ________ ________

Presaurgical (preanaesthetic) ________ ________ ________ ________ ________ ________ ________

Anaesthesia (injections, type of solution, total amount - each type
   Sedation if used).

Projected findings (osseous and/or other)

NOTE: Patient was planned for 2nd stage surgery but because of dehiscence
   around one of the implants we had to proceed urgently.

Summary of Surgical Steps (incisions, flaps, osseous corrections, other
   steps). Describe and diagram.

Suturing and/or use of adhesive - technique(s); no. of sutures. Describe.

Materials(s) used, needle(s) - circle below.

Adhesive: N-butyl cyanoacrylate (Histoacryl)
4-0 silk, CC66, FS-2, CE-6; 4-0 Daxon, CE6.
5-0 silk, CL, C3, FS-2; 5-0 Vicryl, RB-1.

Dressing - circle - none; Coe, Prof. Products Co., foil/other__________
APPENDIX C: Implant surgical summary

UNIVERSITY OF BRITISH COLUMBIA
GRADUATE PERIODONTICS

Patient: 
Operation: Implant Surgery Jaw: maxilla
Surgeon: Stacy Mathew
Premedication: None
Anaesthesia: 1 x 5% 1:200,000 epinephrine 1 x 4% 1:200,000 epinephrine

INJECTIONS:
Premedication: 2 mL of local anesthetic (4%) and a vasoconstrictor (4)

Surgical Report:

Date: 2.6.2003
Chart number: 

Diagnosis: Jaw: maxilla

Operative Procedure:

Incision: Incision along the crest of the ridge

Bone Resorption: moderate
Bone Quality: good
Bone Preparation: pilot twist (3), countersink, screw tap

Primary Stability: excellent
Healing Period: 4 months

Notes:

- Upon preparation, the buccal aspect of the implant
  - Ratios: 1.3 - good
  - 1.2 - see transmucosal margin Buccal
  - 2.2 - good
  - 3.2 - good
  - 3.1 - good

- Had tightened all for last 2 months
- Good bone quality (considering maxilla)
- Cancellous tissue: 3.1 - need to place implant}

Tri-unit surface
APPENDIX D: Post-operative summary

<table>
<thead>
<tr>
<th>FIXTURE INSTALLATION</th>
<th>MAXILLA</th>
<th>MANDIBLE</th>
<th>REGION:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comments:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Suturing: vertical mattress #</th>
<th>interrupted # 8</th>
<th>resorbable</th>
<th>nonresorbable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression: 5 minutes R+L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-operative instructions:</td>
<td>written, verbal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condition of patient at dismissal:</td>
<td>Good</td>
<td>Appropriate</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PRESCRIPTIONS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>antibiotic: GmX</td>
</tr>
<tr>
<td>analgesic: Tylenol / Tylenol 3</td>
</tr>
<tr>
<td>mouthrinse: CTX 12 3</td>
</tr>
<tr>
<td>other:</td>
</tr>
</tbody>
</table>

| Post-surgical appointment date: Aug-03 @ 10AM |

<table>
<thead>
<tr>
<th>Student:</th>
</tr>
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<table>
<thead>
<tr>
<th>Instructor:</th>
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</thead>
</table>
APPENDIX E: Implant guarantee form

Nobel Biocare
Nobel Biocare Canada Inc.
Implant Failure Guarantee Form

1 Patient Information

Patient

2 Surgical Procedure

Fixture Placement

Date of Fixture Placement 05 / 14 / 02

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Product Code</th>
<th>Description</th>
<th>Lot Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
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</tr>
</tbody>
</table>

Healing Abutment (if used)

Date of Healing Abutment 09 / 10 / 02

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Product Code</th>
<th>Description</th>
<th>Lot Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

Treating Surgeon

Customer Number

Implant Placement – Write the size of each implant in the corresponding tooth number boxes below. Circle the number of the tooth that experienced the failure.

<table>
<thead>
<tr>
<th>1-8</th>
<th>1-7</th>
<th>1-6</th>
<th>1-5</th>
<th>1-4</th>
<th>1-3</th>
<th>1-2</th>
<th>1-1</th>
<th>2-1</th>
<th>2-2</th>
<th>2-3</th>
<th>2-4</th>
<th>2-5</th>
<th>2-6</th>
<th>2-7</th>
<th>2-8</th>
</tr>
</thead>
<tbody>
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<td></td>
</tr>
</tbody>
</table>

Please indicate the following for the failed implant site:

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Product Code</th>
<th>Description</th>
<th>Lot Number</th>
</tr>
</thead>
</table>

Please indicate the following for the failed implant site:

- Post-surgical (pro-exposure) loading of the implant
- Post-surgical (healing abutment) loading of the implant
- Biomechanical overload or stress (prosthetic attachment)
- Bone quality insufficient
- Bone quantity insufficient

- Infection
- Poor oral hygiene
- Surgical trauma (please explain):
- Other (please explain):
APPENDIX F: Variables included

Data collected from patient charts:

Demographic data:
• Date of birth/age
• Sex
• Gender

Health status:
• Coagulopathies
• Hypertension
• Diabetes
• Osteoporosis
• Arthritis
• Medications
• Smoking history (current, former, never)
• Pack years
• Year quit
• Reported bruxism

Clinical information:
• Date of initial exam
• Reason for tooth loss
• Periodontal health status
• Date of tooth extraction
• Implant site
• Adjacent tooth probing depth
• Adjacent tooth furcation involvement
• Date of stage 1 surgery
• Previous socket preservation (materials used, healing time)
• Previous guided bone regeneration (materials used, healing time)
• Previous sinus augmentation (materials used, healing time)
• Simultaneous guided bone regeneration (materials used, healing time)
• Simultaneous sinus augmentation (materials used, technique, healing time)
• Date of stage 2 surgery

Implant variables:
• Model/brand
• Surface type
• Taper
• Width
• Length
• Connection
Surgical variables:
- Torque at placement
- Bone resorption at time of placement
- Bone quality
- Bone vascularity
- Primary stability
- Healing time before stage 2 or restoration
- Threads exposed at time of placement
- Presence of bony dehiscence at the time of placement

Post-operative variables:
- Post-operative complications (bleeding, infection, paresthesia)
- Post-operative chemotherapy (antibiotic, analgesic, steroid, chlorhexidine)

Prosthodontic variables:
- Type of temporary restoration
- Type of permanent restoration
- Date of permanent restoration insertion
- Post-insertion complications

Follow up information:
- Date of most recent follow up
- Threads exposed at most recent follow up
- Peri-implantitis treatment (date, defect, materials used)
- Implant failure
APPENDIX G: Implant dimensions

Fig 30. Wide platform Nobel BioCare implant at 16, narrow platform implant at 14, regular platform implant at 13.

Fig 31. Short (8 mm) Nobel BioCare implant

Fig 32. Long (13 mm) Nobel BioCare Implant
APPENDIX H: Radiographic signs of marginal bone loss around implants

Fig. 33 Differences in implant design between Nobel BioCare and Strauman implants in terms of distance from the implant neck to the first thread.

<table>
<thead>
<tr>
<th>No thread exposure</th>
<th>Exposure of two threads on the distal of the implant at 22</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="No thread exposure" /></td>
<td><img src="image2.png" alt="Exposure of two threads on the distal of the implant at 22" /></td>
</tr>
</tbody>
</table>
Exposure of four threads on the mesial of the implant at 35

Fig 34. Amount of marginal bone loss around implants.
APPENDIX I. Documentation for future cases

Implant Case Documentation
*please complete a form for EACH implant placed

PART 1. To be completed at stage 1 surgery

Chart number: ____________ age: _______ gender: _______

Date of stage 1 surgery: _____________ Implant replacing failed implant? ( ) yes ( ) no

Systemic disease: ( ) osteoporosis ( ) diabetes ( ) other: _______________________________

Smoking status: ( ) never ( ) former ( ) current pack years: ________ year quit: ______

Date of initial implant exam: _____________

Reason for tooth loss: ( ) periodontal disease ( ) other ( ) unknown

Current periodontal diagnosis: _______________________________________________________

Date of tooth extraction: _______________ Implant site: ______

Deepest probing depth and/or furcation involvement adjacent to implant site: _________

Previous surgery: ( ) socket preservation ( ) guided bone regeneration ( ) sinus augmentation (specify materials and date completed):

_____________________________________________________________________________

Simultaneous surgery: ( ) socket preservation ( ) guided bone regeneration ( ) sinus augmentation (specify materials):

_____________________________________________________________________________

Implant brand/model: ______________________________________________________________

Implant surface type: ( ) SLA ( ) TiUnite ( ) other: _______________________________

Implant shape: ( ) straight ( ) tapered width: _________ length: __________

Torque: __________ Primary stability: ___________

Post-operative chemotherapy (note all agents prescribed/recommended and dosage):

_____________________________________________________________________________

Number of threads exposed at placement (clinical and/or radiographic): ___________
PART 2. Post-operative and follow up information

Post-operative complications: ( ) bleeding ( ) paresthesia ( ) infection ( ) other: __________

Type of provisional restoration:( ) crown ( ) denture ( ) hybrid ( ) FPD ( ) splinted crowns

Date of stage 2 surgery: ______________ Date of implant restoration: ______________

Type of permanent restoration:( ) crown ( ) denture ( ) hybrid ( ) FPD ( ) splinted crowns

Post-placement soft or hard tissue augmentation (date/type/materials used): ______________

Post-insertion prosthodontic complications (date/type): ______________

( ) Peri-implantitis ; treatment (date/type): ______________

(1) Date of most recent follow up: ______________

Threads exposed at most recent follow up: ______________

(2) Date of most recent follow up: ______________

Threads exposed at most recent follow up: ______________

(3) Date of most recent follow up: ______________

Threads exposed at most recent follow up: ______________

(4) Date of most recent follow up: ______________

Threads exposed at most recent follow up: ______________

(5) Date of most recent follow up: ______________

Threads exposed at most recent follow up: ______________

(6) Date of most recent follow up: ______________

Threads exposed at most recent follow up: ______________

( ) IMPLANT FAILURE Date removed: ______________

*please use an additional form for any replacement implant
APPENDIX J: Ethics course certificate

Issued On: January 16, 2008

Akin to: Council Policy Statement: Ethical Conduct for Research Involving Humans (IRB)
Introduction to the
Institutional Review Board (IRB)
has completed the Institutional Advisory Board on Research Ethics'

[Signature]

This is to certify that

Certificate of Completion

6040 STUDIES
07-17-2008

DE-11114-RE5