CLINICAL OUTCOMES OF SHORT IMPLANTS PLACED IN THE POSTERIOR MAXILLA WITH THE INDIRECT SINUS ELEVATION TECHNIQUE AND IN THE POSTERIOR MANDIBLE: A RETROSPECTIVE STUDY WITH UP TO 5-YEAR FOLLOW-UP.

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Abstract

Purpose: This retrospective longitudinal study evaluates the 5-year survival and success rates of implants placed with the osteotome technique in the maxilla without bone grafting and to show that short implants (less than 10 mm) can be used to adequately treat the atrophic maxilla and mandible.

Material and Methods: 926 implants were placed in the posterior maxilla with the osteotome technique and no added bone graft. This included a subset of 530 short 6 mm, 8 mm, and 10 mm implants. Maxillary implant restorations were splinted together if the implants were placed adjacent to each other. Maxillary crestal bone loss was evaluated at base line and subsequently at 12-month intervals up to 5 years. Also, 720 short 6 and 8 mm implant fixtures were placed in the posterior mandible with no bone graft. All mandibular implant restorations were splinted together. Mandibular crestal bone levels were evaluated at 12 months then at 1-2 year intervals up to 5 years.

Results: The implant survival rate for maxillary implants was 97% up to 5 years follow-up. The implant success rate (less than or equal to 1 mm bone loss) ranged from 87.7% to 97% depending on the implant system and length of follow-up period. Short maxillary implants (n= 530) had survival and success rates similar to conventional length implants. Mandibular implants recorded an overall 5-year survival rate of 100 %. The overall cumulative success rate was 93.4% at 5 years.

Conclusion: It can be concluded that short implants are an effective treatment modality in the resorbed mandible. Also, implant placement with the indirect sinus elevation technique without a

bone graft is a highly successful procedure even when short implants are utilized.

Preface

The contents in Chapters 3 and 4 are based on implants placed at Dr. David French's periodontal office, in Calgary, Alberta. Dr. Batoul Shariati from the UBC Faculty of Dentistry completed the statistical analysis in chapter 3. The Statistical Consulting and Research Laboratory (SCARL) from the UBC mathematics department, contributed to the statistical analysis in chapter 4.

Ethics approval was given by the Clinical Research Board of the University of British Columbia (Certificate number: H13-01664).

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List of Abbreviations

OSFE	Osteotome sinus floor elevation
RBH	Residual bone height
ASA	American Association of Anesthesiologists
RN	Regular neck
WN	Wide neck
CI	Confidence interval
OR	Odds ratio

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To my parents Kayhan and Zhila: I'm infinitely grateful for everything you've done for me. Your love and support have helped me achieve everything I've achieved to date. Thank you.

To my sisters Negaar and Anisa: Thank you for being so supportive and for being great friends.

Dedication

I dedicate this thesis to my parents who have supported me throughout all my years of education

Chapter 1: INTRODUCTION

A medical implant is defined as a device made from one or more materials that is intentionally placed within the body, either totally or partially buried beneath an epithelial surface[1]. The first implants used to replace missing parts of the jaw and missing teeth date back to the pre-Columbian era, before 1492[1]. The first industrial implants were made from materials that consisted of gold, silver, platinum, aluminum, or porcelain[1]. These first implants caused foreign body reactions with the formation of fibrous tissue. The next generation of materials, used presently was made out of biocompatible materials which, osseointegrate and have high survival and success rates[1]. Osseointegration is characterized as "a direct structural and functional connection between ordered, living bone and the surface of a load- bearing implant"[1].

Several clinical and radiographic criteria are used to determine the success and survival of dental implants. The most common objective criteria used to describe implant success is the absence of mobility, radiolucency, peri-implant bone loss, suppuration and bleeding[2]. The objective criteria determining implant success, is the evaluation of patient satisfaction and the absence of pain. The survival rates of dental implants are found to be approximately 90% over 10 years and therefore are a predictable and effective treatment option for patients. However, many failures still occur and several limitations still exist in placing dental implants, therefore greater research is still required in order to improve implant therapy for patients[3].

Previously one of the largest limitations to placing dental implants were the dimensional limitations resulting from bone resorption[4]. Since conventional length implants (greater than 10 mm's) have historically been considered more predictable than short implants, several surgical interventions for bone augmentation have been proposed in order to be able to place these implants. These procedures include bone grafts, guided bone regeneration, distraction osteogenesis, sinus floor elevation, mandibular nerve transposition, and the use of tilted or zygomatic implants[4]. Although these techniques have gained a degree of success through the years, with the exception of sinus floor elevation, there is insufficient data on their predictability[5]. The alternative to avoiding bone augmentation techniques is through the use of short implants[5]. The use of these implants may provide surgical advantages including reduced morbidity, treatment time, and costs.

The recent introduction of new implant designs and roughened implant surfaces that increase the implants surface area seem to make up for the for the adverse effects seen with previous short implants[6]. The rationale behind the use of short implants, is that studies have shown that the portion of the implant most involved in bearing the occlusal load is the marginal portion and that little stress is transferred to the apical portion[7]. Therefore, implant length may not play a role load distribution. However other risk factors, such as the poor bone quality of the atrophic ridge, may influence the short implant's survival.

The present report evaluates the use of short (10 mm's or less) implants placed in the

maxilla and mandible. Furthermore, the use and effectiveness of the osteotome technique without bone grafting to elevate the sinus is analyzed.

Chapter 2: REVIEW OF THE LITERATURE

2.1 ANATOMICAL DIMENSIONAL CHANGES

Extraction of single or multiple teeth leads to a series of structural changes in the alveolar ridge. The resultant loss of teeth and change in function of the extraction site ultimately causes alterations of the edentulous alveolar bone[8]. Typically, the size of the alveolar ridge will become markedly reduced, in both the horizontal vertical dimensions. An adequate volume of alveolar bone with favorable architecture of the alveolar ridge is required to obtain ideal functional and esthetic results following implant therapy[9]. Studies evaluating the morphological changes that take place after tooth extraction were published as far back as the 1960's, such as reported by Pietrovsky and Masler (1967)[10]. This was one of the first objective and quantitative studies to be published investigating the patterns of edentulous ridge alteration after an extraction. The authors measured the amount of alveolar bone resorption by comparing the edentulous ridge to the tooth-bearing ridge on the contralateral side using plaster casts. As a result of comparing the casts, it was noticed that buccal resorption was significantly greater than palatal resorption in the maxilla. Similar findings were found in the mandible where more resorption was found on the buccal than on the lingual aspect of the ridge[10].

These findings were supported by findings by Schropp et al. (2003) using subtraction radiography, casts and clinical measurements, over a 12 month period, to evaluate bone and soft tissue volume changes following the extraction of single premolars and molars[9]. The

reasons for extraction were due to various reasons (caries, periodontal disease, root fractures, endodontic failures. etc.). Measurements were taken immediately after tooth extraction and at the 3, 6, and 12-month post-extraction appointments. Almost all of the vertical loss occurred during the first 3 months, whereas two thirds of the horizontal loss occurred in the first 3 months. A total bucco-lingual reduction of 50 % was noticed at 12 months[9]. Similar to Pietrokovsky e. al's (1967) study, the height of the buccal bone plate was located apical (1.2 mm) to its lingual/palatal counterpart[9].

In another study, evaluating ridge alterations of the edentulous ridge, Araujo and Lindhe (2005) experimented on dogs and examined the changes in the profile of the edentulous ridge following tooth extraction[11]. At 1 week, the marginal ridge of the lingual wall of the extraction socket was significantly wider at 1.4 mm, than the buccal wall at 0.6 mm. The buccal crest was found to be coronal to the lingual crest at this interval. At 2 weeks, newly formed bone was found at the apex of the extraction socket and at four weeks the lingual bone was found to be wider than the buccal bone (1.6 mm and 0.7 mm respectively). Finally, at 8 weeks the lingual bone was significantly wider than the buccal bone and consistent with previous findings, the level of the buccal crest was 2 mm apical to the level of the lingual crest[11]. This pattern of resorption can be explained by the bundle bone concept. According to this theory, a greater proportion of the buccal plate is composed of bundle bone compared to the lingual plate; and bundle bone is rapidly resorbed after tooth extraction with marked reduction in the buccal plate, as bundle bone depends on the

presence of the tooth[11].

Similar findings were published in 2009, comparing flapped and flapless tooth extraction in dogs. The removal of a tooth caused a marked change in the edentulous ridge with substantial reduction in the coronal portion of the ridge. There was no difference found based on the procedure used. Therefore tooth loss (extraction) resulted in marked alterations of the ridge[12].

In human studies, measuring vertical dimensional changes, results indicated that resorption of the buccal plate (0.9–3.6 mm at 3–7 months) was greater than resorption of the lingual plate (0.4–3 mm at 3 –7 months)[13]. This finding was similar to the previously mentioned studies using the dog model[11]. The relative difference in height of the buccal and lingual plate is estimated to be around 0.3–0.6 mm over a period of 3 and 7 months. One possible explanation for the observed differences between human models and canine models is that the buccal plate in humans is on average equally prone to resorption as the lingual aspect of the ridge[13].

A number of re-entry studies have looked at the vertical height change following tooth extraction[8]. A study measuring ridge alterations six months following the extraction of anterior teeth or premolars, found a mean reduction Camargo et al. (2000) reported a mean vertical ridge reduction of and 1.00 ± 2.25 mm[14].

Aimetti et al. (2009 reported on horizontal changes over time in the hard tissue at the level of the alveolar crest and found that documented 6-month horizontal reduction in the hard tissue of the alveolar ridge to be 2.46 mm[15].

A systematic review of the existing literature was recently performed by Tan et al. (2011) to assess the magnitude of dimensional changes for both the hard and soft tissues of the alveolar ridge up to 12 months after tooth extraction in humans. A total of 20 studies were included in the review. The authors found that the weighted mean horizontal reduction at 6 months post-extraction was calculated to be 3.79 ± 0.23 mm horizontal reduction across five studies. This equated to be a 32% reduction at 3 months, and 29–63% reduction in horizontal dimension at 6 months. This illustrated that more than half of the ridge width could resorb after 6 months[8].

Tan et al.'s (2011) review also found that there was greater reduction in horizontal width than in the vertical dimension at 6 months. Percentage calculations in the horizontal reduction were found to be 32% at 3 months, and 29-63% at 6 months. In the vertical dimension there was between 11-22% reduction at 6 months[8].

According to Tan et al. (2011), only one study followed the bone resorption patterns longer than 12 months . The ridge alterations were followed for up to 5 years and found that

although there was a rapid rate of resorption in the first 6 months, there was a consistent resorption rate up until 5 year[16].

It is apparent that dimensional alterations of the alveolar hard and soft tissues can be quite extensive, and the patterns and magnitude of change seem to be more profound on the buccal than palalal aspects, with the greatest rate of resorption occurring within the first 3 months. These alterations make implant treatment more complex and other procedures such as ridge augmentation may be required prior to implant placement.

2.2 RIDGE AUGMENTATION

One of the main criteria for osseintegration and long-term success of implant therapy is having adequate vertical and horizontal bone for implant placement. As previously mentioned, alveolar bone resorption is the unfortunate sequelae of dental tooth loss[9]. Vertical and horizontal alveolar bone loss becomes a challenge for a patient opting for implant treatment[17]. Multiple anatomical limitations exist, particularly with vertical bone loss, such as the pneumatized maxillary sinus, the inferior alveolar nerve and the nasal cavity[17]. Several procedures have been discussed in order to augment the deficient site[18]. There are different materials and biologically active agents used to augment bone volume, and generally different indications for each[19]. The main materials used include:

1) Autogenous bone grafts (grafts taken from the same patient); 2) Allografts (bone harvested from cadavers); 3) Xenografts (grafts harvested from animals, usually bovine bone); 4) Alloplastic grafts (synthetic bone)[19]. The purpose of this section is not to describe the different augmentation techniques, but to review the literature discussing the clinical outcomes associated with vertical and horizontal augmentation.

In a systematic review, using guided bone regeneration by use of a membrane, it was found that there was up to 8 mm gain vertical bone gain, however post-operative complications associated with vertical augmentation were as high as 45% indicating that it may not be a simple procedure[17]. The survival rates of implants placed in vertically augmented bone in the maxilla and mandible ranged from 61.5% to 97.5%, depending on the surgical approach and follow-up time[17,20]. Better results were found, however by Chiapasco et al. (2006) where the overall survival rate of implants placed in sites augmented with vertical guided bone regeneration was 99.3% (range: 99–100%)[18].

The same systematic review evaluating 9369 implants placed in the vertically augmented sinus with grafting found a 96.4% implant survival rate and success rates ranging from 93.5% to 97.8% using the trans-alveolar technique[18]. The survival rate of implants placed in the grafted sinus through the lateral window approach was evaluated at 92.6%, with success rates ranging from 74.7% to 100%[18].

Another method to vertically augment bone is by distraction osteogenesis, whereby a surgically prepared fracture is made and a gap is created between the two segments of bone, which eventually fills with bone[19]. Reports of complications with distraction osteogenesis range from 10-75.7%, an example of which is basal bone fracture. Vertical bone gain with distraction osteogenesis was found to range from 5-15 mm[21]. Implant survival rates ranged from 90-100% and success rates from 59 % to 92% according to Rocchieta et al.'s (2008) systematic review[17].

Reports on the success rates of implants placed in both vertical and horizontal augmented sites by Fugazzotto et al. (2005), revealed that the cumulative success rates of implants placed in the maxilla were 97.2% and 97.4% for those in the mandible, yielding an overall cumulative success rate of 97.4% for up to 133 months[22]. Similar results were found in a study by Buser et al. (2002) with a 98.3% success rate for implants placed in horizontally regenerated bone with a 5 year follow-up[23]. A systematic review assessing the survival rate of implants placed in only horizontally augmented sites was 98% (range: 76.8–100%), with a horizontal gain of bone between 2 to 4.5 mm. The success rate for these implants was 92.6%[20].

When comparing vertical augmentation procedures to the use of short implants, a systematic review by Esposito et al. (2009) found that vertical augmentation resulted in

greater implant failure, more morbidity, increased cost and longer treatment time than the use of short implants[19]. Therefore the use of short implants can be justified over vertical augmentation procedures. Results from multiple other studies show that horizontal augmentation has fewer complication rates and is more predictable than vertical bone augmentation and is a viable treatment option prior to implant placement[19].

2.3 DENTAL IMPLANTS

Dental tooth extraction is a common treatment modality, and that treatment comes with the dental therapeutic goal of restoring lost dentition and masticatory function. As mentioned in the introduction, research by Branemark in the 1960's revealed the concept of osseointegration, defined as "a direct functional and structural connection between living bone and the surface of a load carrying implant"[24]. This finding has led to greater research and development and finally the evolution of dental implants with high survival and success rates, which is now a predictable treatment modality for the restoration of missing teeth. Many studies report success criterion of dental implants in terms of survival rate, meaning whether the implant is in the mouth or has been removed. Since this is the most objective way of assessing an implant, many state that this is the best method of presenting the data. Those against the use of survival as a measure of success, state that an implant may be left in the patient's mouth even though it's causing pain or infected in order to increase published survival rates[25]. Implant success differs from survival and has been typically based on Albrektsson's criteria , which states that a successful implant must present the

following: 1) Implant is immobile when tested clinically; 2) Radiographs do not demonstrate evidence of peri-implant radiolucency; 3) Bone loss that is less than 0.2 mm per year after the implant′s first year of service; 4) No persistent pain, discomfort or infection[2].

The Conscensus of Oral Implantologists Conference in 2008 established a different scale allowing dentists to evaluate an implant using listed criteria, then placing it in an appropriate category of health or disease, and treating it accordingly. Three major categories were established: success, survival, and failure. There are 4 implant groups which describe the clinical conditions of success, survival, or failure[25].

"Success" and excellent prognosis is represented in Group I, which is considered to be an implant in optimum health conditions. The patient in Group I experiences no pain on palpation, percussion, or function. No clinical implant mobility is noted in any direction and less than 2.0 mm of crestal bone loss is observed compared to baseline crestal levels[25].

"Survival" is found in Group II implants and considered to have satisfactory health. These implants are stable, but have a history of, or potential for, clinical problems. These implants have no mobility, and patients do not exhibit any pain or tenderness on palpation, percussion, or function. Crestal bone loss is between 2.0 and 4.0 mm from baseline

readings. The prognosis is considered good to very good[25]. Group III implants show signs of mild to moderate peri-implantitis and compromised health. However, they are also considered a part of the "survival" group. In this group, there is greater than 4 mm radiographic crestal bone, but bone loss is less than 50% around the implant. The prognosis is good to guarded, depending on the ability to adequately intervene, either surgically or non-surgically[25]. The failure group is Group IV. The implants in this group are to be removed due to: (1) pain on palpation, percussion or function, (2) mobility, (3) uncontrolled progressive bone loss, (4) uncontrolled exudate, or (5) more than 50% bone loss around the implant[25]. Although the above groupings provide relatively clear guidelines of success, survival and failure, studies have yet to adopt these terms when publishing results on implants.

The first long-term studies on dental implants published 15 year results with survival rates of 86% and 78 % in the mandible and maxilla respectively[26]. More recently however, studies have found greater survival and success rates of dental implants due to the newer rough surface, resulting in its regular use as a treatment modality for restoring a patient's dentition[26]. Several features of a dental implant are thought to increase its long-term survival and success, one of which is implant length. Most authors consider 10 mm as the minimal implant length for success, and anything less than 10 mm as short[26]. The following section of the review will focus on conventional length implants (10 mm or more).

2.3.1 Conventional Length Implants

One study illustrating the higher survival rates for conventional length implants can be found by Eckert et al. (1998), where a five year cumulative survival rate of 96.3 % was found in 445 patients treated with 631 implants[27]. Similar results were found in a relatively smaller cross-sectional study with 109 subjects, with a mean age of 43.8 years (range 18 to 80), where 372 implants were placed and followed to a mean of 8.4 years. The survival rate of these implants was found to be 95.2%. All subjects had experienced their implant loss before loading. The authors of this study did find that a major risk factor, which had an influence on implant loss, was smoking. All but one subject experiencing a failed implant smoked[28].

Recent longer-term studies however, have failed to show survival and success rates comparable to the high rates found in shorter-term studies. A 16-year follow-up of 162 Straumann implants resulted in a survival rate of 82.94% and a very high post-operative complication rate of 48.03% resulting in what the authors termed as a success rate of 51.97%. Very low long-term success rates were found in this study because the criteria for success differed from the standard Albrektsson criteria as success was defined as being free of any post-op complications over the entire follow-up period[2,29]. Another 20-year study of 145 conventional length machined surface implants 10 mm or greater in length also failed to duplicate what is published in shorter-term studies. The authors found survival rates of 89.5% and success rates of 75.6% at the 20-year mark. However, the authors of this study

concluded that newer implants with rough surfaces should yield more promising long survival and success rates averaging greater than 90%[30]. These higher success and survival rates associated with rough surface implants can be found in a cumulative 4 year study with a success rate of 96.8% of rough surfaced 341 implants[31].

A longer prospective study of 1286 rough surfaces ITI implants with ten year results by Ferrigno et al. (2002) also reinforce Chappuis et al.'s (2013) statement about the success of rough surface implants[26]. This prospective study calculated the 10-year cumulative survival and success rates for the 1286 implants by life table analysis, and the actual survival and success rates for 498 implants after at least five years of functional loading. The actual 5-year survival and success rates of the first 498 implants that were inserted were 97.7% and 95.0%, respectively. The 10-year cumulative survival and success rates were found to be 95.9% and 92.7%, respectively. The cumulative success rate for mandibular implants (approximately 94%) was also more favorable than that for maxillary implants (approximately 91%)[26].

In a systematic review of 16 trials, 1854 implants (617 machined and 1237 implants with roughened surfaces) were evaluated in 771 patients (375 mandibles and 396 maxillae)[3]. During the follow-up period in this review (1, 3 and 5 years) there were 62 implant failures. Thirty-eight of the failed implants had a roughened surface and 24 had a machined surface.

In particular, there were 42 early implant failures (25 implants had a roughened surface) and 20 late failures (13 implants had a roughened surface and two of these fractured)[3].

Another study reporting survival rates greater come from a report of a prospective multi-center investigation, using 461 Brånemark implants to restore partially edentulous arches[32]. At the 10-year follow-up there were 34 reported failed resulting in an overall implant survival rate of 92.6%. The cumulative implant survival rates were 90.2% and 93.7% for maxillae and mandibles, respectively. Marginal bone resorption at the implants was found to be minimal with low (mean = 0.7 mm), and mucosal health was good[32].

Favorable results were also found in a systematic review of 26 studies with a 5 year follow-up[33]. The meta-analysis of these studies, found an implant survival rate of 96.8% after an observation period of 5 years, confirming that high survival rates for implants should be expected[33]. However, the authors did find that there was a high complication rate with implants and the associated restorations. This indicated that even though there are high survival rates with dental implants, complications still exist and intervention may be required[33].

2.3.2 Short Implants

Historically, due to favorable crown to implant ratio, and a larger surface area available for osseointegration, longer implants have been the standard of care when restoring an edentulous site[5]. However, the reduced alveolar bone height associated with post-extraction bone resorption limits the length of implants that can be placed to rehabilitate the edentulous jaw. These height limitations can be overcome with relatively complex surgical procedures, associated with increased patient morbidity and an increased risk of intra and post-operative complications[34]. Recent publications, however support the use of short dental implants as a treatment option to overcome height limitations in order to avoid advanced procedures[34].

One procedure used to overcome the resorbed alveolar ridge includes augmentation using a bone grafting material. This grafting procedure may make it anatomically possible to place a conventional length implant, but at the cost of longer treatment time, greater patient morbidity and a greater financial burden [35]. Another method of overcoming this limitation is by the use of short (10 mm or less) implants, avoiding an extra surgical procedure. In a review by Esposito et al. (2010) on elevation of the maxillary sinus with grafting material, the authors concluded, that "short implants may be as effective and cause fewer complications than longer implants placed using a more complex technique"[36]. In another review on vertical and horizontal augmentation procedures in the mandible, the authors conclude that ''short implants appear to be a better alternative to vertical bone grafting of

resorbed mandibles. As complications, especially for vertical augmentation, are common"[36].

Earlier studies on short implants did not have favorable results[24]. Several reasons have been proposed for the poorer survival rates associated with older short implants placed in the posterior mandible and maxilla. Firstly, machined surface short implants have less bone to implant contact ratio compared to longer conventional implants. Also most short implants are placed in the resorbed posterior region, where the quality of the bone is poorer, especially in type III or type IV bone often found in the posterior maxilla[35]. Finally, the crown to implant ratio for short implants may be unfavorable, which is believed to pose excessive crestal peri-implant bone stress leading to early implant failure[35]. These limitations are now contested, as recent studies have found that peri-implant bone overload is not a result of unfavorable crown to implant ratio[37]. Also, newer rough dental implant surfaces show greater survival rates due to the increases in surface area of the implant allowing for a greater bone to implant contact ratio[34].

According to the literature, there is no objective definition for short implants. Certain authors state that implants under 10 mm in length should be considered short whereas others include 10 mm implants in their definition of a short implant[38,39]. Regardless of the length used to define short implants, they are now considered to have predictable positive outcomes, as reported by several studies.

One report indicating the predictability of short implants, is a multi-center retrospective study over 1 to 5 years of 745 short (7 and 9 mm) implants placed in 273 patients[40]. The authors published a 98.9 % survival rate of these implants[40]. Interestingly, all of the implants in this study that failed did so prior to prosthetic placement. All implants in this study were splinted together, which theoretically decreased the occlusal stress placed on the peri-implant bone[40]. High survival rates of short implants have also been reported in another retrospective study with a 16-year follow-up[39]. In this study, short implants were separated into a splinted and non-splinted group and compared for survival. A total of 453 short (less than 10 mm) implants were placed in 198 patients. The findings in the splinted group resulted in a 97.7% survival rate and a 93.2 % survival rate in the non-splinted group. All implants in this study failed within one year of prosthetic loading and since there was a lower failure rate in splinted implants, the authors stated that splinting short implants may positively influence their survival[39].

Three recent review articles have also supported the use of short implants for the treatment of restoring the resorbed posterior mandible and maxilla. A systematic review by Telleman et al. (2011) on the prognosis of short implants placed in the partially edentulous patient, observed 2611 short implants (lengths ranging from 5 to 9.5 mm), found high survival rates (97.5%) at two years and found greater survival rates in the mandible than in the maxilla. The survival rate of short implants in this review matched the survival rates of conventional length implants[35]. Survival and success rates were also analyzed in a meta-analysis

reviewing two randomized controlled trials and 14 observational studies with a total of 6193 short implants in 3848 patients[5]. With a mean follow-up of 3.2 years, the authors found a cumulative survival rate of 99.1% and success rate of 98.8%[5]. Rough surfaced short implants were also found to have a higher cumulative survival rate than machined surface ones[5]. The authors did state that splinting may not be necessary for short implants as 37.9% of the implants were restored as single crowns and had comparable results to splinted implants[5].

In a more recent review comparing marginal bone levels of 382 short (less than 10 mm) and 258 conventional length implants, the authors found that implant length did not influence crestal bone levels[41]. However, they found that due to the shorter implant length, short implants are susceptible to earlier failure rates. Therefore the authors believe that meticulous maintenance of short implants is essential to increasing their long-term survival rates[42].

The findings from these individual studies and systematic reviews add to the growing evidence that short implants can be placed successfully in the posterior mandible and maxilla, improvements in implant design, and surface topography seems to have lead to the superior survival and success rates of recent short implants. The use of short implant–supported prostheses in patients with resorbed alveolar ridges appears to be a successful

treatment option in the short-term; however, more long-term studies are needed to conclude that these implants are a viable long-term treatment option.

2.4 SINUS ELEVATION

2.4.1 Lateral Window Sinus Augmentation

In the 1960's Boyne had the first report of a maxillary sinus floor elevation[43]. Several years later, Boyne and James in 1980 used autogenous iliac particles as graft material placed in the elevated maxillary sinus for later implant placement. This technique required a window to be made in the lateral wall of the sinus[43]. The Schneidarian membrane lining was lifted and a cavity created into which graft material was placed and allowed to heal for several months. After a few months, blade implants were placed in the newly elevated sinus and then restored. As dental implants have become a more common treatment modality to replace missing teeth, the reduced vertical bone height and insufficient bone volume in the posterior maxilla poses a problem that needs to be dealt with more commonly. Elevating the maxillary sinus therefore is one option in overcoming this problem[44]. The lateral window sinus lift is a commonly used procedure to bypass this limitation with a number of studies confirming its reliability and predictability in terms of implant success and survival.

A recent retrospective study evaluated the survival rate of 65 single implants placed in the grafted sinus[45]. The total survival rate with an average follow-up time of 20 months, was

found be relatively low compared to implants in the non-grafted site at 87.1% with implants placed after the lateral window sinus technique. Second molar sites had the lowest survival rate (78.6%) with the highest survival rate being 90.0% in the second premolar site. The authors found no significant difference between the implants placed immediately, or delayed implants; and no difference with submerged and non-submerged implants. There was however a statistically significant difference in the survival rate of implants where the patient suffered from post-op maxillary sinusitis. The survival rate in cases with maxillary sinusitis was 40.0%, while it was 90.0% in the cases without maxillary sinusitis. The authors concluded that the low survival rate found in this study was most likely directly related to the incidence of maxillary sinusitis and not the procedure itself[45].

The above conclusion by Kim et al. (2013), regarding the influence of sinusitis on implant survival may not have any merit based on a review by Nkenke et al. (2009). This review of 16 articles evaluating sinus augmentation found reports of acute sinusitis in the lateral window technique in as high as 22% of cases, however there was no indication that implant survival rate was influenced by sinusitis[46]. The survival rates of the implants in this review were greater than 90 % with a minimum 12-month follow-up. The only factor that reduced the survival rate of the implants placed in the grafted sinus was smoking, where at 2 years the implant survival rate in smokers was found to be 85.3% and 93.3% in non-smokers. Interestingly, the highest complication found with the lateral window technique was found to be sinus perforation in 19.5% of cases[46]. This complication also did not influence the

integration of the graft or the implants. The authors did conclude however that implant survival may not depend on one single factor, but may be confounded by several different factors – sinusitis and smoking included[46]. Similar conclusions were also made in a review of 43 studies, by Wallace and Froum (2003)[43]. They found the survival rates of implants placed in the augmented sinus using the lateral window technique had an average survival rate of 91.8%[43]. It was reported that there were several factors influencing implant survival, such as the implant surface (machined had more failures than rough surface implants), the use of block versus particulate grafts (block grafts had fewer survived implants than particulate grafting) and the use of a membrane also influenced the survival rate of implants[43]. A third review evaluating over 11 000 implants placed in the grafted maxillary sinus using the lateral window technique found an overall survival rate of 93.8% with at least 3 years in function[47]. The factor having the largest influence on survival rates in this review was the implant surface. Implants with a machined surface (3346 implants) placed in the sinus had a mean survival rate of 86.3% whereas rough surface implants (8303 implants) had a survival rate of 96.7%[47].

Since the lateral window technique is considered to be an invasive procedure, several surgical complications would be expected as a result of the procedure. However, a relatively low incidence of surgical and post-operative complications of the procedure have been reported[48]. As mentioned, the most common surgical complication being the perforation of the Schneiderian membrane[46]. Several studies have evaluated the prevalence of sinus

perforations and the outcomes of these perforations. Barone et al. (2006) perforated the sinus in 25 % of cases in their study, and even though the membrane perforation is thought to allow bacterial infiltration of the graft, Barone et al. (2006) did not find perforated sinuses created any complications during the healing period or influenced the survival rate of implant[48]. In contrast, Hernandez-Alfaro et al. (2007) found that of 1166 implants placed in the maxillary sinus, all failed implants were placed in cases where the Schneidarian membrane was perforated. In this study, 104 cases out of 474 sinus floor augmentations resulted in a perforation (21.9%)[49]. Each perforation was treated using different techniques and materials. The results of this study point toward the notion that the membrane perforation can result in reduced bone formation and a compromised implant survival rate. The authors hypothesize that displacement of the graft material through perforation may lead to transient or chronic sinusitis reducing the survival rate of the placed implants as suggested by Nkenke et al. (2009)[46,49].

A review of six articles, evaluating membrane perforations after a lateral window sinus lift, evaluated the survival rate of implants placed in perforated and non-perforated cases. In maxillary sinus lift cases with perforation of the membrane an 88.6% implant survival rate was found compared to a 98% survival rate, in procedures where the membrane remained intact[50]. The authors did state however that even though there was a lower survival rate in perforated situations, it is possible to continue with the procedure if the perforation is considered small[50].

Even though there is a high success and survival rates associated with the lateral window sinus lift, it seems apparent that complications may negatively influence these parameters.

2.4.2 Osteotome Procedure

As mentioned vertical alveolar deficiency for implant placement in the posterior maxilla was typically overcome with a lateral window sinus lift and tilted implants. In 1986, Tatum proposed overcoming this limitation by augmenting the sinus indirectly through the transalveolar technique[51]. Based on this approach, a ‘‘socket former’’ associated with the appropriate implant size prepared the osteotomy site. Applying vertical pressure to this “socket former” to fracture the sinus floor, allowed for sinus elevation through the osteotomy site. A dental implant was then placed in the prepared site[51].

This technique was followed up by another indirect sinus lift technique described by Summers in 1994. This technique is known as the osteotome technique or the “Summers technique” whereby sets of osteotomes of different diameters are used to prepare the osteotomy site through the edentulous alveolar crest in the maxilla. The Schneidarian membrane was then lifted creating a tenting effect. Since there was no drilling proposed, the osteotome technique aimed to compress the soft maxillary bone and conserve it, in order to achieve better implant primary stability[52].

Although considered a less aggressive procedure than the lateral window approach, the main disadvantage of the osteotome technique is not being able to directly detect a sinus perforation as the procedure is done indirectly[53]. Studies have shown that, although there is the risk of membrane perforation, in the ideal case, a sinus can be elevated using the osteotome technique, as much as 5 mm[54].

Findings from a review article based on 19 studies and over 4 000 implants, implants placed using the transalveolar technique found a 3-year survival rate of 92.8% and 3.8 % incidence of sinus membrane perforation[8]. Slightly more positive results were calculated in a meta-analysis revealing an implant survival rate of 96.0% at 3 years with the transalveolar technique[55]. A third review of 3131 implants and 1822 patients aimed at assessing implant survival rates after the osteotome mediated sinus procedure, and results showed a survival rate of 95 % at 3-year follow-up[56]. After analysis of surgical complications, the authors found that there was no difference in membrane perforation rate between cases treated using and not using grafts. They also found that the incidence of membrane perforation was lower than perforation rates reported for the lateral approach[47]. Perforations may have gone unnoticed due to the difficulty in visualizing the membrane through the indirect approach[57].

The osteotome technique originally used bone graft material in the space made after lifting

the membrane. The grafting material is slowly and incrementally pushed into the sinus cavity until the desired tenting effect is achieved. The use of grafting material in the osteotome technique is controversial due to the possibility of graft failure and graft escape into the sinus with a perforated membrane. Therefore many studies have evaluated the outcomes of radiographic bone gain and implant survival placed in the posterior maxilla using the osteotome technique, with and without bone graft material[57].

Si et al. (2009), for example, randomly assigned 45 patients to two groups using the osteotome technique with or without graft material[54]. The authors found implant survival rates of 95.2 % (with graft) and 95.0% (without graft). Both groups also had similar radiographic bone gains and implant survival[54]. A larger study of 252 implants placed in conjunction with the osteotome technique with and without bone graft resulted in a survival rate of 97.4% with a mean of 3.2 years follow-up[58]. These findings indicate that the use of a graft material may not be required when using the osteotome technique. This is supported by findings in a retrospective study by He et al. (2011) that evaluated the clinical results associated with implant placement using the osteotome technique without grafting. The authors found 100% implant survival and a mean height of newly formed bone at implant sites to be 2.5 mm[59]. Similar positive results were found by Fermergård et al., (2009) with a cumulative survival rate of 94% at 3 years, using the osteotome technique without bone grafting[53].

Therefore, it can be safely concluded that implants placed with the osteotome technique seem to have similar survival rates to those of implants which are conventionally placed in the partially edentulous maxilla or those placed with the lateral window sinus lift. Also, the application of grafting materials has no significant advantage in terms of clinical success and findings seem to indicate that the rate of membrane perforations are less than those found in the lateral window technique.

2.5 TIMING

2.5.1 Implant Placement Timing

Minimizing the number of surgical interventions, reducing patient morbidity and preserving alveolar bone after an extraction, are goals of implant therapy. Attempts at achieving these goals began as early as the 1970's where immediate placement of a dental implant in an extraction socket was attempted[60]. According to a consensus report from 2004, regarding the timing of implant placement, a new classification description was developed, using numerical descriptors reflecting the conditions of both the hard and soft tissues[61]. This report categorized the classification into 4 types: " Type 1 placement: the implant is placed immediately following the extraction of a tooth; Type 2 placement (immediate –delayed approximately at 2 weeks): the implant is placed in a site where the soft tissues have healed and mucosa is covering the socket; Type 3 placement (8weeks) the implant is placed in an extraction site at which substantial amounts of new bone have formed in the socket; and Type 4 placement: the implant is placed in a fully healed ridge "[61].

Although immediate implant placement has many advantages, as mentioned previously, several factors may adversely affect it. For example, the morphology of the extraction site, the presence of infection, the absence of keratinized tissue, thin tissue biotype, lack of soft tissue closure and dehiscence of the flap over the site all adversely affect immediate implant placement[62].

Several studies have evaluated and compared the survival and success rates of immediate to immediate-delayed and delayed implants. In a retrospective study of 110 immediately placed implants without bone grafting; 72 patients – 21 of which were smokers were followed up for 1 year[63]. Teeth were extracted due to multiple reasons (endodontic, trauma, periodontitis etc.). The results of this study found that none of the patients experienced intra-operative or immediate post-operative complications. At osseointegration check (3 months), however 4 implants had clinically detectable mobility with associated bone loss. Therefore the 5-year survival rate of immediate implants in this study was found to be 95.5%[63]. Another study comparing an immediate implant group to a delayed implant group found similar positive results with the immediately placed implants with a 92% survival rate[64]. In this study, 50 patients were enrolled into two groups (immediate and delayed). Bone grafting was used along with a resorbable membrane at the time of implant placement. Although two implants failed in the immediate group, there were no statistically significant differences for prosthesis and implant failures between the two groups[64]. Another study by

Block et al. (2009) comparing immediate versus delayed implants found that, two years after loading, no statistically significant difference could be found between the two groups in terms of survival or success[65].

In a randomized control trial reviewing 20 implants placed immediately and 20 delayed implants in the anterior maxilla, the authors found that after 24 months there were no significant differenced between the two groups in survival (100% for both groups) and in crestal bone loss around the implants[66]. A similar study with fewer subjects by Palatella et al. (2008) evaluated nine immediate implants and compared them to nine immediate-delayed implants placed 8 weeks after extraction[67]. The authors found no significant difference two years after implant placement when comparing survival rates, complication rates, and marginal bone levels after two years[67].

When comparing delayed-immediate and delayed implants, a study with a follow-up of 5 years after functional loading resulted in survival and success rates greater than 90% for both groups[68]. The statistical analysis concluded that after 2 and 5 years there were no statistically significant differences in implant failures or complications and marginal bone level changes between the two groups. After 5 years, however, there was a significantly higher number of complications in the immediate-delayed implant group[68].

In a meta-analysis of 270 patients enrolled in 7 randomized controlled trials, Esposito et al. (2010) concluded that with all the data collected there is still a lack of sufficient evidence to determine possible advantages or disadvantages of immediate, immediate-delayed or delayed implants. The findings in their review do suggest that immediate and immediate-delayed implants seem to be at a greater risk of implant failure and complications than delayed implants[69]. However, a more recent systematic review of twenty studies concluded that immediate implant placement following tooth extraction might be a viable alternative to delayed placement, with careful case selection[60]. According to Ortega-Martinez et al. (2012) the decision regarding the timing for implant placement, in relation to tooth extraction, "must be based on a proper understanding of the structural changes that occur in the alveolar process following the loss of the tooth"[60]. Therefore with proper case selection immediate and immediately delayed implants are predictable treatment options reducing patient treatment time.

2.5.2 Loading Times

As can be seen with one of the rationales behind placing immediate implants, minimizing treatment time is important for the patient. Conventional implant loading requires successful osseointegration of the implant resulting in waiting times sometimes as long as 4 to 5 months[70]. This would result in delayed restoration of phonetic and masticatory function. However, over the years different implant loading protocols have been developed and adopted resulting in quicker restoration of the implants[70]. Loading times can be categorized

into 4 major categories: "1) Immediate restoration which refers to the insertion of a restoration within 48 hours of implant placement but not in occlusion with the opposing dentition; 2) Immediate loading when the restoration is placed in occlusion with the opposing dentition within 48 hours of implant placement; 3) Early loading which is defined as a prosthesis being placed 48 hours after the implant placement but not later than 3 months afterward and; 4) Delayed loading which is defined as restoring the implant 3 months after implant placement"[71].

Historically, the idea behind delayed loading was to avoid any micromovement of the implant during the osseointegration phase[71]. It is thought that micromovements of as little as 50 to 100 microns can result in fibrous union, instead of osseointegration of the implant ultimately resulting in implant failure[72]. Many studies have compared the different loading protocols and evaluated the survival and success rates of the loaded implants and have found mixed results.

A recent randomized controlled study evaluated the 2-year success rates of 307 implants, which were divided into three groups: 1) Implants with an immediate restoration; 2) Implants with immediate loading and 3) implants with delayed loading[70]. All implants were placed in the mandible with a minimum insertion torque value of 30N/cm. The results illustrated that the overall cumulative survival rate in groups 1 and 3 were 100% whereas,

there were 7 implant failures in the functionally loaded immediate group, resulting in a survival rate of 93.26%. The implants that failed in this group, failed within the first 7 weeks, but were successfully replaced with a second implant loaded conventionally. Evaluating radiographic bone levels, the authors found no significant difference between the 3 groups, concluding that non-functional immediate loading of dental implants placed with the appropriate insertion torque values have comparable outcomes compared to those loaded conventionally up to 2 years[70].

In another study by Donati et al. (2008) with 139 subjects, reviewing the results of different loading protocols for implants placed in the second pre-molar position, where immediately loaded implants were compared with conventionally loaded (3 months) ones for 1 year[73]. All implants were functionally loaded and placed with a minimum torque of 20N/cm. The results found that the immediate group had a survival rate of 95% at 1 year, and the conventional group had a survival rate of 100%. There was no difference found in the mean marginal bone levels between the two groups at 1 year. However, the fact that the immediate group had failures at year 1 follow-up leads to the assumption that functional loading of immediate implants may need to be delayed until osseointegration has taken place[73].

In contrast to the findings in the Donati et al. study (2008), BarsGüncü et al. (2008) reported differing results in a split-mouth design comparing one immediately loaded implant with one contralateral conventionally loaded implant replacing first mandibular molars with a 1-year follow-up. All implants in this study were functionally loaded, had high primary stability (as measured by the implant stability quotient) with no baseline difference between contralateral sites. Of the 24 implants placed in both groups, there was a single implant failure in the immediate group. However, there were no statistically significant differences found between the two groups in survival or success rates. The success rates of both groups were 100%. Although there was an extremely small sample size in this study, the authors concluded that immediate functional loading of implants had comparable results to delayed loading of implants at 1 year [74].

A split mouth randomized controlled study by Cannizzaro et al. (2009) compared single short 7 mm implants, placed with a flapless technique, immediately occlusally loaded to single short implants loaded at 6 weeks with a 5 year follow-up[75]. Thirty participants were originally included in the study. The authors found no baseline differences in the bone quality, implant diameter and position between the two groups. A minimum of 40 N/cm torque was required prior to loading. In total, two implants failed (one in each group) within the first two months after loading. There were no statistically significant differences for bone levels at loading and after 6 months of loading between the two groups. Even though there were a limited number of subjects in this study, results indicate that immediate and

early loading of even short implants can provide favorable results [75]. Similar conclusions were suggested by Merli et al. (2008) in a randomized controlled trial comparing implants placed with a flapless procedure and restored immediately or early loaded (6 weeks) implants[76]. The authors state that "placing dental implants in conjunction with nonocclusal immediate loading in select patients can provide excellent clinical results"[76].

A 1-year prospective randomized-controlled study by Zöllner et al. (2008) comparing immediate and early loading of dental implants also found favorable results. Both immediately non-functionally loaded implants and early (1 month) non-functionally loaded implants, placed in posterior sextants (premolar and molars areas) supporting single crowns/partial bridges had survival rates of 98% and 97% respectively. The results suggested that with appropriate case selection, early and immediate non-functional loading of implants is an appropriate restorative protocol[77].

In accordance with the previously mentioned studies, the conclusions of a review of four randomized controlled trials by Esposito et al. (2012) found insufficient evidence to conclude whether there is a difference between immediate and early loading in survival and success rates[78].

With a cumulative review of 26 randomized controlled trials including greater than 1200

patients comparing immediate, early and conventional loading of implants, Esposito et al. (2012) concluded that the low failure rate of both prostheses and implants in all the reviewed trials indicate that there is still insufficient information to draw definitive conclusions about the timing of early loaded implants. The only statistically significant difference in the meta-analysis was a small reduction in crestal bone loss associated with immediate loading compared to conventional loading. This difference however was too small to have any clinical significance [78].

In a more recent review by Engelhardt et al. (2014) evaluating 10 randomized controlled trials, the authors found an annual failure rate of 3.3% for immediately loaded implants whereby 17 of 520 immediately loaded implants failed at or prior to the 1 year follow-up. Similarly, 6 of 365 conventionally loaded implants failed at the 1-year follow-up, resulting in a 1.6% annual failure rate of conventionally loaded implants[79]. However, the annual failure rate for both conventionally and immediately loaded implants dropped to 0% at the 2nd, 3rd and 5-year interval indicating the 1st year seems to be the at highest risk for the survival of an implant. The meta-analysis revealed no significant difference between the two loading protocols [79].

In the same review, the authors found that there was no overall significant difference in the mean differences in marginal bone level changes between immediately loaded and

conventionally loaded implants. The cumulative marginal bone level difference between immediately loaded and conventionally loaded implants was 0.02 mm after the first year 0.08 mm after the second year and -0.10 mm after the third year. There was however, a statistically significant difference at the year 5 follow-up of -0.30 mm in favor of the conventionally loaded implants at the 5-year time interval. Overall, the weighted mean difference for all 5 years was 0.01 mm and therefore not statistically significant [79].

The authors of both meta-analysis have similar conclusions in that there is a limited number of data from randomized controlled trials with at least 1-year follow-up in respect to immediately loaded implants to make a definitive conclusion in regards to their predictability[78,79].

2.6 SPLINTING

Splinting teeth in dentistry is defined as "the joining of 2 or more teeth into a rigid unit by means of fixed or removable restorations or devices"[80]. According to Grossman et al. (2005) splinting teeth has been indicated in the following cases: 1) To treat mobile teeth affected by secondary occlusal trauma; 2) To provide stability after periodontal treatment for mobile teeth affecting a patient's comfort or function; 3) To prevent relapse after orthodontic treatment and; 4) To replace missing teeth[80]. The reasons for splinting implants, which are immobile, differ from the indications for splinting teeth. Implants do not move

when forces are applied to them. Microfractures are thought to occur in the bone from excessive load of the peri-implant tissue, which lead to bone loss, prosthetic complications and mechanical failure [81]. Therefore, splinting implants together would, in theory, distribute forces more evenly between implants and minimize the stress applied to the peri-implant bone and restorations. Several studies have attempted to illustrate the favorable long-term outcome associated with splinting implants, but results are mixed.

A prospective clinical study of 660 subjects with 1956 machined surface implants, for example, compared different types of implant restorations[82]. The authors placed 1,212 implants in the maxilla and 744 implants were placed in the mandible. The implants were restored with 810 restorations; 235 were single crowns, 166 were supported by implants and teeth, and 409 were free standing implant-supported fixed partial dentures. The cumulative survival rate of all implants was 91.4% and 95.8% for all restorations over a period of 16 years. The splinting of implants to teeth resulted in a cumulative survival rate of 93.6%. The authors concluded that splinting implants did not have a significant effect on the survival of implants[82].

Similar conclusions were made by Nissan et al. (2010), stating that splinting implants had no positive effect on peri-implant bone levels or prosthetic success[83]. In fact, the authors found that splinting increased cervical stresses and did not prevent prosthetic failure. This

study however, applied twenty-kilogram non-axial forces to splinted implants with varying crown to implant ratios in a photo-elastic block[83].

Contrasting results however were reported by Bergqvist et al. (2010) using finite elemental analysis to analyze stress levels and loading on implants in the maxilla[7]. The authors analyzed stimulated bite force load on splinted and unsplinted implants to determine whether the splinting made a difference in bone loss associated with the restoration. In both groups, a bite force of 300 N was applied from various directions (angled and vertically). The authors stated that they found that splinting reduced the stress levels in the peri-implant tissue, especially when exposed to angled forces[7].

Looking at the benefits of splinting short implants, a retrospective study by Mendonca et al. (2014) evaluated the survival and success rates of short splinted and non-splinted implants with up to 16 years follow-up[39]. The implants placed were all 10 mm and shorter and the subjects in this study were divided into a splinted and non-splinted group with a mean follow-up of 9.7 years. Of the 219 splinted implants, 5 failed resulting in a 97.7% survival rate, with 16 of 234 non-splinted implants failing resulting in a 93.2% survival rate. There was no statistically significant difference in the marginal bone loss around implants in either group. According to the authors, the survival of splinted implants was not associated with any variable; whereas the non-splinted implants had a higher risk of failure in men and

when implants shorter than 10 mm were used. This indicates that short implants under 10 mm's may benefit from splinting, however splinting may only have minor benefits[39]. Another systematic review on short implants, found that splinting of short implants may not be necessary as single short implants had success and survival rates comparable to splinted short implants. Therefore the review concluded that the prognosis of short implants depends more on bone quality and surgical protocol instead of prosthetic features such as splinting[5].

In another review by Grossman et al. (2005), it was found that splinting posterior implants does enhance the stability of forces coming from a mesial and distal direction and less on forces acting in a buccolingual direction [80]. Hence, splinting implants have minor benefits compared to non-splinted implants, but there are clear disadvantages to splinting implants as well. A major advantage of non-splinted restorations is the fact that patients have better access to maintain appropriate oral hygiene. Splinted restorations exclude the use of dental floss and make it difficult for the patient to maintain appropriate proper oral hygiene[80]. It is suggested that fabricating easy access to the interproximal surfaces is required when restoring with a splinted restoration. This review concludes that as long as occlusion is stable and canine guidance is present, multiunit single quadrant restorations do not need to be splinted[80].

2.7 PRIMARY STABILITY

Successful implant integration is paramount for implant survival and success. This depends on several factors, and it is thought that adequate primary stability of an implant is a basic requirement for implant success. Primary stability is associated with the mechanical engagement of an implant with the surrounding bone [72]. The factors that affect primary stability include bone quantity and quality, implant design, and surgical technique[84]. However, up to date, there is no consensus on an optimum insertion torque or implant stability quotient (ISQ) score value which depict primary stability.[63]. Since optimal primary stability is not well defined some consider values greater than 32 N/cm to be an indication of adequate primary stability [85]. Therefore adequate primary stability is achieved when the implant is "well- seated" in the bone, which then allows the implant to adapt to the host bone until secondary stability is achieved [72].

Bone quality is often referred to as the amount of cortical and cancellous bone present in the alveolus[72]. The bone quality is assessed radiographically and during implant osteotomy site preparation. Bone quality has been classified into four different types described by Leckholm and Zarb (1985): Type 1 = entire jaw is comprised of compact bone; Type 2 = a thick layer of compact bone surrounds a core of dense trabecular bone; Type 3 = a thin layer of cortical bone surrounds a core of dense trabecular bone of favorable strength; Type 4 = a thin layer of cortical bone surrounds a core of low density trabecular bone[72,86].

One of the main risk factors for low insertion torque values and subsequently implant failure is poor bone quantity and quality (Type 4). Trabecular bone could be associated with excessive bone resorption and healing impairment compared with higher density bone [21]. This can be seen in the higher survival rates of implants placed in the mandible compared to those placed in the maxilla[32,87]. Bone quality has been considered as the basic cause of this difference. In the posterior maxilla, type 4 bone is more commonly found than the thicker type 1 or 2 found in the mandible [88]. Achieving high primary stability or high insertion torque values is difficult in type 4 or soft bone.

These differences can be seen in a clinical study of 85 patients with 158 implant sites indicating a strong correlation between bone density and dental implant stability[84]. Miyamoto et al. (2005) demonstrated that dental implant stability is positively associated with the thickness of cortical bone thickness assessed radiographically and intrasurgically[89]. Both papers found that greater primary stability was achieved in the mandible due to greater bone density compared to the maxilla.

As mentioned, primary stability is thought to positively influence implant survival, and part of the reason is due to the micromotion that could occur from a lack of stability. Trisi et al. (2009) evaluated the part stability plays in implant survival and its relationship with insertion torque. One hundred twenty implants were placed in bovine bone samples of three

different bone density categories: hard, normal and soft. Insertion torque was evaluated at five categories (20, 35, 45, 70 and 100 N/cm). The authors found that in soft bone, the implants could not be placed at an insertion torque of 35 N/cm's or higher and found that the higher the insertion torque, then the lower the level of implant micromotion. This meant that high micromotion was consistently found in soft bone, which could explained the lower survival rates found in the maxilla[90].

Insertion torque and host bone density are not the only parameters that influence primary stability, implant geometry and surface features also play a role. A report by Dos Santos et al. (2009) compared rough surface and machined implants as well as cylindrical and conical shaped implants[85]. It was noted that, surface roughness leads to a higher friction coefficient and therefore higher insertion torques and primary stability[85]. Therefore acid-etched (rough surface) implants had higher insertion torque values than machined surface implants. The authors also found that conical implants were placed with greater primary stability that cylindrical implants with similar surfaces. The thread geometry of the conical implant was thought to increase the bone to implant contact ratio. Therefore rough surfaced conical shaped implants had the highest insertion torque value, and provide the greatest survival rates[85].

Akkocaoglu et al. (2005) also reported that wider neck implants result in higher primary

stability compared to regular diameter implants[91]. Javed et al.'s (2013) review also found that aside from the quantity and quality of bone and design and geometry of the implant, the surgical technique plays a role in primary stability during implant placement. This review states that several surgical factors play a role in achieving adequate primary stability. For example are: 1) an atraumatic surgical technique and 2) using an osteotome condensing technique, which increases primary implant stability by increasing the bone density [72]. Javed et al. (2013) conclude that the establishment of good primary stability is an important factor to establish during implant placement. The evidence indicates that primary stability is influenced by bone density and quality, implant shape, design and surface characteristics and surgical technique[72].

Chapter 3: AIM OF THE STUDY

The aim of this manuscript is to evaluate the 5-year survival and success rates of implants placed in the posterior maxilla with the osteotome technique without added bone grafting and to evaluate that short implants (less than 10 mm) can be used to adequately treat the atrophic maxilla and mandible.

It is hypothesized that short implants can be adequately used to treat the posterior maxilla and mandible, with success and survival rates comparable to published results from conventional length implants.

Chapter 4: SURVIVAL AND SUCCESS RATES WITH THE INDIRECT SINUS ELEVATION TECHNIQUE WITHOUT BONE GRAFTING: A RETROSPECTIVE STUDY WITH 5-YEAR FOLLOW-UP

4.1 INTRODUCTION

In a large percentage of implant scenarios, the pneumatization of the sinus may limit implant placement [92]. The lateral window sinus elevation is a well-established protocol to gain bone and allow implant placement. However, it is a time consuming and complicated procedure that carries a risk of graft dislodgment and infection, as well as of membrane tearing in about 20% of cases [58,93,94] . Thus, a number of studies have aimed at simplifying the augmentation procedure.

Tatum (1986) was the first to propose a crestal approach for sinus floor elevation with subsequent implant placement in 1986 [95] . Summers (1994) later described a trans alveolar sinus elevation procedure using a series of osteotomes, with bone added apically to the osteotome site, termed the osteotome technique, also known as the osteotome sinus floor elevation (OSFE) [96] . There have been variations on the protocol for this procedure including the optional use of bone graft material and whether any drilling of the site is performed [97] . Numerous studies have reported survival rates and are the subject of systematic reviews however there are fewer studies without added bone graft and reporting on both survival and success rates, in particular on short implants and in sites with RBH less

than 5mm [56,58,98]. Nedir et al. (2006), with a sample size of 25 implants, demonstrated bone graft material was not necessary with OSFE, which has recently been shown to be successful in a prospective study even with short residual bone height (RBH) below 5 mm[97,99]. In addition, a preliminary study comparing the OSFE with and without bone grafts demonstrated no significant differences and showed that bone forms spontaneously in the absence of a bone graft following OSFE [100].

The challenge to bone height gain using the osteotome technique is the ability of the membrane to be elevated without tearing it. One cadaver study reports this limit being about 3-4 mm [101]. In living patients, however the membrane may be more pliable allowing greater elevation of the membrane. In addition, using multiple adjacent implants may feasibly produce a broader tenting effect leading to a greater elevation of the membrane, as other studies have reported increased elevation if visualization is included during the osteotome technique [102].

Another reported issue is benign paroxysmal vertigo, which has been described following the osteotome technique in case reports. Treatment of these benign cases using the Epely maneuver has been shown to be successful but no overall incidence of vertigo has been reported in case reports[103,104]. The aim of the present retrospective 5-year longitudinal study, using clinical and radiographic data was to evaluate the survival and success rates

from a sample of 926 implants following sinus elevation using the osteotome technique without bone grafting. Furthermore, the clinical performance of short implants placed in basal bone less than 5 mm was separately evaluated. This paper also intends to show that complications including vertigo and infection are rare with the osteotome technique.

4.2 MATERIALS AND METHODS

4.2.1 Implant Database and Patient Sample.

From a database of implants placed by one of the authors (DF) in private practice between 1998 and 2010, a total of 6244 implants were available for data evaluation. Of the 6244 implants, 926 were placed using the osteotome technique with no added bone material in 541 patients (279 females, 262 males). Patients with less than 2 mm residual bone height at multiple adjacent edentulous sites and those with less than 4 mm residual bone height at a single edentulous site were excluded from undergoing the osteotome procedure. Patients classified as American Association of Anesthesiologists (ASA) status 3 or above were also excluded from this surgical procedure. In cases with edentulous maxillary posterior sextants where the basal bone was between 2 and 5 mm and when multiple teeth were missing, patients were given the option of short splinted implants using the osteotome technique or longer implants placed following a lateral window sinus elevation. If the residual bone height was 4 mm to 6 mm in a single edentulous site then either an 8 mm or 10 mm implant was placed using the osteotome technique. In these cases a single non-splinted implant was placed whereas 6 mm implants were never restored as non-splinted. In multiple edentulous sites, where the anatomy of the sinus floor or the elasticity of the Schneidarian membrane

limited the amount of sinus elevation using the osteotome technique, 6 mm implants were used. Single edentulous sites with less than 3 mm of residual bone would be treated with a lateral window sinus elevation. All patients were made aware of risks with the osteotome technique including infection and vertigo and the limited published data for short implants in short residual bone. Patients were advised to report any post-operative problems. The patients ranged in age between 18 and 88 years old, with a mean age of 60 years.

4.2.2 Surgical Osteotome Technique Protocol

All cases were done with a sterile field protocol including pre-treatment rinse with 0.12% chlorhexidine, a draped sterile field per Branemark's original protocol using sterile saline irrigation[14]. The patients were conscious during the procedures and were given local anesthetic with the option of mild oral sedation (1 mg Ativan or 0.25 mg Halcion). Patients with no penicillin allergy were given 2 grams of amoxicillin 1 hour pre-operatively, and prescribed 250 mg amoxicillin, three times a day, for 7 days post-operatively. Patients allergic to penicillin were given Clindamycin 600 mg, 1 hour pre-operatively, followed by a post-operative prescription for Levaquin 250 mg, to take orally every 24 hours for 6 days. A full thickness flap was elevated followed by a 2 mm twist drill (W. & H. Implant med. Hatfiel, PA , USA), drilled 1-2 mm short of the sinus floor. A narrow tapered tip osteotome (Aseptico Lerex p2) was used to create the initial fracture of the sinus floor extending only 1 mm into the sinus floor. This was then followed by straight walled concave tipped osteotomes (Aseptico Lerex) increasing in width increments from 2.8 mm, to 3.3 mm and finally to 4.0 mm, if a wide implant was to be placed. The concave tip was used to displace

autogenous bone apically from the osteotomy site as the osteotome was advanced (Table 4.1). The osteotome site was then sounded with a depth gauge smaller than the last osteotome in order to test for rebound from the elevated soft tissue membrane. If resistance was felt or rebound visualized, then it was deemed to have no tear but if no resistance, the site was recorded as having a membrane tear. The implants reported in this study were then placed into the osteotomy site with no bone graft material added apically. Where possible partial dentures were adjusted or not worn. In fully edentulous cases the complete upper denture was relined with soft liner. All cases were put on a recall for annual follow-up and patients who did not return were tracked as "failed to show".

4.2.3 Implant Types, Sites and Restorations

The majority of implants placed were Straumann Tissue Level implants with a body diameter of 4.1 mm or 4.8 mm and a regular neck (RN) or 4.8 mm wide neck (WN) configuration, respectively (Figure 4.1). Tapered Nobel Biocare Replace Select implants with machined 1.5 mm collar were also frequently used. A third group of implants considered "other" were also placed involving different implant systems. The same examiner (DF) placed all implants. Bone loss was evaluated radiographically between the base line (3 months after implantation) and the 12-month follow-up and subsequently at 12-month intervals. The values were normalized to the neck of the respective implant so that the smooth-rough interface was the baseline. A total of 926 implants were placed using the osteotome technique. The data was further separated to 792 Straumann and 90 Nobel Biocare implants. There were 44 "other" various implants (Figure 4.1, Table 4.2). The

implants were all placed in the posterior maxilla (Figures 4.2, 4.3 and 4.4). Implants were considered short if they were 6 mm or 8 mm long in the Straumann Tissue Level system and 10 mm long in the Nobel Biocare Replace Select system with a machined 1.5 mm collar left above bone (i.e. functional implant length of 8.5 mm)**.** When multiple adjacent implants were placed, the prosthetic plan was to splint the crowns (Figures 4.2 and 4.4).

Bone gain was determined by comparing the height where bone was crossed, taken from the mid body of the implant once inserted and measured to the apical extent of the implant on a radiograph taken with a standard alignment device. The apex of the implant was used as a reference point for total bone gain since studies have shown the total bone displaced beyond the implant apex is eventually lost and theoretically is of no functional value since it does not support the implant. Radiographs were taken and interpreted by the same examiner that placed the implants, using a periapical and Dexis proprietary parallel film holder (Hatfield, PA USA). The dexis radiograph software program which measures calibrated to sensor dimensions, was used to measure bone loss looking at the smooth/rough interface (beyond 2.8 or 1.8 mm collar on Straumann and beyond 1.5 mm collar on Nobel Biocare Replace). All bone loss measurements were taken from the coronal aspect of the implant shoulder to the coronal aspect of the alveolar crest at the most apical level, regardless of mesial or distal position thus measuring the side with the greatest bone loss. The amount of exposed rough implant surface would indicate the amount of bone lost from time of implant placement.

4.2.4 Implant Stability

The insertion torque was recorded using the same electric torque device (W. & H. Implant med, Bürmoos, Austria), used for insertion of the implant. Results were recorded in increments of 5 N/cm from 10 N/cm to 40 N/cm. The implants that needed >45 N/cm torque to fully seat were removed and the site re-prepared to prevent bone compression such that all implants were placed with 40 N/cm torque or less. Implants requiring removal were done with a counter torque technique or an explant device. All cases (n=926) were evaluated at 1-week post-operatively for signs of infection or mobility. The implants seen at three months, were tested for clinical soft tissue health, radiographic integration, and stability by a forward - reverse torque test of 35 N/cm with a manual strain gauge. Implants that were not obviously loose and passed radiographic tests but rotated slightly at a torque of 35 N/cm were given another three months to allow bone to mature and these cases were listed as “delayed” in the results section.

4.2.5 Definition Criteria

Implant survival was defined as an implant deemed osseointegrated after the torque test and subsequently restored. Implant success was defined as an implant with less than 1 mm crestal bone loss recorded at the 12-month recall exam and every recall exam thereafter. Major adverse events such as infection, loss of implant and vertigo were recorded. Clinical scores for inflammation were given using the following criteria: A score of 0 = no bleeding on probing; 1= light single point bleeding on probing but healthy gingival appearance; 2 = moderate bleeding on probing in multi-sites; 3 = profuse immediate bleeding and obvious

inflammation in tissues; 4 = suppuration and inflammation. If an implant had a clinical inflammation score of 2 or more with greater than 1 mm of progressive bone loss, interventions such as open flap debridement or gingivectomies were undertaken to control peri-implant bone loss.

4.2.6 Statistical Analysis

Implant survival was analyzed by calculating the percentage of surviving implants as a function of time. The success rate was analyzed as the percentage of implants fulfilling the success criteria independent of the observation period. The chi-squared test was used to test the relationship between categorical variables such as implant height (short/conventional) and success (yes/no). We applied Fisher's Exact test if assumptions for chi-squared test were not met. The effect of implant length and residual bone height on survival rate was analyzed at the implant level using the Cox Proportional Hazards Model. The Kaplan Meier analysis and Log Rank test were used to analyze the equality of survival functions of the three-implant types. The significance level was 5% (95% confidence interval) using SPSS (version 20.0) statistical package.

4.3 RESULTS

4.3.1 Implant Survival and Success Rates

Among the 926 implants placed with the osteotome technique using no added bone graft, there were 530 short implants (Nobel Biocare and Straumann) in total with 467 evaluated at 12-month post-prosthetic loading; 396 were splinted and 71 were single unit crowns (4.2). There were a total of twelve failures noted resulting in a cumulative survival rate of 97% after 5 years (Table 4.3). Six of the failures were pre-prosthetic and six failed after prosthetic connection. Four of pre-prosthetic failures occurred under provisional dentures in different patients or were short implants placed with very low insertion torque (10 N/cm). The one

sinus tear reported was also among the failures (with a short 6 mm implant). Results of the Kaplan Meier (Log Rank) test found that the survival rate of the 3 groups of implant types did not differ significantly. Overall, however, the 5-year survival rates were found to be 97% for Straumann Tissue Level, 95% for Nobel Biocare Replace Select, and 93% for "Other" implants, respectively (Note: Although the individual contributions of the brands are equal to or less than 97 %, the overall value survival rates are 97 % because 85.5 % of the implants used in this study were Straumann implants which had the greatest survival rates). Implant length was assessed and the hazard ratio for conventional length implants was found to be 80% less than for short implants revealing a slightly higher risk of failure for short implants which was not statistically significant (p-value for beta coefficient in the Cox regression model is more than 0.05). The probability of failure during the first year was less than 0.0001% for Straumann implants while it was 0.1% for Nobel Biocare implants and 0.6% for "other" implants. The risk of failure at the end of year 1 (given the implants survive during the first year) was <0.0001% for Straumann and Nobel Biocare implants and 1% for the "other" implants.

Success rates using a threshold of less than or equal to a total of 1 mm bone loss for the two main implant systems used (Straumann and Nobel Biocare) was 97.7% for Straumann implants and 87.5 % for Nobel Biocare implants for a cumulative success rate of 95.4% (Table 4.4 & 4.5). There was no statistically significant relationship between implant companies and its success (Chi^2 =90.8, df=2; p-value<0.00). Also, when comparing the

cumulative success rate of short implants with those of conventional length, short implants had a success rate of 97.1% and conventional implants had a success rate of 93.1 %, which was statistically significant (p-value=0.004) (4.6). Odds of success in short implants in this study was found to be 2.5 times higher than normal implants (Odds Ratio= 2.5; 95% CI= 1.3-4.8.)

An additional delay of three months was required for seven implants to pass the integration torque test but at six months all seven implants had achieved clinical stability to 35 N/cm and radiographic evidence of solid implant-tooth interphase was evident. None of these delayed implants failed during subsequent follow-up.

4.3.2 Medical Complications

In the present study, we recorded adverse events using the osteotome technique including vertigo and infection. In the 926 implants placed there were no reported cases of benign paroxysmal vertigo and only one post-surgical infection in the sinus (0.1%).

4.3.3 Post-surgical Interventions

The majority of implants throughout the follow-up period (85%) had light to no bleeding on probing (score 0-1) indicating minimal to no inflammation. However, 8% of implants had significant inflammation with a bleeding score of 2 or more at some point during the follow-up period. A gingivectomy or flap procedure was carried out to reduce peri-implant

pocket depth in 22 of 926 cases (2.4%). There was a statistically significant difference (p-value<0.001) in the success rates of implants requiring post-surgical intervention (87.8%) compared to those that did not require intervention (96.8%). The odds of success of implants that did not require intervention were found to be 4.2 times higher than those requiring intervention (OR=4.2; 95%CI=2.2-7.9). When controlling for all other variables, odds of success was actually 5.7 times higher in not repaired implants than the repaired ones (OR=5.7; 95% CI= 2.7-11.8).

4.3.4 Insertion Torque

Insertion torque data was recorded from 2005 onwards and not available for all earlier inserted implants. From the total number of 926, there were only 600 Straumann implants and 67 Nobel Biocare implants from which data on insertion torque was available. Insertion torque recordings taken on this subset revealed that 3 implants failed when insertion torque was 20 N/cm or higher (3/455 or 0.66%). However when torque was under 20 N/cm there were four failures (4/212 or 1.89 %). There were an additional seven implants placed with a torque of under 20 N/cm that were not stable to 35 N/cm torque test at 3 months. These required extended healing time but all passed a 35 N/cm torque test and were deemed integrated at 6 months. Each of the sites that required extended healing were short implants placed in short residual bone where osteotome sinus gain was between 3 and 5 mm. The relationship between success and torque was not statistically significant as the success rate for implants placed with a torque of under 20N/cm was 96.7% and 97.1% for those placed

in torque 20 N/cm and greater. Due to the small number of implant failures, Cox analysis was not doable when assessing torque in relation to survival. However, comparing overall mean torque between survived and failed implants, no significant difference was found.

4.3.5 Sinus Elevation Measurements

Of the 926 implants, 607 were placed with 1-2.9 mm sinus floor elevation and 319 were placed with 3-5 mm elevation. Of interest is the subset of 209 implants placed in short initial residual bone height ranging from 2.0 mm to 5.0 mm (mean 3.38 mm). This subset of short implants in short bone revealed that the risk of failure in implants with less than 5.0 mm base height was 4.79 times greater than the risk for 5.0 mm or greater base height using the Cox Proportional Hazards Model and Kaplan Meier (Log Rank) (hazard ratio = 4.79; 95% CI : 1.52-15.08). This was a statistically significant difference (Chi^2 =8.7; p value 0.003) between survival rate of implants with less and greater than 5.0 mm base height). However of the surviving implants, success rates of implants placed in base height of less than 5 mm was found to be 96.6% with no statistically significant difference in success with implants placed in sites with base height greater than 5.0 mm (95.1 % success).

4.4 DISCUSSION

Studies have reported that using the osteotome technique with and without bone grafting leads to 94% success rates at 1 year[105]. In the present study, there was no bone graft used

and cumulative survival and success rates were found to be as high as 97% depending on the implant system used. The 1 mm bone loss criterion to determine implant success in the present study was used as it is a more critical threshold for calculation of bone loss. This threshold comes from guidelines recently provided by Sanz & Chapple [106,107].

A common complication with sinus elevations is the risk of infection and vertigo. Post-operative infection rate is typically around 2.3%[108]. In the present study, the infection rate was only 0.1%. This may be explained by the lack of graft material acting as a foreign object, or the use of sterile field as well as pre and post-operative antibiotics which may have been positively influencing the low infection rate and low incidence of post-operative complications in the present study. A study of four cases of vertigo secondary to the placement of implants using the osteotome technique by Peñarrocha-Diago et al. (2008) indicated that otoliths may be displaced during this procedure leading to benign paroxysmal vertigo [109]. The authors mention that this is likely from the trauma caused by the percussion of the surgical hammer and neck extension [109]. The very low risk of vertigo in the present study, however, may be in part due to pre-drilling of bone to within 1-2 mm of the sinus floor and the use of straight walled osteotomes minimizing percussion. Our clinical experience in the early adoption of the osteotome technique was that the use of the more common tapered osteotomes required higher mallet forces with many patients reporting uncomfortable sensations. Subjective patient acceptance was found to be much higher with the straight walled osteotome.

Success rates reported here ranging from 87.7% to 97% are similar to conventional bone height cases where no sinus procedure is required[110]. In the present study, no bone graft was added to the osteotomy site and based on the high success rates; bone grafting is not required even when residual bone was less than 5 mm with short, splinted implants. The use of bone graft adds cost and may increase complications if an inadvertent sinus tear is unnoticed. It is likely that some of the osteotome cases in the present study had tears of the Schneiderian membrane and it is our speculation that small tears without bone grafting have little effect for the clinical outcome and do not promote infection compared to the potential for graft dislodgement into the sinus via a tear increasing the risk of infection.

To test for tear we manually sounded the membrane for elastic integrity. Consideration could be given to the use of a Valsalva test. There are no available studies in the international literature concerning the Valsalva maneuver in respect to detection of a maxillary sinus tear. In the present study, the Valsalva maneuver to reveal a maxillary sinus tear was not attempted in all early cases but was adopted in later cases. Although it may be beneficial, since this test was not part of our standard protocol for all cases, we do not include the Valsalva test as our standard protocol for testing a sinus membrane tear. The sinus rebound test with the osteotome used in this study, may not reveal all tears but is easily done as part of osteotome procedure. Since the infection/adverse event rate was 0.1%, it was decided that a minor tear even if undetected by membrane rebound was not

significant.

Previous studies on the osteotome technique that showed loss of sinus graft height over time raised the question about the validity of the osteotome technique[52]. It is clear from the present study the critical question is not how much bone is gained above the implant apex but what minimum implant length can be used in a site that is too short for conventional implant placement. However, as can be seen in the present study a stable dome of bone can be seen at the apex of the implants after loading indicating that a bone graft may not be required.

Previously, there have been lower survival rates associated with short implants in the posterior maxilla or mandible [24,111]. Explanations for this when comparing to longer implants of similar diameter, was that the bone to implant contact ratio is lower with short implants and any marginal bone loss e.g. due to peri-implant inflammation was thought to lead to loss of stability on a shorter implant [24,111].

The success of the short implants in the present study may be due to the use of multiple splinted structures of short implants. All 6 mm implants placed in sites with a residual bone height of 2 to 3 mm that survived were splinted. In a previous study on short implants

revealed a much higher failure rate of 45 % but the authors did not clarify the protocol for loading and the sample size was small, therefore the failure rate may not reflect the true survival rate of short implants in application of the osteotome technique[52]. In a study by Sevimay et al. (2005) stress magnitudes have been found to be greatest in trabecular bone, generally found in the posterior maxilla, when vertical load was applied to a 3 dimensional finite elemental model [112]. In addition, a report on the stress distribution of splinted and non-splinted implants on peri-implant bone found that, the splinting implants reduced the stress on peri-implant bone when comparing to non-splinted implants[113]. This homogenous stress distribution could, in theory, lower the risk of crestal bone loss and therefore explain the significantly higher success rates found with short implants in the present study.

The twelve implants that did fail were in eleven individual patients. Half of implants that failed in the present study failed before prosthetic loading. It warrants further evaluation of the factors that led to the loss of the short implants with insertion torques below 20 N/cm. Although not statistically significant due to the low number of failures, the trend to more implants lost or delayed when insertion torque is below 20 N/cm is suggestive that this may be a critical threshold that once exceeded has no added benefit. Closed healing with flap coverage of implants seated below 20 N/cm would be an alternative option if patients need to keep their dentures for esthetics or function.

In cases of the six late post-loading failures, there was enough bone gained at the apex of the implant after removal of the initial implant to later allow placement of a longer implant.

It appears that the implant system does not significantly influence the long-term survival rate as long as rough surface implants are used. This large sample comparison of Straumann Tissue Level to Nobel Biocare Replace T/S implants found no difference in initial integration and implant survival rate but over time an advantage could be seen with Straumann implants when using < 1 mm crestal bone loss as an indicator of success. This finding is in agreement with a meta-analysis by Laurell and Lundgren (2011) where the mean marginal bone level changes after 5 years were greater in Nobel Biocare implants than Straumann implants[114]. This is despite the advantage seen with Nobel Biocare implants at the time of placement where the percentage of Nobel Biocare implants torqued in at 30 N/cm (85%) was greater than the percentage of Straumann implants torqued in at 30 N/cm (20%) in the present study**.** It is worth noting that even in the early time frames where bone loss was beyond the smooth rough interface in Biocare implants, it is unlikely to find one single reason for crestal bone loss around an implant. Jemt and Albrektsson (2008) state that "marginal bone loss at implants is a complex problem, caused by many different factors that are not yet fully understood. A single-minded explanatory model for bone loss at implants is not acceptable" [107]. Multiple factors (implant hardware, clinical handling, and patient characteristics) may cause marginal bone loss [115]. However, it is important to note that implant survival between the two-implant systems was similar. Despite exposure of rough

implant surface in 6% to 20% of implants, the need for intervention to prevent progressive bone loss was low at only 2.5 % (22/ 926) where a flap or gingival reduction was needed.

One significant limitation in this study is the lack of detail on patients lost to follow-up. Due to the nature of a private practice surgical referral office many patients do not follow-up or return to the referred dentist/specialist for recall appointments. The majority of the patients that declined examination at the surgical office were being seen in the original referral practice. The referral offices of the patients lost to follow-up were notified to contact us if any untoward events occurred. Therefore it is our assumption that a patient with a failed implant would return to our surgical practice or we would be advised of a significant adverse event.

Another limitation of this retrospective study could be that non-standardized peri-apical radiographs were taken, and the resulting measurements could make it more difficult to compare peri-implant bone levels. However, the calibrated computer software system to measure the bone level normalized any dimensional distortion, as has reported Romeo et al. (2003, 2012) using other computer programs [116,117]. Sanz et al. (2005) also reports that using the 1 mm bone loss threshold is the adequate threshold for radiographic assessment of bone loss even with the 2 to 3 times standard deviation of the radiographic measurement error[106]. Therefore, non-standardized peri-apical radiographs are still a valid method of assessing marginal bone levels.

The data presented in this study provides solid evidence for a protocol with no added bone graft even with limited amount of residual bone. The use of the osteotome technique could replace the majority of cases that would otherwise be treated with lateral window sinus elevation. In addition, this technique offers patients less invasive surgery, faster treatment time and reduced cost for the patient.

In conclusion, implant placement in the edentulous posterior maxilla can be greatly extended and simplified by using the osteotome technique with no added bone graft even with short implants and in limited residual bone as low as 2-4mm. With short implants insertion torque below 20N/cm may be instructive as to post surgical management of loading. The procedure appears to be predictable and allows treating the compromised posterior maxilla with reliable long-term results.

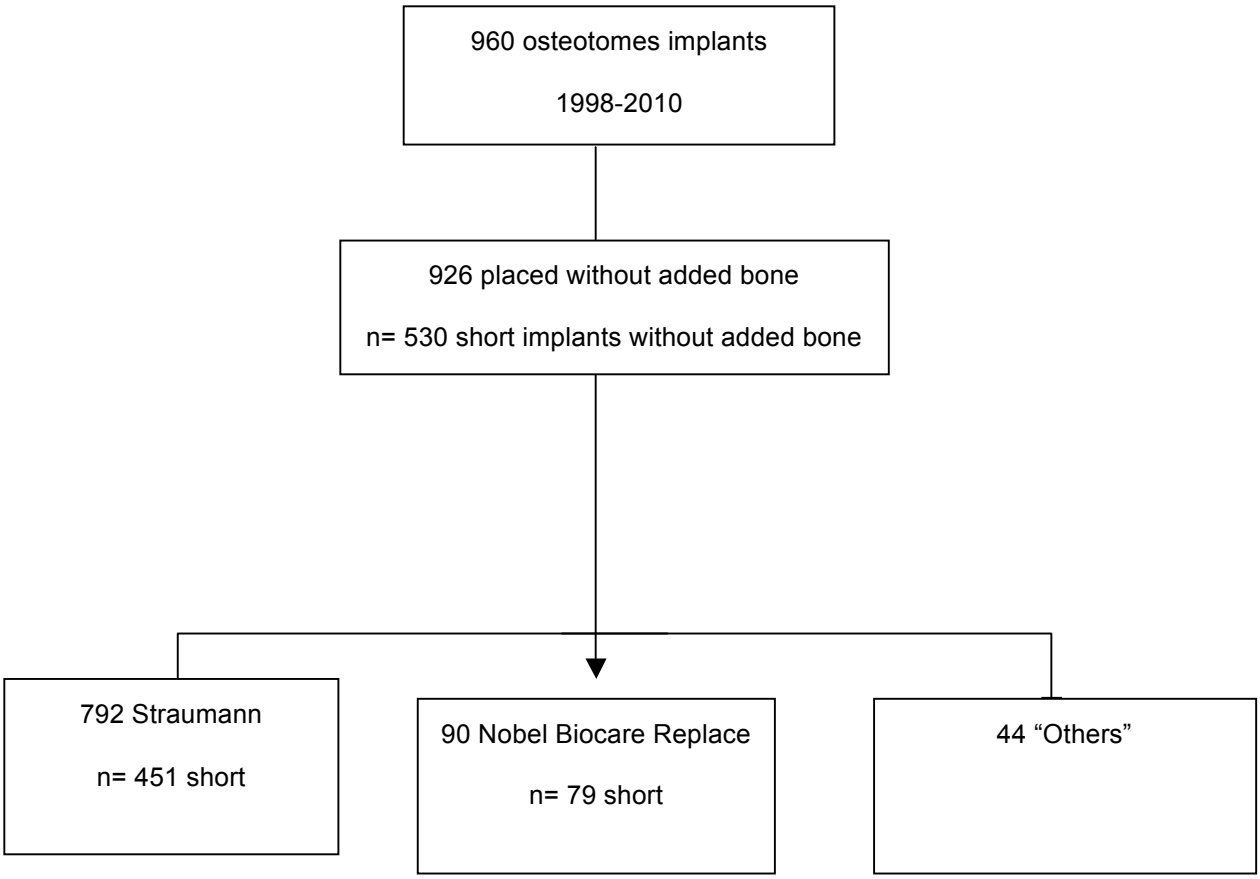

Figure 4.1 Osteotome implant flow diagram

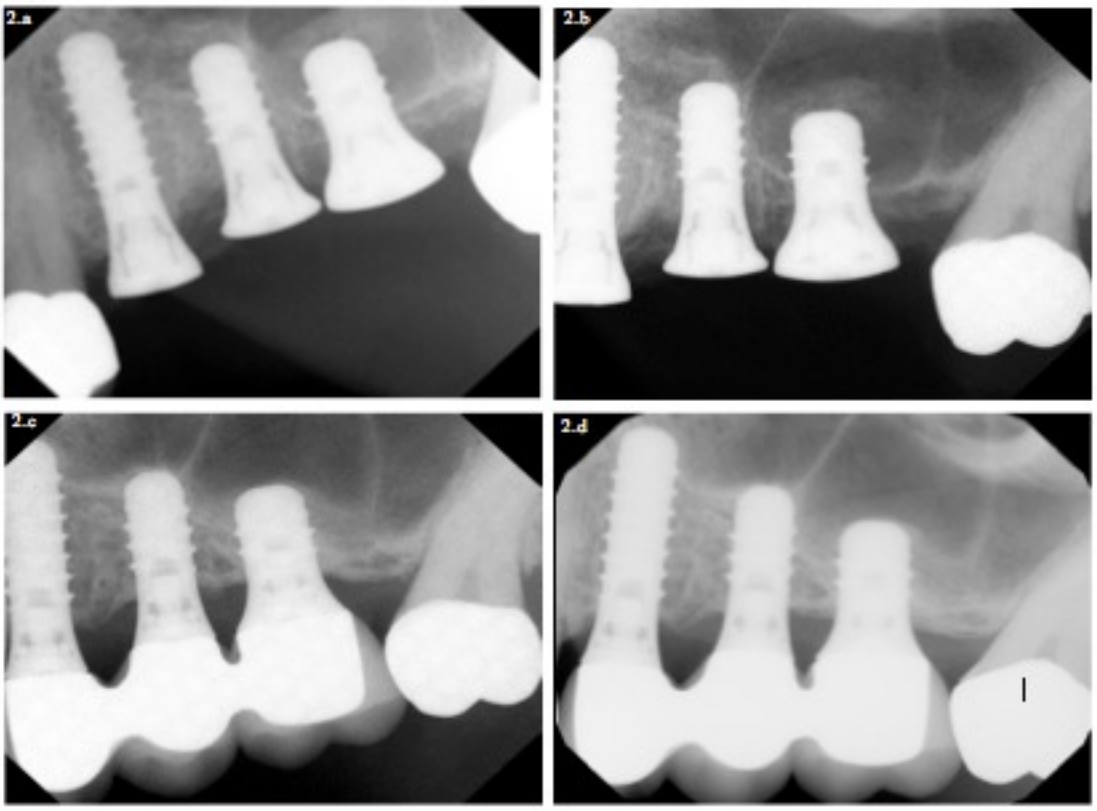

Figure 4.2 Bone remodeling around implants placed with the indirect osteotome technique, without a bone graft. Fig. 4.2.a and 4.2.b - Post-surgical peri-apical radiographs of three implants placed in the left posterior maxilla; 4.2.c - One year after implant placements; 4.2.d- Five years after implant placement. Note in 4.2.c and 4.2.d the stable dome of bone that can be seen at the apex of the implants. (Photos courtesy of Dr. David French)

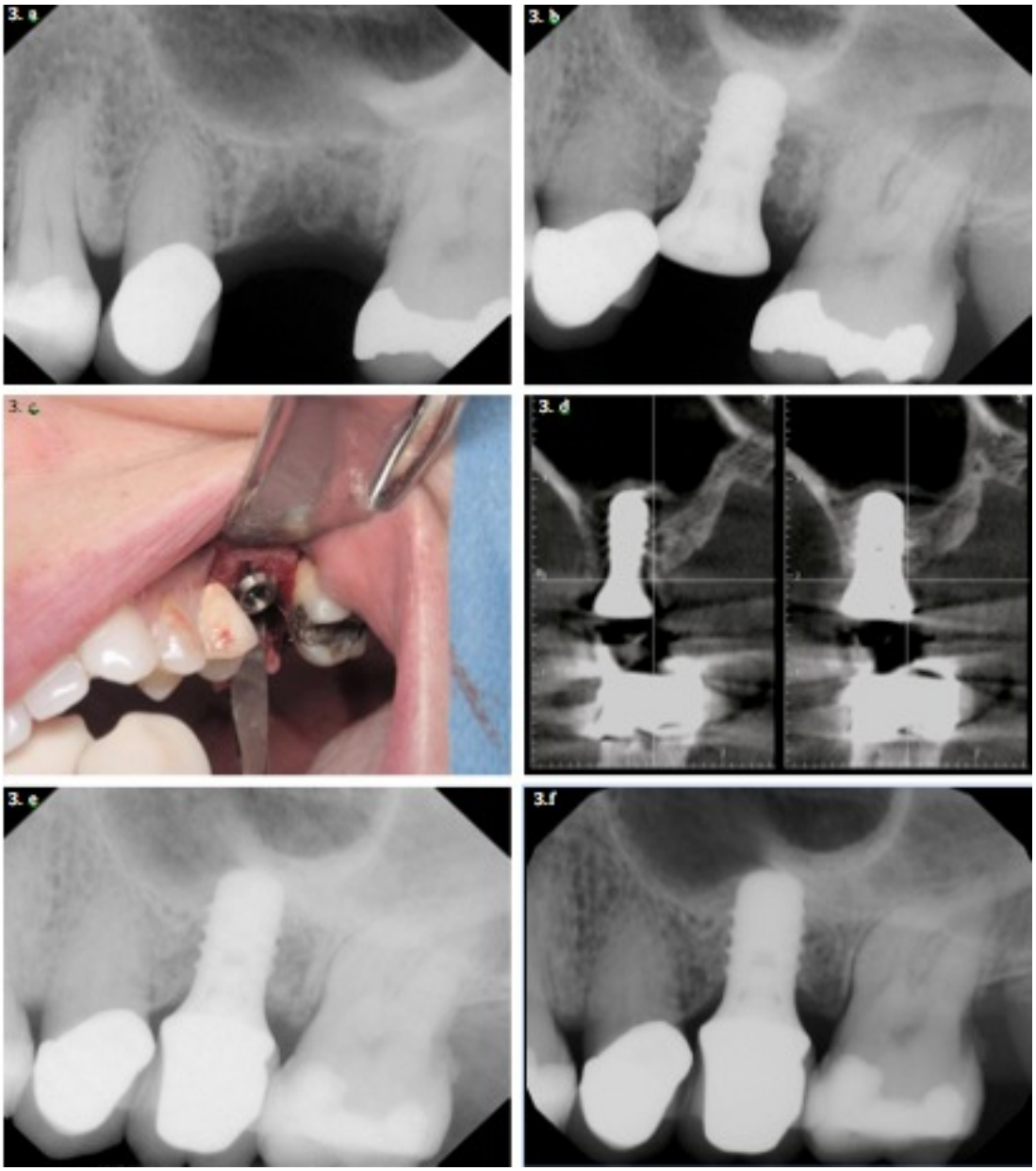

Figure 4.3 Osteotome case with a single short implant. 4.3.a - Pre-osteotome radiograph 4.3b - Peri-apical radiograph taken immediately after implant placement; 4.3c - Clinical photo after implant placement; 4.3d - Cone beam computed tomography ruling out a sinus perforation at 3 weeks post-operatively due to the only case of infection. Note the cross-sectional view of tenting of the membrane by apical bone displacement; 4.3.e - Radiograph at 1-year post-operative visit; 4.3.f - Radiograph 2 years post-operatively indicating a stable dome of bone at the apex of the implant. (Photo courtesy of Dr. David French)

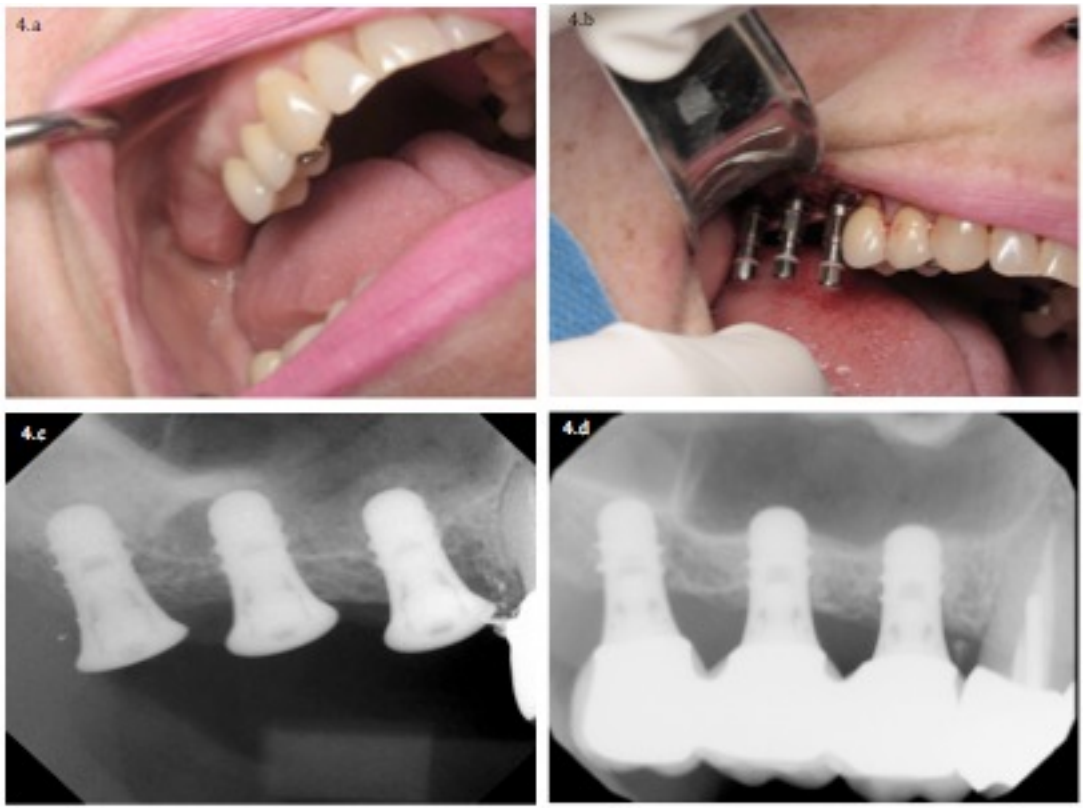

Figure 4.4 An osteotome case in a patient with 2.8 mm of residual bone prior to implant placement. 4.4.a - Pre-treatment clinical photo; 4.4.b - Surgical site preparation for three short 6 mm implants; 4.4.c - Peri-apical radiograph taken immediately after implant placement; 4.4.d - Radiograph taken 5 years post-operatively. (Photo courtesy of Dr. David French)

Table 4.1 Osteotome protocol used for the present study

Osteotome Protocol
. Full thickness mucoperiosteal flap raised
. 2 mm twist drill used 2 mm short of the sinus floor
. Narrow tapered tip osteotome to create initial fracture of the sinus floor extending 1 mm into sinus floor
. Straight walled – concave tipped osteotome increasing in width increments – 2.8 mm, 3.3 mm and 4.0 mm (if wide implant is to be placed).
. Implant placement

Table 4.2 Distribution of implants used in the present study

Implant type		Frequency	Percent
Valid	Straumann	792	85.5
	Nobel	90	9.7
	Other	44	4.8
	Total	926	100.0

Table 4.3 Life table analysis of cumulative implant survival

Interval Duration (months)	Number Entering Interval	Lost to follow-up during Interval	Number Failed	Failed (%)	Surviving (%)	Cumulative Percentage Surviving at End of Interval (%)
0	926	111	6	.01	.99	.99
12	809	198	1	.00	1.00	.99
24	610	141	0	.00	1.00	.99
36	469	167	2	.01	.99	.99
48	300	106	1	.00	1.00	.98
60	193	58	2	.01	.99	.97

Table 4.4 Description of the overall success rates

		Number	Cumulative Percent
Valid	Successful	872	95.4
	Unsuccessful	42	4.6
	Total	914	100.0

Table 4.5 Comparison of the success rates of all three implant groups.

			Implant Type			Total
			Straumann	Nobel	Other	
Success	Yes	Number	767	77	28	872
		% Distribution between implant group	88.0%	8.8%	3.2%	100.0%
		Success within implant group	97.7%	87.5%	68.3%	95.4%
	No	Number	18	11	13	42
		% Distribution between implant group	42.9%	26.2%	31.0%	100.0%
		Not Successful within implant group	2.3%	12.5%	31.7%	4.6%
Total		Number	785	88	41	914
		% within Success	85.9%	9.6%	4.5%	100.0%
		% within Implant Type	100.0%	100.0%	100.0%	100.0%

Table 4.6 Comparison of the success rates of short and conventional length implants.

			Implant Length		Total
			Short Length	Normal Length	
Success	Yes	Number	506	362	868
		Distribution between length groups (%)	58.3%	41.7%	100.0%
		Success within length group (%)	97.1%	93.1%	95.4%
	No	Number	15	27	42
		Distribution between length groups (%)	35.7%	64.3%	100.0%
		Not successful within length group (%)	2.9%	6.9%	4.6%
Total		Number	521	389	910
		% within Success	57.3%	42.7%	100.0%
		% within Implant Height	100.0%	100.0%	100.0%

Chapter 5: SURVIVAL AND SUCCESS RATES OF SHORT STRAUMANN IMPLANTS PLACED IN THE MANDIBLE: A RETROSPECTIVE STUDY WITH UP TO 5-YEAR FOLLOW-UP

5.1 INTRODUCTION

The atrophic mandibular posterior ridge has traditionally been an area that is difficult to restore with dental implants [17]. Historically a ridge height over the mandibular nerve of 13 mm was required in order to place a "standard" 10 mm implant with 1.5 mm over drill and a 1.5 mm safety margin for error as implants less than 10 mm's in height had greater failure rates [118]. A posterior ridge that has had long-term atrophy would be untreatable with this 13 mm height threshold. Subsequently a number of bone grafting options have been developed for vertical bone augmentation. Success with augmentation is still, however, uncertain and it increases the cost of treatment and the rate of complications significantly[17]. A review on horizontal and vertical bone augmentation techniques concluded that short implants appeared to be a better alternative than vertical bone grafting [19].

The success rate for short implants, although initially controversial, has recently been established as a viable treatment option by a number of articles and has opened opportunities to treat a variety of atrophic ridges without the need for augmentation [5]. Implants with a roughened surface provide more bone to implant contact ratio compared to the original machined implant designs and so may offer adequate implant bone stability to rival the longer implants. This evidence has been reinforced by several biomechanical studies suggesting that

maximum bone stress is independent of implant length and even that implant width is more important than the additional length for optimizing loading stress distribution [119,120]. Splinting implants was initially indicated in areas of load risk such as the posterior mandible and maxilla [119,121]. It is possible that short implants may be at risk for overload, therefore splinting short implants may be necessary in the edentulous posterior region. Additionally, studies have demonstrated that during functional loading, there is even greater strain distribution when splinting short implants [80].

The original implant designs had an overdrill distance of about 1.5 mm, which required an additional clearance over vital structures, such as nerves, in order to avoid complications from implant placement. Newer implant systems have an overdrill of 0.4 mm with clear concise drill markings and radiographic indicators matching each implant size so the implant can be placed with greater accuracy. The use of pre-treatment computed tomography and intraoral digital radiographs, allowing real-time evaluation of depths, provide greater accuracy of placement and thus allow implant placement closer to the nerve than the conventionally recommended 2-3 mm clearance from the superior border of the inferior alveolar nerve canal[122].

The purpose of this paper was to retrospectively assess the survival and success rates of short implants (8 mm and less) in atrophic mandible without added bone graft.

5.2 MATERIALS AND METHODS

This retrospective observational study consisted of 720 short (6 and 8 mm) Straumann implant fixtures in posterior mandibular sextants. The posterior mandible was defined as FDI sites 4-5-6-7-8, which included both bicuspids and all three molar sites. Exclusion criteria were implants in the anterior positions, implants of length greater than 8 mm and bone grafting done simultaneous or prior to implant placement in the same area. The implants were placed between 01/03/1999 throughout 01/03/2012 at a private periodontal practice in Calgary Alberta, Canada with all surgeries completed by a single Periodontist (DF) and restored by a variety of general dentists and prosthodontists. The examiner placing the implants (DF) took and recorded all measurements. There were no patient-based exclusion criteria other than ASA (American Society of Anesthesiology Physical Status Classification System) class 3 or higher [123]. Informed consent to implant surgery was obtained from all patients. The study was approved by the Clinical Research Board of the University of British Columbia. All implants were placed and prosthetic components used according to the manufacturer's instructions including a pre-treatment rinse with 0.12% chlorhexidine, a draped sterile field and sterile saline irrigation. The patients were conscious during the procedures and were given local anesthetic (Marcaine 2% 1:200,000 epinephrine) with the option of a mild oral sedative (1 mg Ativan or 0.25 mg Halcion). Patients were typically given 2 grams of amoxicillin 1 hour pre-operatively with no prescribed post-operative antibiotic regimen. Patients allergic to penicillin were typically given Clindamycin 600 mg, 1 hour pre-operatively. A full thickness flap was elevated followed by a 2.2 mm twist drill and then following standard drilling protocols per manufacturers guidelines. Straumann drills, implants and prosthetic components including abutments were used.

Surgical protocols varied from immediate placement in extraction sockets to placement in the mature ridge. All implants were placed using open flap surgery with the only exception being implants placed in the fresh extraction socket, which was done flapless. Immediate implants were placed without bone graft. Implant loading protocol varied according to individual case requirements but was separated into 2 categories; immediate (within 48 hours of placement) and conventional loading (2 to 4 months after placement) or delayed (6 months after placement).

The patients were evaluated at 2-3-month post implant insertion and implants were load tested to 35 N/cm forward torque test to ensure integration. Radiographic bone levels were also measured at this time to establish a baseline. An implant was deemed initially "survived" if it was functionally inserted, non-mobile and passed the torque test 2-3 months after placement. This also was the time-point of first radiographic bone measurement and provided a baseline for future evaluation. Subsequent follow-up was generally scheduled on 1, 3, and 5-year intervals but considering the nature of this open-cohort study the patients were seen at various time points and not all patients returned for follow-up. Subsequent to 5 years the follow-up was less defined with patients either returning because they were patients with large and complex multi unit prosthesis or patients needing more implants sites or patients with a potential concern noted by the referring dentists.

Several Straumann implant types were used, including Standard (S) and Standard Plus (SP), Bone Level (BL) and Tapered Effect (TE) implants. The vast majority of implant surface used was SLA with smaller numbers of the hydrophilic SLActive surface.

The main outcome variables in the analysis are "time to implant failure" and bone loss over time as measured from the smooth rough interface. Failure was defined as the removal of the implant for any reason. Bone loss was measured on standardized peri-apical radiograph using the DEXIS (Pennsylvania, USA) radiograph software program was used to measure bone loss from the smooth/rough interface, i.e.: beyond the 2.8 or 1.8 mm collar on Straumann implants. All bone loss measurements were taken from the coronal aspect of the implant shoulder to the coronal aspect of the alveolar crest at the most apical level, regardless of mesial or distal position thus measuring the side with the greatest bone loss. A threshold of 1 mm bone loss was used to determine implant success in the present study and this was chosen as a critical threshold for calculation of bone loss and thereby exposed rough surface. The 1 mm bone loss criterion to determine implant success comes from guidelines recently provided by Sanz & Chapple[106.]

Implant survival and success were analyzed using a life table analysis as a function of time. We applied Fisher's exact test to test the relationship between categorical variables such as implant height (6 mm/8 mm) and success (yes/no). The Kaplan Meier analysis and Log Rank test were

used to analyze the equality of success functions. The significance level was 5% with a 95% confidence interval using the R software statistical package.

5.3 RESULTS

5.3.1 Implant Types and Sites

A total of 322 mandibular posterior partially edentulous patients had 720 short 6 and 8 mm Straumann implants placed and followed up to 5 years. The mean age of the patients was 60.3 years. The implants were all placed in the posterior mandible (Figure 5.1). 516 (71.6%) of the implants were 8 mm and 204 (28.4%) were 6 mm long (Table 5.1). All implants were restored with splinted restorations. Thirty implants were placed immediately after extraction two of which were immediately loaded. There was immediate loading of 7 other implants placed in the healed site. The other 711 implants were loaded conventionally (after at least 3 months of healing).

5.3.2 Implant Survival and Success Rates

Among the 720 implants placed, there were no recorded failures for an overall 5-year survival rate of 100%. Success rates were evaluated using a threshold of 1 mm total bone loss. The overall cumulative success rate of all implants was 95.8% at 3 years and 93.4% at 5 years, respectively (Figure 5.2, Table 5.2). Success rates of the 6 mm implants were 92.3% and 90.5% at 3 and 5 years, respectively (Figure 5.3, Table 5.3). Success rates for the 8 mm

implants were found to be 97.2% and 94.6% at 3 and 5 years, respectively (Figure 5.3, Table 5.4). There was no statistically significant difference in the success rates of 6 and 8 mm implants. The success rates of the 30 immediate implants was 100% and the 9 immediately loaded was 100% at 3 and 5 years, respectively.

5.3.3 Post-Surgical Infection

In the present study, we recorded the incidence of post-surgical infection. In the 720 implants placed there were 3 cases of post-surgical infection, which were treated successfully with antibiotics and debridement, which represents 0.4% infection rate. There were no cases of inferior alveolar nerve injury.

5.3.4 Insertion Torque

53 implants were placed with an insertion torque of less than 20 N/cm. The success rate of implants placed with low and high torque was 95.8% and 92.2 % at 5 years, respectively. There was no significant difference between the two groups. (Figure 5.4)

5.4 DISCUSSION

Avoiding complex grafting procedures in the mandible for conventional implant placement by placing short implants is of benefit for the patient. These additional surgical procedures are a

greater financial burden and increase the risk of complications and patient morbidity. Previously short implants were considered to be less reliable than the conventional counterparts[5,6,8]. However, recent studies have found highly successful results for short implants, most likely due to changes in implant design, surface characteristics and possibly splinting the restorations[5,7,9]. All the implants used in this study were Straumann 6 and 8 mm implants and were splinted with fixed prostheses. A meta-analysis with a minimum of 12 months follow-up revealed mean survival rates of short implants 6 mm Straumann implants to be 98.6% [34]. Similar findings were found in another meta-analysis of short implants less than 8.5 mm in length with 1 to 5-year follow-up and found that the cumulative survival rate for short implants of varying lengths was greater than 95% [124]. In both reviews, the majority of short implants that failed did so before loading. Two separate reviews found that short implants had an estimated 1-year cumulative survival rate of 97.9%, and an estimated 14-year cumulative survival rate of 88.1%, whereas conventional length implants had a survival rate of 86.7% at 14 years, showing no statistically significant difference between both groups[42,125]. Although they did not indicate whether or not splinting influenced the survival rates of short implants, these systematic reviews support the findings in our study, of a cumulative survival rate of 100% up to 5 years, that short dental implants are a valid treatment option in the atrophic ridge.

Similar to the high survival rates found in this and previous studies, high success rates have also been implicated with short implants. Using the 1 mm crestal bone loss threshold, also used in

the present study as the limit for success, a study of 7 mm implants placed in the mandible found a one year success rate of 97.8% for short implants [45]. In another review of over 6000 short implants with 3458 placed in the posterior mandible a pooled success rate of 98.8% was found with a mean of 3.2-year follow-up using Albrektsson's success criteria[5]. In this review, implants were both splinted and non-splinted.

All implants in the current study were splinted, which could have positively influenced the high survival and success rates of short implants. Marginal bone loss due to biological complications has been seen in many studies, however, the role of occlusion and occlusal load is also considered to play a part in marginal bone remodeling [126]. Although the review by Annibali et al. (2012) indicates that splinting of short implants is not a requirement for success, Bergkvist et al. (2007), using finite elemental analysis found that splinting implants reduced the stress levels in bone tissue around the implants by a factor of 9 compared to stress levels around non-splinted implant [5,7]. In another study by Mendoca et al. (2013) comparing splinted and non-splinted short implants, splinted implants tended to be more successful although no statistically significant difference was found between the two groups [39]. Although the published findings on splinting implants is inconclusive, the 100 % cumulative survival rate found in the current study, indicates that splinting implant restorations is a favourable and recommended option.

Insertion torque values did not seem to influence the survival or success rates of the implants placed in the present study. Opposite results have been noticed previously in a study that

showed 86% cumulative survival rate of implants placed in less that 20 N/cm torque compared to 96% in implants placed with a torque of 30 N/cm or higher [87]. In this study, however "spinner" implants were removed at the time of implant placement and counted towards the not-survived implants immediately reducing the survival rate of the low insertion torque group. The lack of a difference in success rates between the high and low insertion torques, in our study, could be due to several reasons. For example, in the present study, all implants were placed in the posterior mandible, which is known to have better success rates than implants placed in the maxilla [72,127]. Also, all implants used, had a rough surface. Surface roughness is believed to positively influence bone to implant contact ratio and implant healing by promoting favorable cellular responses [72,127]. All implants were placed by the same clinician who followed the same surgical protocol for all implants, possibly positively influencing the survival and success rates of the implants in this study [72,127].

Post-operative infection rates are typically around 2.1% [128] . In the present study, the infection rate was only 0.04%. This may be explained by the lack of graft material acting as a foreign object, which may have been a factor in the low infection rate and low incidence of post-operative complications in the present study. In this study, a single dose of antibiotics was given 1 hour prior to the implant procedure. Some studies have suggested that a single dose of antibiotics given 1 hour pre-operatively reduces the odds of dental implant failure by as high as 66.9% [129]. Pre-operative antibiotics were not, however found to reduce the incidence of infection [128,129]. Therefore, prophylactic antibiotic use may have only positively influenced the

survival rate of the implants in our study and not have influenced the post-operative infection rate. The use of chlorhexidine rinse as part of a post-operative home care regimen could have positively influenced the low infection rate as seen by Powell et al. (2005)[128]. Although the patient's medical history was not evaluated for the purpose of this study, the fact that all patients classified as ASA 3 or above were not treated due to surgical and post-surgical risk, it is possible that the health of the patients played a role in the low post-operative infection rate.

Although few studies report on success rates rather than survival rates in the literature on immediate implants. According to a review by Ortega-Metinez et al. (2013), short-term clinical results of immediate implants were comparable to those obtained with delayed implant placement[60]. A recent review also failed to find a difference in success rates between immediately loaded and conventionally loaded implants[130]. Although the number of immediately placed (0.04%) and immediately loaded implants (0.01%) in this study were low compared to the entire data set the results are in accordance with recent literature. Choosing the appropriate case, immediate placed implants and immediate loaded implants can result in survival and success rates that are equal to the conventionally placed and loaded implants. It is possible that splinting in both scenarios may have also positively influenced the results in our study.

The findings of this retrospective study of 720 short splinted implants demonstrate survival and

success rates that are comparable to conventional length implants. The high or low insertion torque values do not seem to play a role in the long-term survival or success rates of short, splinted implants. Therefore, splinting short implants is recommended. It can be concluded that short implants are an effective treatment modality in the resorbed mandible instead of bone grafting.

Table 5.1 Descriptive analysis of data set

Total Number of Patients	322
Mean Age	60.3
Age Range	40-83
Total number of implants placed	720
Number 6 mm implants placed	204 (28.4%)
Total number 8 mm implants	516 (71.6%)
Immediately placed	30 (0.04%)
Immediately loaded	9 (0.01%)

Table 5.2 Life table for overall success rate of all short implants

Time	Total Number	Unsuccessful	Percent Success	Standard Error	Lower 95% CI	Higher 95% CI
3 months	645	3	99.5	0.00268	0.990	1.000
1-2 years	478	9	97.7	0.00672	0.964	0.990
2-3 years	313	6	95.8	0.01004	0.938	0.978
4-5 years	163	4	93.4	0.01519	0.905	0.965

Table 5.3 Life table for the success rate of all 6 mm short implants

Time	Total Number	Unsuccessful	Percent Success	Standard Error	Lower 95% CI	Higher 95% CI
3 months	179	2	98.9	0.00786	0.974	1.000
1-2 years	136	3	96.7	0.01463	0.939	0.996
2-3 years	88	4	92.3	0.02562	0.874	0.975
4-5 years	50	1	90.5	0.03105	0.846	0.968

Table 5.4 Life table for the success rate of all 8 mm short implants

Time	Total Number	Unsuccessful	Percent Success	Standard Error	Lower 95% CI	Higher 95% CI
3 months	466	1	99.8	0.00214	0.994	1.000
1-2 years	342	6	98.0	0.00739	0.966	0.995
2-3 years	225	2	97.2	0.00955	0.953	0.991
4-5 years	113	3	94.6	0.01739	0.912	0.981

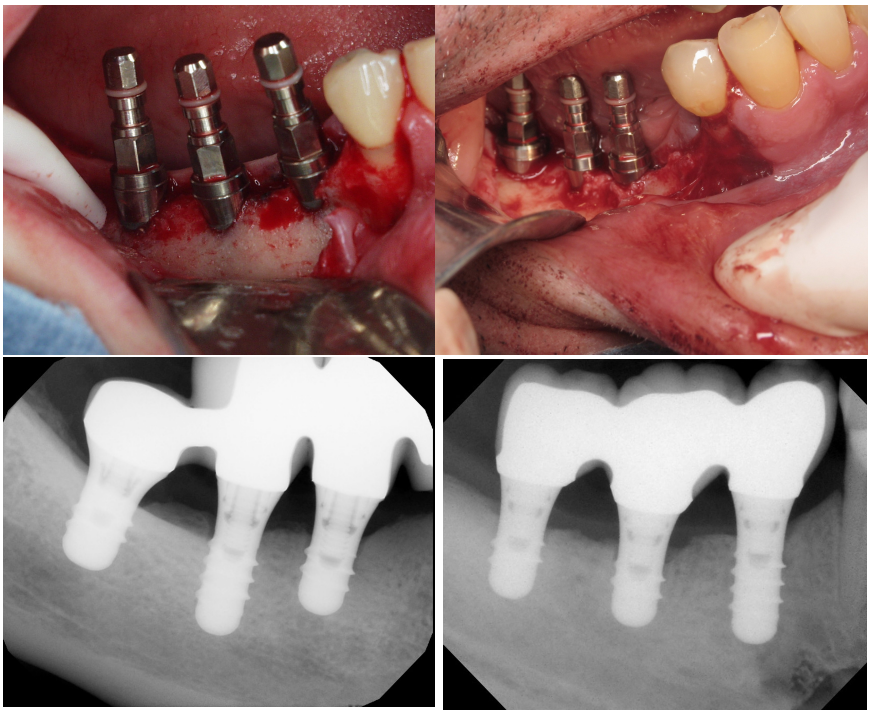

Figure 5.1 Short implants placed in the posterior mandible. 5.1 a. and 5.1.b. Surgical site preparation for three implants. 5.1.c. and 5.1.d. Periapical radiograph of 3 short implants placed and splinted. (Photos courtesy of Dr. David French)

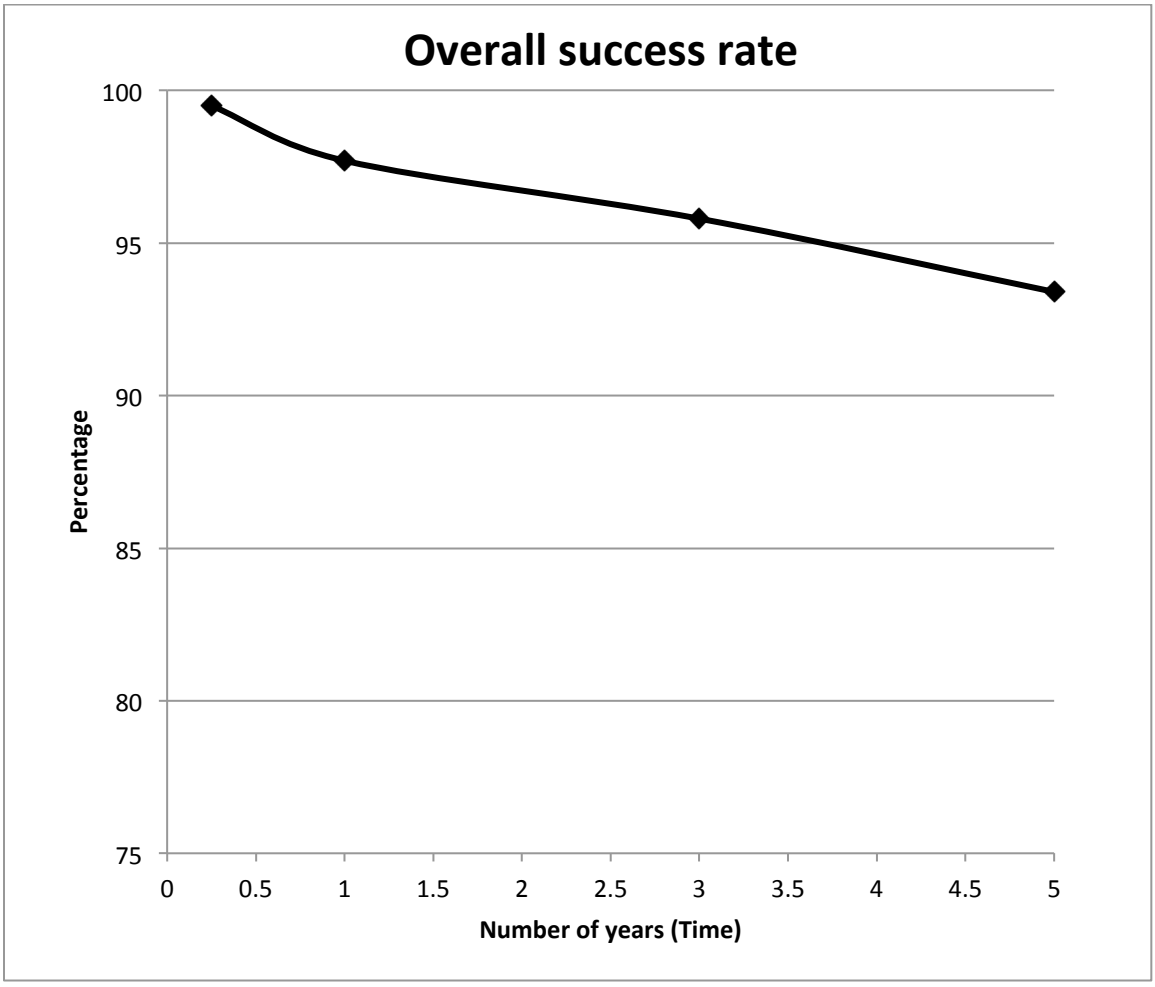

Figure 5.2 Kaplan Meier Curve for the overall success rate of all implants placed and followed up to 5 years**.**

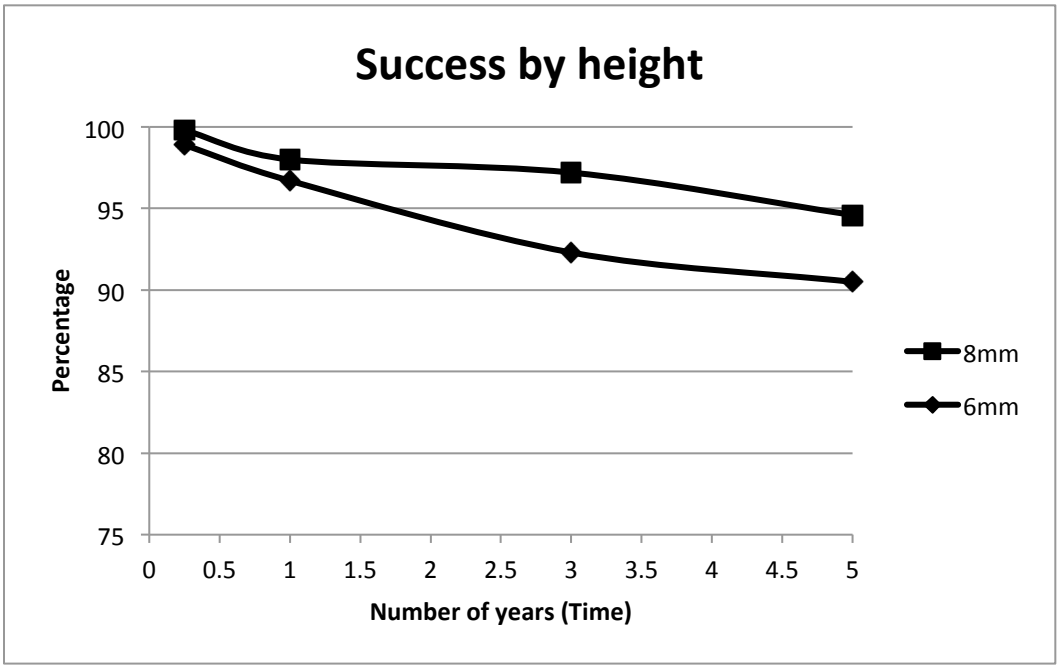

Figure 5.3 Kaplan Meier Curve comparing the success rates of 6 mm and 8 mm implants followed up to 5 years.

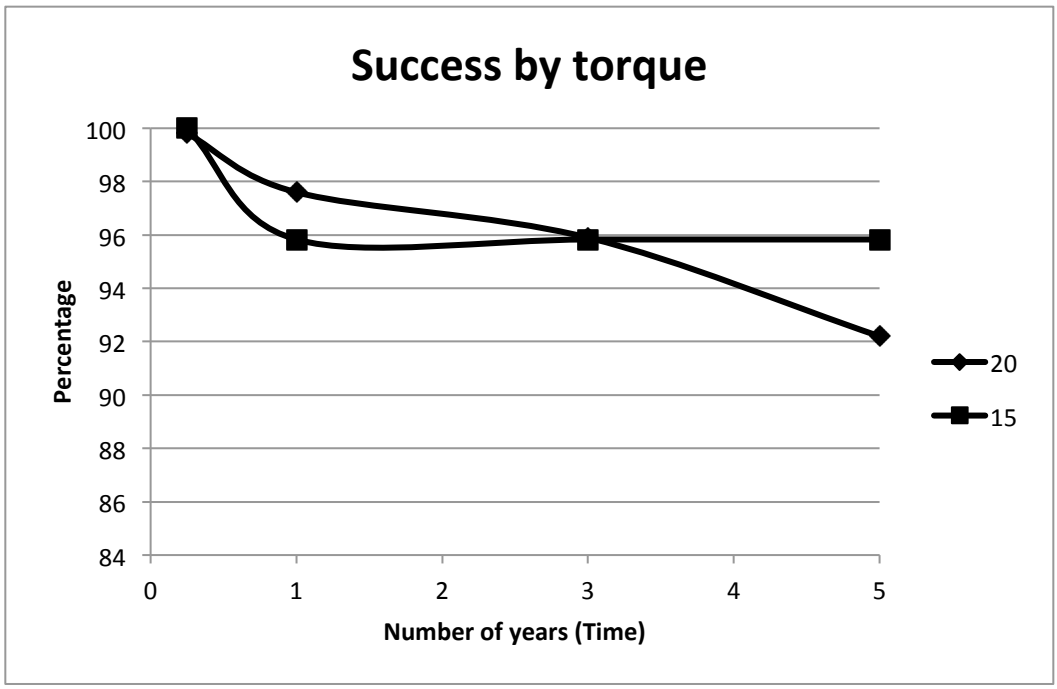

Figure 5.4 Kaplan Meier Curve comparing the success rate of implants placed in low torque (15N/cm or less) compared to implants placed in high insertion torque (20N/cm or more) followed up to 5 years.

Chapter 6: CONCLUSION

The present studies demonstrate that short implants placed in the posterior maxilla using the osteotome technique without bone grafting, and short implants placed in the posterior mandible without grafting are predictable and reliable treatment options. Multiple conclusions can be made from the findings of both studies.

Firstly, the evidence from the implant failures found in the posterior maxilla that the majority of implants failed before prosthetic loading, suggests that the immediate loading and even the use of removal dentures should be avoided when dentures are placed with a torque of less than 20 N/cm.

Splinting short implants in this study provided favorable results since all implants in the mandible were splinted and a very small sample of implants in the maxilla were not. Therefore, it would be fair to conclude that based on the results of these studies, that splinting does not negatively impact the survival and success rates of short posterior implants. Further evaluation on the span of the splinted restoration and comparison of splinted and non-splinted restorations of short implants is still required.

The low post-operative infection rate of less than 0.5% in these studies compared to published rates above 2%, imply that the lack of grafting material, and post-operative use of 0.12% chlorhexidine may positively influence post-operative healing.

Even though a very small cohort of implants in the mandible were placed immediately loaded, the promising results suggest that in an ideal case with adequate torque and favorable bony support, short implants can be placed and/or loaded immediately. Studies with greater number of cases and longer follow-up are required prior to coming to a firm conclusion on immediate placement and immediate loading of short implants.

It is evident that the use of the osteotome technique without bone grafting is a viable treatment option for augmentation of the posterior maxilla even in sites of extremely low residual bone.

Some of the limitations of both studies should be discussed, aside from its retrospective nature, was the large pool of patients lost to follow-up and the low failures to evaluate risk factors in both the mandible and maxilla. It would be of use to look at the influence factors, such as medical history, reason for tooth loss and smoking history would have had on survival and success rates.

Further long-term prospective randomized controlled trials are needed to assess the long-term outcomes related with short implants. However, the findings in these studies indicate that short implants constitute a viable alternative to longer implants, which may often require additional augmentation procedures.

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