Short Dental Implants in Maxillary Sinus Augmentation Sites: A Preliminary Study

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BY

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Lastly, a special thanks to the Bicon Institute for providing me unlimited access to their patient records and also for their kind hospitality during my stay in Boston, Massachusetts.
Dedication

To my parents, Nancy and Thomas Yang, who grew up with nothing but constantly pushed their children to become something.

To my siblings:

Mee Misty Yang
Ka Kelly Yang
Kashoua Kristy Yang
Mai Der Mary Yang
Chai Crystal Yang
Toua Tim Yang
Jean Lea Yang
Lisa Yang
Kimberly Yang
Cha Yang

You have taught me that you if you did not “eat fast enough you didn’t eat at all.” Thank you for all your love and companionship. There is no greater friend than you.
Abstract

Background: Bone resorption patterns in the posterior maxilla may preclude the placement of implant lengths ≥10mm. In order to attain adequate height for implant placement below the sinus floor, additional bone grafting may be necessary. After sinus bone augmentation, a 6 to 9 month healing period is often required prior to implant placement, which prolongs the healing time and increases costs to the patient.

Purpose: The purpose of this retrospective study is to evaluate the number of short-plateau design dental implants, 8 mm or less in length, in maxillary sinus augmented sites with either an internal sinus lift procedure or a sinus transport procedure with or without bone grafting.

Materials and Methods: A retrospective chart review was accomplished on patients that received a short plateau design dental implant 8mm or less in length from January 1, 2008 to December 31, 2009. All dental implants were placed with either an internal sinus lift or a sinus transport with or without the use of grafting materials. Descriptive statistics were gathered.

Results: Sixty-three out of 67 dental implants were included in the study. Fifty dental implants were placed with an internal sinus lift compared to 13 dental implants placed with the crest transported through the sinus. The bone quality assessed at each site of placement ranged from type III (7.9%) to type IV (88.9%). Bone graft materials included SynthoGraft™ only (65.1%), SynthoGraft™ and autogenous bone (6.3%), autogenous bone only (9.5%), or no bone graft material (17.5%). The success rate of implant osseointegration at the time of uncovering was 98.4%. Implant loading ranged from 234 to 1,135 days in 49 dental implants that were restored. Ten (15.9%) implants incurred complications related to the restoration. Eighty-four percent did not have any implant complications.

Conclusions: This preliminary study demonstrates that placing short dental implants 8mm or less at the time of sinus augmentation may be possible. Minor complications may be experienced with these procedures. However, long-term data on survival and performance of short dental implants is needed.

Key words: short dental implants, sinus augmentation, crown-to-implant ratio
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INTRODUCTION

Maxillary sinus bone augmentation was first introduced by Hilt Tatum more than 30 years ago. Since then, there has been an evolution of sinus augmentation techniques. Earlier practices of sinus augmentation procedures were performed in a hospital setting by harvesting autogenous bone from the iliac crest.\textsuperscript{1,2} By harvesting bone at a secondary site, there was an increase in the amount of morbidity and the healing time involved. Through improvements in implant design and evolution of maxillary sinus augmentation techniques, postoperative complications have been reduced, gaining popularity with in-office grafting.\textsuperscript{2}

An epidemiologic study on general and local contraindications for dental implants showed that most posterior edentulous ridges have minimal bone height. Fifty percent of the patients in the study had bone heights greater than 6\,mm in the mandible compared to 38\% in the maxilla. The primary reason implants could not be placed in the edentulous maxillary ridge was maxillary sinus enlargement resulting in inadequate bone height.\textsuperscript{3}

According to the National Health and Nutrition Examination Survey from 1999 to 2004, the prevalence of tooth loss and partial edentulism has declined over the years.\textsuperscript{4} Although more people are retaining their teeth due to water fluoridation and improved preventive care, the most commonly missing teeth are first and second molars.\textsuperscript{5} A computerized tomography study of maxillary sinuses by location showed that 90 to 100\% of the time the sinuses are present
at the first and 2\textsuperscript{nd} molar sites.\textsuperscript{6} Following posterior tooth loss, the maxillary sinuses pneumatize and the alveolar bone crest resorbs. The recommended placement of dental implant lengths of 10 mm or greater may be difficult in the maxillary posterior area without bone grafting. Implant lengths of 10mm or greater have been the standard in implant dentistry due to a greater bone-to-implant contact and primary stability.\textsuperscript{7}

The most commonly practiced sinus augmentation technique involves a lateral window approach. The lateral window procedure is recommended when the residual bone height is less than 5mm. A window is prepared on the lateral wall of the maxillary sinus and the Schneiderian membrane is reflected superiorly to allow grafting material to be placed on the sinus floor. Implant placement is performed after approximately 6 to 9 months of healing.\textsuperscript{8} A review by Wallace and Froum reported implant survival with the lateral window approach varied between 61.7\% and 100\% with an average survival rate of 91.8\%.\textsuperscript{9} Implants having a rough surface tend to have a higher survival rate compared to a machined surface dental implant when placed in the posterior maxilla.\textsuperscript{10}

Aghaloo and Moy published a review article that showed survival varied between the different types of bone grafts. Maxillary sinuses augmented with particulate grafts showed a higher survival rate than block grafts. Xenografts performed the best at 95.6\% survival rate compared to the 88\% of autogenous bone grafts. Despite the differences in success with each bone graft material, the overall outcome between grafting and no grafting were similar. Operator skill and
technique may be of greater importance than the grafting materials used.\textsuperscript{11}

Another common sinus augmentation procedure is the osteotome sinus floor elevation technique, which is credited to Robert Summers. Osteotome sinus elevation is an internal sinus lift that begins at the ridge crest. One of the requirements of this procedure involves at least 6mm of crestal bone height. A trephine instrument is used to demarcate a bone plug that is lifted superiorly with increasing diameter osteotomes. The Schneiderian membrane is elevated through hydrostatic pressure and packed with bone graft material. This technique is followed by a healing period prior to implant placement or alternatively, immediate implant placement.\textsuperscript{12}

Variations in the internal sinus lift procedure have been published since its introduction. A new trend is to shorten the implant healing time by utilizing new surgical techniques. Bruschi et al. described in a clinical report localized management of the sinus floor with simultaneous implant placement without the use of bone graft material in 5 to 7 mm of residual alveolar bone height. The crestal bone is demarcated with a chisel and lifted by tapping on an osteotome with a mallet until the sinus cortex is fractured. The implant stability is maintained by the maxillary cortical bone, cancellous bone, and blood clot. With 499 implants placed, the success rate was 97.5\% with a range of 24 months to 5 years of functional loading.\textsuperscript{13} In another study on localized management of the sinus floor, 58 dental implants were placed in the posterior maxillary ridges with $\leq 4$ mm of bone. The success rate was 91.4\% after an average of 22 months of
Short dental implants can minimize the need for extensive bone grafting but few studies have investigated the performance of short dental implants in maxillary grafted sinuses. The purpose of this preliminary study is to evaluate the number of short plateau-design dental implants, 8mm or less in length, that remain osseointegrated after placement with either an internal sinus lift or a sinus transport technique with or without bone grafting. The sinus transportation technique utilized is a variation of that performed by Bruschi and Winter. Crown-to-implant ratios will also be calculated.
MATERIALS AND METHODS

Study Design and Sample

A retrospective chart review was performed at the Implant Dentistry Centre in Boston, MA. The Implant Dentistry Centre is a private practice facility. Patients that had one or more implants placed in the maxillary sinus utilizing either the internal sinus lift or sinus transport procedure with or without grafting material between January 1, 2007 and December 31, 2008 were included in the study. All implants were 8mm or less in length and Calcium Phosphate coated (Figure 1). Both pre-operative and post-operative radiographic data was gathered. All implants utilized a 2-stage approach or in other words, left to heal for an average of 6 months before uncovering. Patients with uncovered implants at the time of the study were excluded. All dental implants were placed by one oral maxillofacial surgeon and restored by restorative dentists at the Implant Dentistry Centre or by an outside referral source.
Radiographic Analysis

Radiographs of high resolution from patients that met the inclusion criteria were reviewed and measured with DIGORA (Soredex, Tuusula, Finland). Ninety-eight percent of the radiographs studied were digital periapical films taken with the paralleling technique. The remaining 2% were digital panoramic images. Magnification distortion was accounted in calculating the crown-to-implant ratio by using the following equation:

\[
\frac{The \ radiographic \ implant \ length}{The \ actual \ implant \ length} \times 100\% = Length \ Magnification
\]
Making linear measurements after adjusting for magnification distortion is a reliable means with periapical and panoramic radiographs. However, pretreatment radiographs lacked an objective magnification marker and thus direct radiographic measurements of the alveolar bone height were made without compensating for magnification distortion.

Maxillary Alveolar Bone Height Measurements: A horizontal line is drawn along the crest of the ridge. Another parallel line is drawn from the lowest point of the maxillary sinus along the site of implant placement. A third line is drawn perpendicular to both parallel lines to give a measurement of the maxillary sinus height prior to implant placement. Measurements were made twice and the average was calculated. See Figure 2.

Figure 2. Maxillary alveolar bone height measurement
**Crown-to-Implant Ratio:** Three horizontal lines are drawn along the following landmarks: the base of the dental implant, the neck of the dental implant, and the highest point of the occlusal table. Perpendicular lines are drawn connecting one parallel line to the next. The vertical measurements equate to the dental implant length and the crown height (**Figure 3**). Measurements were made twice and the average was calculated.

**Figure 3. Crown to Implant Ratio**

![Image of dental implant with lines indicating crown-to-implant ratio]

**Study Variables**

- **Demographics:** gender and age.
- **Health Status:** Patient health status was assigned with the American Society of Anesthesiology (ASA) system, ranging from ASA 1 to 3.
Smoking history was also collected.

- **Anatomy**: Anatomic variables include maxillary posterior regions. Bone quality was assigned at the time of surgical placement. Type I is mainly dense cortical bone. Clinical presentation is cortical bone without blood. Type II is porous cortical with coarse trabecular bone. Bone and blood will fill flutes in type II quality. Type III bone is porous cortical bone with fine trabecular bone. Type IV bone is fine trabecular bone. Type IV bone is the poorest quality of bone and is clinically absent in the flutes of the reamer. (Figure 4).

**Figure 4. Clinical Bone Quality Assessment**

Type I: Dense Cortical

Flute of a 3.5mm reamer bur filled with bone and minimal blood

Type II: Porous Cortical and Coarse Trabecular

Flute of a 3.5mm reamer bur filled with blood wetted bone
**Figure 4. Clinical Bone Quality Assessment**

- **Implant-Specific Variables**: Implant specific variables include implant length 8mm or less and diameter 4.5 to 6.0mm (well size 3.0mm). All implants were coated with Calcium Phosphate and placed using a 2-stage technique.

- **Prostheses**: The final prosthesis was classified as single crown, fixed partial denture, or overdenture. The length of time in function of all restorations was recorded.

**DATA ANALYSIS**

Descriptive statistics was utilized for patient demographic, implant distribution, radiographic alveolar bone height measurements, sinus augmentation procedures, crown-to-implant ratio, implant failure, and implant complications.
RESULTS

A total of 67 dental implants were placed in the maxillary sinuses from January 1, 2007 to December 31, 2008. Sixty-three dental implants were uncovered in 49 patients during the time of this study, meeting the inclusion criteria. There were 26 males and 23 females in the study with ages ranging from 37 to 82-years-old (average age of 61). Seventy-three percent were classified as ASA I (healthy), and 27% as ASA II (mild systemic disease). Twelve percent of the patients were smokers (Table 1).

Table 1. Demographic

<table>
<thead>
<tr>
<th></th>
<th>Implants K=63</th>
<th>%</th>
<th>Patients N=49</th>
<th>%</th>
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</tr>
<tr>
<td>Male</td>
<td>29</td>
<td>46.0</td>
<td>26</td>
<td>53.1</td>
</tr>
<tr>
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<td>54.0</td>
<td>23</td>
<td>46.9</td>
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<td>Health Status</td>
<td></td>
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<td>ASA I</td>
<td>46</td>
<td>73.0</td>
<td>39</td>
<td>79.6</td>
</tr>
<tr>
<td>ASA II</td>
<td>17</td>
<td>27.0</td>
<td>10</td>
<td>20.4</td>
</tr>
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<td>ASA III</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Medically compromised</td>
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<td>yes</td>
<td>46</td>
<td>73.0</td>
<td>34</td>
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<td>17</td>
<td>27.0</td>
<td>15</td>
<td>30.6</td>
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<tr>
<td>tobacco use</td>
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<td>8</td>
<td>12.7</td>
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<td>55</td>
<td>87.3</td>
<td>43</td>
<td>87.8</td>
</tr>
</tbody>
</table>
All patients included in the study received dental implants 8 mm or less in length. The number of implants placed by length and diameter were the following: (1) 4.5x6, (9) 4.5x8, (2) 5x5, (9) 5x6, (13) 5x8, (26) 6x5.7 and (3) 6x8 (Table 2).

Table 2. Implant Length and Diameter

<table>
<thead>
<tr>
<th>Length(mm)</th>
<th>Diameter</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.5mm</td>
<td>5mm</td>
<td>6mm</td>
<td></td>
</tr>
</tbody>
</table>
| 5          | ---------| 2  | -----
| 5.7        | ---------|----| 26 |
| 6          | 1        | 9  |
| 8          | 9        | 13 | 3  |

The 63 implants were distributed approximately equal in both right and left maxillary sites (Table 3). There were more dental implants placed in tooth number 14 (24) compared to tooth number 3 (17). Fifty implants were placed with an internal sinus lift procedure versus 13 dental implants placed with a floor transport technique. The bone quality of the prepared sites was mainly type IV (88.9%). Type III bone was reported in 7.9% of the cases. Two implant sites were not reported (3.2%). The average maxillary bone height was 5.9 mm with a range from 2.5 mm to 11.8 mm (Table 5).
Fifty-six dental implants (88.9%) were placed immediately at time of sinus augmentation and 7 sites were left to heal prior to implant placement. The minimum time before implant uncovering was 2.5 months and the maximum time was 1 year and 4 months with an average overall healing period of 6 months. Grafting materials placed during these procedures were alloplasts (SynthoGraft™, 65.1%), autographs (9.5%), or a combination of both graft materials (6.3%). No bone graft was used in 17.5% of the cases. The type of graft material utilized was not classified for one implant case (1.6%). Table 4.
Table 4. Anatomical Variables

<table>
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<tr>
<th></th>
<th>Implants</th>
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<tr>
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<td>K=63</td>
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<tr>
<td><strong>Anatomic Variables</strong></td>
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<td><strong>Bone quality</strong></td>
<td></td>
</tr>
<tr>
<td>Type I</td>
<td>0</td>
</tr>
<tr>
<td>Type II</td>
<td>0</td>
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<tr>
<td>Type III</td>
<td>5</td>
</tr>
<tr>
<td>Type IV</td>
<td>56</td>
</tr>
<tr>
<td>NA</td>
<td>2</td>
</tr>
<tr>
<td><strong>Bone graft Material</strong></td>
<td></td>
</tr>
<tr>
<td>Synthograft only</td>
<td>41</td>
</tr>
<tr>
<td>Synthograft and Autogenous</td>
<td>4</td>
</tr>
<tr>
<td>Autogenous only</td>
<td>6</td>
</tr>
<tr>
<td>No bone graft used</td>
<td>11</td>
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<td>1</td>
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<tr>
<td><strong>Type of sinus augmentation</strong></td>
<td></td>
</tr>
<tr>
<td>Internal sinus lift</td>
<td>50</td>
</tr>
<tr>
<td>Floor transport</td>
<td>13</td>
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</tbody>
</table>

A total of fifty-seven dental implants were restored. Fifty-one dental implants were restored with single unit crowns (81%), 2 dental implants were restored with a fixed prosthesis (3.2%), 4 dental implants were restored with an overdenture prosthesis (6.3%), and 6 dental implants were unknown restoratively. The range of function was determined by the date of the prosthesis insertion to the month of data collection (July 2010). Restoration in function ranged from 8.5 months to 3 years with an average of 1 year and 7 months. Of the 51 dental implants restored with a fixed restoration, only 43 radiographs were available to calculate crown-to-implant ratio. The average crown-to-implant ratio
was 1.8 with a range from 1.2 to 3.6 (Table 5).

Table 5. Alveolar bone height and C:I measurements

<table>
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<tr>
<th>Measurement</th>
<th>No of implant sites</th>
<th>MIN</th>
<th>MAX</th>
<th>AVERAGE</th>
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<tr>
<td>Direct alveolar bone height</td>
<td>61</td>
<td>2.5</td>
<td>11.8</td>
<td>5.9</td>
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<tr>
<td>Crown to implant ratio</td>
<td>39</td>
<td>1.2</td>
<td>3.6</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Complications incurred during the course of treatment and post restorative treatment were classified as prosthetic complications or other reasons. Ten dental implant complications were categorized as prosthetic complications (11.1%) and other reason (4.8%). Prosthetic complications generally involve porcelain fracture or screw loosening, but in this study, prosthetic complication was defined as any alteration to the restored prosthesis regardless of the extent of the correction made. Seven implants with prosthetic complications in this study involved occlusion and food entrapment, which were corrected by adjusting the occlusion, polishing, or replacing the implant abutment. One complication was unknown and one implant complication was due to bone loss not leading to implant immobility (Table 6).

One dental implant failed before it was uncovered (Table 6). The dental implant that failed occurred 7 weeks after placement in type IV bone with simultaneous bone augmentation in a site with 3.0mm pretreatment bone height.
Sixty-two dental implants were deemed osseointegrated. Clinical assessment of osseointegration was determined by inserting a guide pin into the implant well, while oblique and vertical forces were applied to check for implant immobility. Success in this study is defined as any implant that did not exhibit mobility during 2\textsuperscript{nd} stage uncovering. A success rate of 98.4\% was calculated in this study.
Table 6. Implant Variables and Complications

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<th>Implants</th>
<th>Implant Specific Variables</th>
<th>Well size</th>
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<th>3mm</th>
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<td>56</td>
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<td>33.3</td>
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DISCUSSION

Although the prevalence of partial and total edentulism has declined over the years, the number of patients seeking dental implant treatment continues to rise as evidenced by the growth of the dental implant market in the US and internationally.\textsuperscript{18,19} In this preliminary study, short plateau-designed dental implants 8 mm or less in length were placed in maxillary sinus augmented sites. Most implants were placed in 1\textsuperscript{st} and 2\textsuperscript{nd} molars sites (74.6\%) compared to premolar sites (25.4\%). In the 1\textsuperscript{st} and 2\textsuperscript{nd} molar sites, bone augmentation is utilized if maxillary pneumatization limits the available bone height for implant placement. Studies show that sinus enlargement variations exist from site to site and also with the number of teeth lost. Due to the anatomic limitations of the maxilla, additional bone grafting is necessary if a longer implant is selected.\textsuperscript{20}

Different views on the success rate of short dental implants have been published in the dental literature, but emerging studies indicate success with short dental implants.\textsuperscript{21-24} According to a review by Renouard et al that evaluated 53 human studies, short dental implants fall under 4 outcome subgroups: 1) Short implants fail more than long implants; 2) Short implants have increased failure rates but adequate survival rate; 3) Short implant lengths did not have any significant influence on survival rate, and; 4) Survival rates are similar in short and long implants (88-100\%).\textsuperscript{24} In this study, the success rate of 63 dental implants placed was 98.4\%. The result indicates plateau-design implants 8 mm or less falls into the last category.
As reviewed by Renouard et al, some studies report a higher failure rate with shorter implants compared to longer implants. However, the success seen in this study questions this theory. A claim made to support poorer success of short dental implants is the less bone-to-implant contact between the short dental implant and surrounding bone. The implants utilized in this study have more surface area than most other implants of the same length and diameter. The macro and micro design may play a role in osseointegration regardless of the implant length.

Implant failure was defined as complete removal of the implant prior to 2nd stage surgery. In this descriptive study, one implant failed 7 weeks after placement. Early wound healing around dental implants involve a crossover between primary stability and secondary stability around 3 weeks. During this transition period, newly formed bone may not be adequate to maintain implant stability. Although the implant was explanted at 7 weeks, failure may have been initiated during this critical time period.

Direct pre-treatment radiographic measurement of the failed implant revealed 3.0 mm of alveolar bone height coronal to the maxillary sinus. Cortical bone thickness has been positively correlated with implant stability. Due to the minimal thickness of the cortex, this may have put the implant at an increased risk to micromotion. Micromotion has been theorized to cause soft tissue encapsulation instead of bone growth around dental implants.

A review of the surgical placement of the failed implant indicated it was
placed in tooth site 14 with the sinus transport technique. At the time of implant placement, the bone quality was classified as type IV. Bone graft (Synthograft™) was simultaneously used to augment the sinus. Although there is lacking evidence of a causal relationship between osseointegration and bone quality, multiple studies have presented the importance of bone quality for primary stability. Bone quality may be of significance because of the cellular components. Trabecular bone is filled with bone marrow, which provides a good source of bone cells in comparison to cortical bone.32,33,34 As seen in the classification system in this study, type IV bone consists of fine trabecular bone and there is lack of clinical evidence of bone on the reamer bur. This further supports the notion that the bone quality of site 14 may be a risk factor for implant failure.

Although studies recommend a delayed implant placement approach when there is minimal alveolar bone height, Winter et al. reported 91.4% success rate utilizing a similar sinus transport technique in alveolar bone heights \(\leq 4\) mm without use of any bone graft.14 Although one implant failed, success of the sinus transport technique in this study was 92%, which suggests placement of short dental implants in sinus augmented sites may be done with proper case selections.

Thirty-nine restored dental implants had an average crown-to-implant ratio of 1.8 after adjusting for magnification distortion. The maximum crown to implant ratio was 3.6. Four implants were excluded in calculating crown-to-root ratio
because overdenture attachments were utilized instead of single crowns. The maximum crown-to-implant ratio falls outside normal parameters for natural dentition which generally has a crown-to-root ratio of 0.5. The difference between crown-to-root and crown-to-implant ratio is expected because of the reduced alveolar bone height post extraction.\textsuperscript{35,36} Sinus augmentation does not reduce the crown-to-implant ratio because the inter-arch distance is not altered. A recent publication by Birdi et al. on crown-to-implant ratio of short plateau-designed dental implants found the mean crown to implant ratio of 309 dental implants was 2.0 with a range from 0.9 to 3.2. Bone levels were also recorded and fell within the guidelines for success. This further supports the idea that having an increased crown-to-implant ratio may not related to implant failure.\textsuperscript{37,38}

Complications that required additional clinical visits comprised 10% of the study sample and were categorized as prosthetic complications. Most prosthetic complications were related to occlusion and corrected by performing occlusal adjustments. The remaining prosthetic complications involved inadequate abutment size that allowed for food entrapment. In those instances, the size of the abutment was replaced with another. In various reports, prosthetic complications usually involve porcelain chipping or implant screw loosening.\textsuperscript{39} However, the short plateau-designed implant does not encounter this screw loosening because of the elimination of screw engagement and reliance on a 1.5 degree locking taper connection. Thus, the type of prosthetic complication experienced in this study cannot be compared to an implant system that delivers
a preload to screws to maintain the abutment implant connection. However, longer follow-up period of function of the restoration is needed to compare future prosthetic complications.

The findings of this preliminary study are promising but there are limitations that require further investigation. Larger sample sizes are needed with longer observations to evaluate the performance of short dental implants in maxillary augmented sites. A prospective study design may be more accurate in comparing different augmentation techniques and materials used in conjunction with short dental implants but require greater time and experience to accomplish. Furthermore, one experienced oral surgeon placed all implants. Results may vary based on the clinician's skill; therefore, case selection cannot be overlooked.
CONCLUSION

This retrospective chart review reports the results of 63 dental implants 8 mm or less in length placed in either the internal sinus lift or sinus floor transport techniques from January 1, 2007 to December 31, 2008. A success rate of 98.4% was reported at the time of uncovering. This preliminary study demonstrates that short dental implants can safely be placed in maxillary sinus grafted sites with little or no complications. Placement of short dental implants may be a less invasive approach because of reduced healing time. However, long-term survival studies are needed to evaluate the survival and performance of short dental implants in combination with maxillary sinus augmentation.
REFERENCES


(25) Bozkaya D, Muftu S, Muftu A. Evaluation of load transfer characteristics of five different implants in compact bone at different load levels by finite element analysis.


