THE CHALLENGE OF IMPLANT THERAPY IN THE POSTERIOR MAXILLA: PROVIDING A RATIONALE FOR THE USE OF SHORT IMPLANTS

Marianne Morand, DMD; Tassos Irinakis, DDS, MSc, FRCD(C)

Rehabilitating patients with a resorbed maxilla presents several challenges when the desired treatment plan involves the placement of endosseous implants. Correct diagnosis requires knowledge on jaw healing patterns, systemic effects, and the impact of bone quality changes on implant success rates. Appropriate treatment planning requires an in-depth understanding of the materials and methods available to the contemporary implant surgeon. The clinician must be able to persist on evidence-based techniques and adhere to those proven methods. Successful surgical placement requires correct use of the available armamentarium and acceptance of the limitations that implant dentistry still presents. Especially challenging is the implant treatment of maxillary molars due to the plethora of complicating factors such as limited bone availability, interarch space challenges, sinus problems, etc. These are just a few of the factors that may lead us to placement of short implants in these sites. An extensive review of the literature that is available for short implants (implants <10 mm in length) indicates that although they are commonly used in areas of the mouth under increased stress (posterior region), their success rates mimic those of longer implants when careful case selection criteria have been used. The available studies and case-series offer a valid rationale for placement of short implants so long as one understands the limitations, indications, risk factors, and limited studies that actually follow-up success rates of short implants for over 5 years. This review of the literature will provide the reader an in-depth view of the evidence in using short implants as an alternative treatment modality for the maxillary molar region.

Key Words: short implants, sinus lift, maxilla, sinus augmentation, bone grafting, surface

INTRODUCTION

Conventionally, surgeons aim for placement of the longest possible implant in any given site as long as its placement does not hinder the final prosthetic result in terms of esthetics. This was especially crucial in the past, when implants presented a machined surface and the most common way to increase implant-to-bone contact was to increase the surface area available by placing a wider or longer implant. The longer and wider implants were clearly associated with higher success rates at that time (when placed in similar intraoral
However, the posterior maxilla presents a uniquely challenging site for implant placement due to several complicating factors. Some of the factors that lead to difficulties in implant placement and success in the maxillary molar region are:

- Difficult and challenging access
- Limited visibility
- Commonly reduced interarch space
- Postextraction resorption that leads to extensive tissue loss over time, as well as sinus pneumatization
- Poor (type IV) bone quality (thin layer of cortical bone surrounding a core of low-density trabecular bone) associated with the least favorable success rates

To compensate for the poor bone quality, research teams have improved implants’ texture and design to facilitate osseointegration. Using different techniques (e.g., acid etching, grit blasting, titanium plasma spraying, surface coating), implant companies today have replaced the traditional polished surface on implants with “rough” surfaces that have led to significantly better long-term results. These techniques result in implant surface irregularities in height, wave length, and spatial dimension. Arguments in favour of rough implant surfaces include:

- Increased contact area to offer better mechanical stability between bone and implant immediately following insertion
- Provides surface configuration that properly retains the blood clot
- Stimulates the bone healing process

An additional way to compensate for the limited bone height that is commonly present in the posterior edentulous maxilla was sinus lift augmentation using autogenous bone or bone substitutes. More experienced maxillofacial surgeons would also proceed with total or segmental bone onlays and Le Fort I osteotomy with interpositional bone grafts. The implant industry contributed to resolving the problem of bone height with the fabrication of zygomatic and short implants. Zygomatic implants are associated with some controversy and are not the topic of this paper. This article will focus on the treatment option of using short implants in the posterior upper jaw.

**Sinus Augmentation With Bone Grafting**

Prior to analyzing the evidence on use of short implants—as supported by the literature—it is important to mention the difficulties associated with sinus augmentation. This is the procedure of choice for surgeons that do not elect to use short implants or when short implants are contra-indicated. The maxillary subantral augmentation procedure (techniques of hinge osteotomy; lateral window; complete osteotomy), is a well-proven procedure that is used to increase the bone volume in the deficient molar maxilla. However, there are times that it is not prudent to proceed with such techniques due to chronic history of sinusitis, excessive tobacco abuse, pathologic lesions, odontogenic infections, and large prominent septa. If short implants can provide a successful alternative, then in some cases the operator will have more options when clinically judging the situation.

**CURRENT UPDATE ON SHORT IMPLANTS**

The minimal length for predictable success was always considered that of 10 mm and thus implants of this length are commonly referred to as “standard length implants.” As a result, any implant under 10 mm in length has come to be referred to as a “short” implant (Figures 1 through 4). Before freely advising the use of short implants, the authors decided to research the answers to the most commonly asked questions from other colleagues. For example, why would a surgeon offer this option when there are other proven methods of success? What are the advantages and what are the difficulties of short implants? How do they overcome certain challenges associated with their reduced length? Do they offer success rates comparable to those of “longer” implants?

**Advantages**

There are several advantages associated with the use of short implants as a treatment option in the severely resorbed posterior maxilla (Table 1). Patients don’t necessarily need to invest in additional pre-surgical diagnostic tests such as computerized tomography (CT) when perhaps “bone sounding” may prove adequate in cases where the sinus is to be avoided. Tests such as CT scans lead to additional costs, time, and radiation exposure. These scans are most commonly requested when investigating a borderline 10-mm implant case or when researching the option of a sinus augmentation surgery. In many cases, when the bone height is sufficient, short implants will allow the operator to avoid sinus lifts entirely, along with the complications and challenges associated with such procedures. In return, these advantages offer motivation to patients and an increased acceptance rate of implant-based treatment plans. Therefore, if it can be proven through the available follow-up clinical
studies that it is prudent to use short implants in certain scenarios, there will be an additional treatment option in the inventory of treatments for the implant surgeon.

**Disadvantages**

If we take into account the advantages mentioned in Table 1, it would seem reasonable to assume that short implants would be part of mainstream implant dentistry by now. However, there is still controversy on their indications due to several challenges that have been associated with them:

- Reduced implant surface; thus leading to less bone-to-implant contact after osseointegration.
Reduced surface of force distribution after loading; more pressure at the crestal bone; more resorption leading to more threads exposed, decreasing the surface of osseointegrated implant.

Compromised crown-to-implant ratio

So how can we overcome the challenges associated with short implants?

**Reduced Implant Surface**

The area of contact is determined by 4 factors: the length, diameter, taper, and texture of the implant surface. The average surface area of roots of a maxillary first molar is 533 mm$^2$, compared to 256 mm$^2$ for a threaded 18-mm Nobel Biocare implant. (polished 3.75-mm diameter implant). It seems logical, therefore, to always strive for the longest possible implant. If we consider that a root form implant is approximately cylindrical, the surface is grossly estimated by $2\pi r^2 + 2\pi rL$, where $L$ is the length in mm and "$r$" is the radius in mm. When the length or the radius increases, the surface area increases. However, in cases with compromised bone height where short implants seem to be the only solution, to compensate for a shorter length, a wider-diameter implant (5 mm) can be used. In fact, the use of a 5-mm diameter implant that is 6 mm long increases the surface area available to contact the bone similar to that of a 3.75-mm diameter implant that is 10 mm in length. To reduce the risk of failure of endosseous implants used in the posterior applications, wide-diameter implants have been suggested.

When studying the influence of diameter, length, and taper on strains in the alveolar crest with a three-dimensional finite-element analysis, the authors came to several conclusions. The same force (200 N vertical and 40 N horizontal) was applied to implants of different lengths (5.75 to 23.5 mm), diameters (3.5 to 6 mm), and taper (0 to 14 degrees). They found that increasing implant diameter resulted in as much as a 3.5-fold reduction in crestal strain, increasing length creates as much as a 1.65-fold reduction, and increasing taper increases the crestal strain as much as 1.65-fold, especially in narrow and short implants. The authors remind us that diameter sizes and lengths have to be considered together because of their interactive effects. In low-density bone, short, narrow, and taper implants should be avoid because

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**TABLE 1**

Advantages of short implants in the resorbed posterior maxilla

1. Minimizes the need for CT (when “bone sounding” is deemed adequate in determining ridge width and a sinus lift is going to be avoided), thus resulting in:
   - Lower cost
   - Less presurgical time
   - Less radiation exposure
2. Reduces indications for sinus lift procedures, thus reducing:
   - Costs for surgery and materials
   - Waiting period for treatment completion
   - Complications that result from advanced grafting procedures
3. Improves surgery options by not pressing the surgeon into placing the longest possible implant in borderline cases
   - Increases patient’s acceptability
   - Less surgeries involved
   - Lower costs
   - Fewer complications
   - Quicker rehabilitation time

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**FIGURE 4** A Branemark implant 7 mm in length and 5 mm wide by Nobel Biocare with a Ti-Unite surface. This implant has an external connection system; namely the “external hex.”
low-density cancellous bone already increases the strains around the implants.47–49 It was further found that the influence of the diameter on crestal bone strains dominates over the effects of the length and taper.

In addition, the surface area increases significantly simply by altering the texture configurations on rough implants. Rough implants offer extensive surfaces for osseointegration and therefore allow the clinician to consider usage of short implants with some confidence.39 A rough implant has a micro-texture that increases the surface area and the anchorage of the implant to the bone during osseointegration.50 The literature emphasizes the importance of the geometry of the implant, especially for a short implant placed in the posterior maxillary. In fact, it has been demonstrated by Bernard et al, who studied Branemark and ITI implants, that textured implants of various lengths offer a significantly stronger anchorage compared to machined implants.51 Increasing the diameter of the implant in a poor quality and quantity bone would be a way to increase tolerance of occlusal forces, to improve the initial stability and to provide favorable stress distribution to the surrounding bone. Wider implants have shown excellent clinical results in several studies that included the posterior jaw.52–56

CROWN-TO-IMPLANT RATIO AND OCCLUSAL FORCES

The crown-to-root ratio in human natural teeth has a mean value of 0.6 for maxillary teeth and 0.55 for mandibular teeth.57,58 In treatment planning of conventional fixed prosthetic restorations using natural teeth as abutments, Ante’s law dictates that “the combined peri-cemental area of all of the abutment teeth should be equal to or greater than the peri-cemental area of the teeth to be replaced.” As a result, clinicians would consider tripodization. However, in the posterior maxilla, there is usually natural resorption of the alveolar ridge as a result of prolonged edentulism that leads to an amplified inter-arch distance. The consequent limited available bone leads the implant practitioner to consider the option of short implants. This would lead to a poorer 1:2 implant-to-crown ratio. Surprisingly, the improvements of surfaces and implant systems, along with prosthetic occlusal adjustments, have allowed such ratios to be applied with success under certain criteria.40,59

The force in the premolar area is 61.4 N and 82.0 N in the molar area, while the occlusal table of a molar crown is approximately 96 mm², compared with 44 mm² for a 3.75 mm–wide implant.60 Simple math dictates that this would lead to challenging loading forces on the prosthetic table of a 3.75 mm–wide implant and to an increased buccolingual cantilever. Investigating such cases, Tawil et al placed 262 Branemark implants (10 mm or less in length) with machined surfaces in 109 patients to determine the influence of some prosthetic factors on the survival and complications rates.51 The patients were followed 12 to 108 months (mean, 53 months). They found no significant difference in the marginal bone loss that they could correlate with the crown-to-implant ratio. They concluded that when the load distribution is favorable, increased crown-to-implant ratios are not a major risk factor. The authors believed that short implants are long-term viable solutions in sites with reduced bone height, even when prosthetic parameters exceed the normal values, provided that force orientation and load distribution are favorable and parafunction is controlled. A reduced mesiodistal dimension of the prosthesis compared to the corresponding natural tooth would contribute to a more favorable load distribution, and potentially more successful results. The reduction of the occlusal table and the flattening of the cuspal inclines are principles used with periodontal prosthesis concepts that can be used in implant-supported prostheses. Nedir et al supported these observations in their 7-year study of ITI implants, where the implant-to-crown ratio ranged from 1.05 to 1.80, and no detrimental consequences on the final success rate were noted.60 Tripodization of implants in the posterior has also been suggested and strongly supported in the recent past.61 However, the overwhelming success rates of short implants replacing natural teeth suggests that tripodization may not be a significant factor for success any longer.

SHORT IMPLANT SUCCESS RATES

In order to study the success rate of short implants, many factors have to be considered (Table 2).

Because there are so many variables, it is difficult to compare the success rate of implants in different studies. Most of the articles don’t give all the data necessary to do a thorough systematic analysis of the successful and the failed implants. Nevertheless, it is interesting to look at the literature to see what final
results previous studies have obtained and their conclusions.

It has become apparent through reviewing the literature that the one improvement that had the most dramatic effect in improving implant treatments was the evolution of implant surfaces from machined/poised to rough-textured surfaces. We took this into account when evaluating the literature, and Table 3 provides some examples of implant success rates.

After studying the literature, it becomes evident that concerns regarding placement of implants under 10 mm in length have diminished due to the newly developed implant surfaces. It is reasonable to assume that with careful case selection criteria, the contemporary implant surgeon would be able to achieve long-term success rates that surpass the 90% mark. In fact, in most studies the success rates surpassed 95%, closely mimicking the success rates traditionally reserved for longer implants (although all mentioned studies had an average length of time of less than 10 years).

The aforementioned success rates become even more important when one considers the circumstances under which short implants are selected. For example, it is more likely that most of the short implants were placed in the posterior maxilla, where there commonly is less bone height available with poor bone quality.21 Poor bone quality is strongly linked to higher failure rates in implants, although rough surfaced implants nowadays have somewhat dampened this negative effect. In one of the few studies where length was assessed alone (implant system, implant width, and implant position were kept constant) as the only changing factor, Bahat found short implants to present with 90.5% success (length of observation was 5–70 months) compared to 96.2% for longer implants. However, the implants used were machined/polished. In a following study, when investigating the 10-year survivability of Branemark machined implants, he noted that when short (7 mm) implants were not stand-alone in free-end situations, they had similar success rates as the longer implants.

**DISCUSSION**

Perhaps clinicians should reconsider the way they view placement of short implants. Short implants can be a very successful alternative to sinus grafting (with subsequent placement of longer implants). However, there are several guidelines/suggestions that should be stressed. The most important aspect of implant treatment with short implants is “case selection.” For example, it would seem prudent to follow a 2-stage implant surgery approach when placing short implants, since this approach has been linked with higher success rates with short implants.39 It may also prove wise to avoid placing short implants in single molar cases in free-end situations but rather splint them to an additional implant (preferably longer), especially when placed in soft bone; type III or type IV. Soft bone is alone a risk factor, so coupling it with a single short implant only magnifies the potential problem. Most implant failures can be attributed to poor bone quality.40,65 Occlusion is a crucial factor in longevity of implant treatments. Maximal occlusal forces applied and tolerated vary greatly according to implant position in the arch, parafunctional habits of the patient (bruxism/clenching), and nature of the opposing dentition. Biomechanical overload can easily be rendered with high bending moments, unfavorable force distributions, and increased force magnitude regularly seen in the posterior region of the mouth.

<table>
<thead>
<tr>
<th>Table 2</th>
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<tbody>
<tr>
<td><strong>Various factors that need to be considered when selecting a case for placement of short implants</strong></td>
</tr>
<tr>
<td><strong>1. Patient</strong></td>
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<tr>
<td>Systemic medical condition</td>
</tr>
<tr>
<td>Smoking habit</td>
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<td>Periodontal health</td>
</tr>
<tr>
<td>Reason for tooth loss</td>
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<tr>
<td>Parafun&amp;</td>
</tr>
<tr>
<td><strong>2. Implants</strong></td>
</tr>
<tr>
<td>The type of fixture (subperiosteal, root from, hollow)</td>
</tr>
<tr>
<td>The implant system (Branemark, Nobel Replace, Straumann, Astra, 3i, MIS)</td>
</tr>
<tr>
<td>The surface (machined, rough)</td>
</tr>
<tr>
<td>The shape (straight, tapered)</td>
</tr>
<tr>
<td>Length</td>
</tr>
<tr>
<td>Diameter (wide, regular, narrow)</td>
</tr>
<tr>
<td><strong>3. Bone</strong></td>
</tr>
<tr>
<td>Bone quality (Type I to IV)</td>
</tr>
<tr>
<td>Position into the maxilla</td>
</tr>
<tr>
<td>Primary stability</td>
</tr>
<tr>
<td><strong>4. Surgery</strong></td>
</tr>
<tr>
<td>One or two stages/immediate loading</td>
</tr>
<tr>
<td>Bone augmentation technique (lateral augmentation or sinus lift [lateral window, osteotome])</td>
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<tr>
<td>Grafting material/membrane</td>
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<tr>
<td>Skills of the surgeon</td>
</tr>
<tr>
<td><strong>5. Prosthesis</strong></td>
</tr>
<tr>
<td>Splinted or not</td>
</tr>
<tr>
<td>Tooth-implant prosthesis</td>
</tr>
<tr>
<td>Cantilever</td>
</tr>
<tr>
<td><strong>6. Success/survival rate</strong></td>
</tr>
<tr>
<td>Definition of success rate</td>
</tr>
<tr>
<td>Definition of survival rate</td>
</tr>
<tr>
<td>Duration of the follow-up</td>
</tr>
</tbody>
</table>
Overloading may lead to loss of osseointegration and fracture of the implant or the superstructure. 66–68 When placing short implants, it has also become apparent from the literature that compensating with wider implants is the most reasonable approach.

**CONCLUSIONS**

The literature seems to show that there is good reason to contemplate the use of short implants even in the...

### TABLE 3

<table>
<thead>
<tr>
<th>Study</th>
<th>Implant Surface</th>
<th>Implant Length</th>
<th>Implants</th>
<th>Years after Loading the Implants</th>
<th>Success Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>van Steenberghe 1990</td>
<td>Machined</td>
<td>&lt;10 mm (short)</td>
<td>120</td>
<td>1 years</td>
<td>97.5%</td>
</tr>
<tr>
<td>Bahat 1993</td>
<td>Machined</td>
<td>&lt;10 mm (short)</td>
<td>Total of 732</td>
<td>0.5–6 years</td>
<td>90.5%</td>
</tr>
<tr>
<td>Buser et al 1997</td>
<td>Rough</td>
<td>&lt;10 mm (short)</td>
<td>389</td>
<td>8 years</td>
<td>96.2%</td>
</tr>
<tr>
<td>Winkler et al 2000</td>
<td>Mostly machined</td>
<td>&lt;10 mm (short)</td>
<td>814</td>
<td>3 years</td>
<td>91.4%</td>
</tr>
<tr>
<td>Friberg et al 2000</td>
<td>Machined</td>
<td>&lt;10 mm (short)</td>
<td>247</td>
<td>8 years</td>
<td>93.7%</td>
</tr>
<tr>
<td>Romeo et al 2002</td>
<td>Rough</td>
<td>&lt;10 mm (short)</td>
<td>11</td>
<td>Up to 7 years</td>
<td>92.3%</td>
</tr>
<tr>
<td>Ferrigno et al 2002</td>
<td>Rough</td>
<td>&lt;10 mm (short)</td>
<td>176</td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>Ibanez et al 2003</td>
<td>Rough</td>
<td>&lt;10 mm (short)</td>
<td>Total of 654</td>
<td>3 years</td>
<td>93.0%</td>
</tr>
<tr>
<td>Bergkvist et al 2004</td>
<td>Rough</td>
<td>Mostly ≥10 mm</td>
<td>146</td>
<td>2 years</td>
<td>99.2%</td>
</tr>
<tr>
<td>Fugazzotto et al 2004</td>
<td>Rough</td>
<td>&lt;10 mm (short)</td>
<td>979</td>
<td>Up to 7 years</td>
<td>96.6%</td>
</tr>
<tr>
<td>Griffin et al 2004</td>
<td>Rough</td>
<td>&lt;10 mm (short)</td>
<td>168</td>
<td>Up to 6 years</td>
<td>95.1%</td>
</tr>
<tr>
<td>Nedir et al 2004</td>
<td>Rough</td>
<td>&lt;10 mm (short)</td>
<td>111</td>
<td>1–7 years</td>
<td>100%</td>
</tr>
<tr>
<td>Renouard et al 2005</td>
<td>Rough</td>
<td>&lt;10 mm (short)</td>
<td>417</td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>Bischof et al 2006</td>
<td>Rough</td>
<td>≥10 mm</td>
<td>42</td>
<td>3 years</td>
<td>99.3%</td>
</tr>
<tr>
<td>Misch et al 2006</td>
<td>Rough</td>
<td>≥10 mm</td>
<td>102</td>
<td>1–5 years</td>
<td>97.6%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥10 mm</td>
<td>161</td>
<td></td>
<td>98%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥10 mm</td>
<td>745</td>
<td>1–5 years</td>
<td>100%</td>
</tr>
</tbody>
</table>

Overloading may lead to loss of osseointegration and fracture of the implant or the superstructure. 66–68 When placing short implants, it has also become apparent from the literature that compensating with wider implants is the most reasonable approach. Crucial decision-making factors are summarized in Table 4. Dentists should carefully consider these—along with other factors they deem necessary—prior to making final decisions in their treatment plans. 43

### TABLE 4

<table>
<thead>
<tr>
<th>Factors Influencing Our Decision</th>
<th>Suggestions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single implant case</td>
<td>Perhaps a second molar does not need to be replaced all together and the patient can function with first molar occlusion. If a first molar is missing as well, then we should consider splitting a short implant to an additional implant or placing a longer implant after sinus augmentation.</td>
</tr>
<tr>
<td>Diameter of implant</td>
<td>If the clinician chooses a short implant, then he or she should strive to place the widest possible fixture. Short and narrow platform implants have not yet been proven through the literature as stand-alone implants.</td>
</tr>
<tr>
<td>Bone quality</td>
<td>When suspecting or encountering poor bone quality, consider altering our protocol (eg, wait longer prior to loading, consider additional implant, two-stage surgery).</td>
</tr>
<tr>
<td>Opposing dentition</td>
<td>There is a different level of occlusal forces when the opposing dentition is natural dentition than when it’s a removable prosthesis.</td>
</tr>
<tr>
<td>Parafunctional habits</td>
<td>Should be addressed with fabrication of a night-guard as part of the treatment plan and long-term maintenance.</td>
</tr>
<tr>
<td>Surgical approach</td>
<td>Consider a two-stage surgical approach, allowing the short implant undisturbed osseointegration.</td>
</tr>
<tr>
<td>Osseointegration period</td>
<td>Allow longer periods for osseointegration and avoid immediate loading (unproven in the literature with short implants).</td>
</tr>
<tr>
<td>Surgical protocol</td>
<td>Site preparation has to be precise with least possible number of entries and minimal soft tissue trauma to allow best possible vascularity and quicker and superior healing. In addition, screw tapping should be avoided (unless proven necessary) since it could over-enlarge the osteotomy site.</td>
</tr>
<tr>
<td>Primary stability</td>
<td>Strive for primary stability under the ideal torque range as suggested by the implant company (eg, 35–45 Ncm is most commonly suggested)</td>
</tr>
<tr>
<td>Maintain hopeless teeth till loading</td>
<td>Consider maintaining some of the teeth that you have planned for extraction temporarily to provide support for a potential fixed provisional prosthesis and avoid transmucosal loading of the implants.</td>
</tr>
</tbody>
</table>

The literature seems to show that there is good reason to contemplate the use of short implants even in the
posterior maxilla. It is an option we should always consider and offer to the patient. The literature is not always consistent, but many recent studies show that short implants can be quite predictable and have a success rate similar to longer implants. The research on implants is very active, and it seems that the tendency to use shorter implants will become more and more accepted. Clinicians still have to be cautious and to select their cases safely and carefully.

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