Nongrafting Implant Options for Restoration of the Edentulous Maxilla

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Patients who need implant-supported prostheses in the maxilla might not have sufficient bone height in the posterior region for implants. Treatment alternatives in such cases include either bone graft augmentation followed by implants or nongrafting options. This report discusses 2 nongrafting options for prosthetic rehabilitation in these patients. An extensive summary of the published data has been performed to provide evidence for these recommendations.

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Patients with an atrophic maxilla present with complex problems for the restorative dentist. The treatment can include augmentation grafting procedures to re-establish lost bone and to provide bone bulk for an implant-supported prosthesis.1 Augmentation procedures such as crestal onlay grafting,2,3 inlay grafting to the maxillary antrum and nasal floor,4,5 Le Fort I osteotomy with interpositional grafting,6-10 and distraction osteogenesis have been used to reconstruct the atrophic edentulous maxilla before implant placement for an implant supported restoration.11

Although complications are few, autogenous bone grafting procedures produce postoperative pain and scarring and can result in donor site neurosensory disturbances, gait disturbance, and the need for recovery time, and have the potential for donor site infection.12-15 Furthermore, autogenous grafting requires an additional surgical site that increases the hospital costs, time away from work, and adds to the overall treatment time. Autogenous grafts have shown variable degrees of resorption with implant success rates of 87% to 95%.14,16,17 When presented with these factors, patients would prefer a nonautogenous grafting treatment alternative.

Keller et al18 performed a retrospective study of 118 maxillary inlay autogenous bone grafts and 248 endosseous implants placed in 54 consecutive patients with severely atrophic maxillas during a 12-year period. The success rate for the 248 endosseous implants placed into the grafted maxillas was 87%, with a mean follow-up of 57.1 months.18 In 2001, Brånemark et al19 presented their long-term results with autogenous onlay bone grafting and simultaneous endosseous implant placement. The success rate of the original endosseous implants was 80%, with follow-up of 2 to 15 years.

Widmark et al20 found that maxillary implants placed in native bone had a greater success rate than implants placed into grafted bone. After 1 year, the success rate for implants placed into the grafted maxillas was 82%, but implants placed into native bone had a 96% success rate. At the 3- to 5-year follow-up examinations, the corresponding implant success rates were 74% and 87%, Rasmussen et al,21 using a rabbit model, found similar results.

The morbidity from autogenous bone harvesting, the social problems when patients are advised to avoid wearing their removable dentures, and the common 1-year delay from grafting (either autogenous or nonautogenous) to final restoration, all are motivating factors that led to the development of a nongrafting...
option for the edentulous patient with an atrophic maxilla. This report reviews the evidence-based literature on the use of zygomatic or angled implants, without grafting, in such cases.

**Zygomatic Implants as Alternative to Sinus Grafts**

**ZYGOMATIC IMPLANT LITERATURE REVIEW**

Zygomatic implants were described in 1988 by Bränemark,22 (Nobel Biocare, Goteborg, Sweden) as an alternative to grafting procedures in the severely atrophic maxillae. Zygomatic implants can be used in situations in which adequate anterior maxillary bone is available to support conventional implant placement but minimal posterior maxillary bone is present.1 In addition toplacement of bilateral zygomatic implants in the molar/premolar regions of the maxilla, the placement of 2 to 4 conventional dental implants in the anterior maxilla allows cross arch bar fabrication, which provides mechanical stability and retention for an implant-supported fixed prosthesis without the need for grafting procedures.23-27

**ADVANTAGES OF ZYGOMATIC IMPLANTS**

The potential advantages of zygomatic implants are numerous compared with bone graft augmentation combined with placement of traditional endosseous implants in the posterior maxilla. As described, donor site morbidity is eliminated because no additional grafting procedures are necessary, provided adequate anterior maxillary bone is present. By eliminating bone grafting in the posterior maxilla, zygomatic implants reduce the total treatment time. Van Steenberghe et al5 noted that traditional endosseous implants placed at maxillary grafting have a success rate in the posterior maxilla of about 80% to 90%. Zygomatic implants have a success rate of 90% to 100% (Table 1).

Sinus grafting with delayed traditional implant placement requires 6 months of healing before the placement of traditional dental implants. Simultaneous implant placement and grafting can result in a 6-month period to restoration, but it is limited to those patients with sufficient posterior bone for immediate implant stabilization. The nongrafting option requires only the time for implant integration before restoration and, hence, a shorter period from implant placement to eventual restoration.

Zygomatic implants placed with 2 to 4 traditional premaxillary implants can be either immediately loaded, or, more traditionally, a final fixed prosthesis can be placed after a 6-month healing period. Thus, the total treatment time is routinely 6 months or less for zygomatic implants compared with grafting with subsequent implant placement. Zygomatic implants allow the patient to convert his or her pre-existing maxillary denture into a temporary removable prosthesis after a soft tissue reline or into an immediately loaded fixed provisional acrylic resin prosthesis.1

Zygomatic implants do not necessarily require hospitalization, which is usually needed for autogenous bone harvesting from the iliac crest. The use of bone from the jaws, allograft, or xenograft bone can also be performed in an office setting, but these grafts do require up to 6 months for bone formation before implant placement. Fewer implants are required to support a prosthesis compared with traditional bone grafting and implant placement.11,22,25,28,30 The overall laboratory fees are equal to or slightly less than those for traditional implants.36

**DISADVANTAGES**

One disadvantage is that the surgeon must be trained to place a zygomatic implant. This training requires the doctor to leave the office setting and travel to a distant course.

The main disadvantage of the zygomatic implant is related to the perceived difficulty in implant placement and the palatal emergence profile. Because the platform of the zygomatic implant might be palatal to the crest, the perception is that the patient will feel excess bulk and have problems with the prosthesis. However, this has not been reported to be a critical factor in the ultimate successful restoration of the patient.

The restorative dentist must have the clinical proficiency to fabricate a full arch implant-supported prosthesis, which could exclude dentists who do not have the clinical experience with this type of prosthesis.

The placement of the zygomatic implant is limited by the anatomy of the zygoma.31 In patients with concave lateral walls of the maxilla, surgical placement of the zygomatic implant within the bone might be difficult. The surgical access to the zygoma and orbital rim requires a surgeon who has experience with surgery in this area.22,26,29,32

Because of the palatal emergence of the implant platform, the restorative plan must include a retentive attachment, with the limitations of obvious bulk.1 The palatal emergence profile requires the retentive bar to be slightly palatal in position and might be difficult to place within a screw-retained prosthesis.35 A prosthesis can be fabricated that minimizes primary occlusal contact on the buccal cusps, thus decreasing the cantilever effect.24

The reported complications associated with zygomatic implants include postoperative sinusitis, oroantral fistula formation, periorbital and conjunctiva hematoma or edema, lip lacerations, pain, facial edema,
<table>
<thead>
<tr>
<th>Reference</th>
<th>Patients (n)</th>
<th>Zygomatic Implants (n)</th>
<th>Follow-Up (mo)</th>
<th>Success Rate (%)</th>
<th>Smokers</th>
<th>Complications</th>
<th>Restorations</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>81</td>
<td>164</td>
<td>12-120</td>
<td>160/164 (97)</td>
<td>?</td>
<td>2 ZIs needed custom abutments</td>
<td>Fixed hybrid prosthesis</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>22</td>
<td>44</td>
<td>34</td>
<td>44/44 (100)</td>
<td>?</td>
<td>Multiple</td>
<td>Multiple</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>55</td>
<td>103</td>
<td>≤48</td>
<td>103/103 (100)</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>45</td>
<td>77</td>
<td>6-30</td>
<td>77/77 (100)</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>9</td>
<td>15</td>
<td>17-47</td>
<td>15/15 (100)</td>
<td>100%</td>
<td>Difficult to clean, articulation difficulty for several weeks due to prosthesis suprastructure</td>
<td>Used varied head angulations of ZI</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>28</td>
<td>52</td>
<td>60-120</td>
<td>49/52 (94)</td>
<td>77/106 (73)</td>
<td>2 mobile at abutment connection/1 lost at 6-y follow-up</td>
<td>Fixed prosthesis</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>16</td>
<td>25</td>
<td>?</td>
<td>24/25 (96)</td>
<td>80/80 (100)</td>
<td>1 ZI failed to integrate; patient had chronic sinusitis noted on radiographic evaluation</td>
<td>?</td>
<td>No cross-arch stabilization</td>
</tr>
<tr>
<td>14</td>
<td>1</td>
<td>2</td>
<td>18</td>
<td>2/2 (100)</td>
<td>6/6 (100)</td>
<td>No</td>
<td>None</td>
<td>Only 1 patient</td>
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<tr>
<td>38</td>
<td>24</td>
<td>37</td>
<td>12</td>
<td>36/37 (97)</td>
<td>?</td>
<td>3 ZIs removed after period of loading in patients with acute and/or chronic sinusitis that did not resolve with treatment</td>
<td>Fixed bridges Gingivitis 9/16; fistula 5/16; sinusitis 6/16</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>16</td>
<td>31</td>
<td>9-69</td>
<td>28/31 (90)</td>
<td>71/74 (96)</td>
<td>?</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>5</td>
<td>10</td>
<td>12-18</td>
<td>10/10 (100)</td>
<td>18/18 (100)</td>
<td>1/5</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>10/10 (100)</td>
<td>20/20 (100)</td>
<td>?</td>
<td>None</td>
<td>1 ectodermal dysplasia patient</td>
</tr>
<tr>
<td>25</td>
<td>69</td>
<td>131</td>
<td>6-60</td>
<td>131/131 (100)</td>
<td>302/304 (99)</td>
<td>27/69</td>
<td>Fixed full-arch bridge</td>
<td>All immediate loaded</td>
</tr>
<tr>
<td>Reference</td>
<td>Patients (n)</td>
<td>Zygomatic Implants (n)</td>
<td>Follow-Up (mo)</td>
<td>Success Rate (%)</td>
<td>Smokers</td>
<td>Complications</td>
<td>Restorations</td>
<td>Other</td>
</tr>
<tr>
<td>-----------</td>
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<td>--------------</td>
<td>-------</td>
</tr>
<tr>
<td>36</td>
<td>14</td>
<td>28</td>
<td>12-34</td>
<td>28/28 (100)</td>
<td>?</td>
<td>None</td>
<td>Fixed provisional prosthesis</td>
<td>All immediate loaded</td>
</tr>
<tr>
<td>11</td>
<td>11</td>
<td>22</td>
<td>18-46</td>
<td>22/22 (100)</td>
<td>7/11</td>
<td>Sinus discomfort 3/11 (1 underwent antrostomy)</td>
<td>Fixed prosthesis, 7/11 had natural opposing teeth</td>
<td>Smokers quit 2 mo before surgery and during healing phase</td>
</tr>
<tr>
<td>31</td>
<td>18</td>
<td>34</td>
<td>≥6</td>
<td>32/34 (94)</td>
<td>?</td>
<td>2 of 34 ZIs failed due to recurrent sinusitis 7.1 mo after placement</td>
<td>Fixed bridges and overdentures</td>
<td>Only 10/18 had severely resorbed maxilla, others were CLP/trauma</td>
</tr>
<tr>
<td>27</td>
<td>13</td>
<td>25</td>
<td>11-49, after loading</td>
<td>25/25 (100)</td>
<td>?</td>
<td>3/13 suborbital hematomas; 1/13 burn to lip</td>
<td>?</td>
<td>2/13 CLP, 2/13 had bruxism</td>
</tr>
<tr>
<td>1</td>
<td>60</td>
<td>145</td>
<td>36, after loading</td>
<td>140/145 (96)</td>
<td>15/76 (20)</td>
<td>Sinusitis 14/60; fistula 3/60; persistent paresthesia to RT IAN after 3 y; follow-up 1/60</td>
<td>?</td>
<td>5% had radiation to head and neck, 29% had serious ongoing or previous illness</td>
</tr>
<tr>
<td>30</td>
<td>4</td>
<td>8</td>
<td>9-24</td>
<td>8/8 (100)</td>
<td>14/14 (100)</td>
<td>?</td>
<td>3 fixed, 1 removable prosthesis</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>12</td>
<td>48</td>
<td>30</td>
<td>46/48 (95)</td>
<td>NA</td>
<td>1 implant failed at 6 mo from rotational mobility; 1 implant removed at 30 mo for rotational mobility</td>
<td>Fixed</td>
<td>Immediate loading and 2 ZIs per side (4 per patient); 2/12 had orbital penetration</td>
</tr>
<tr>
<td>32</td>
<td>21</td>
<td>40</td>
<td>12-45</td>
<td>40/40 (100)</td>
<td>?</td>
<td>Maxillary sinusitis 2/21</td>
<td>20 complete fixed screw retained prosthesis, 1 partial fixed</td>
<td>1 had ectodermal dysplasia</td>
</tr>
</tbody>
</table>

Total 529 1041 6-120 1020/1041 (98) 844/888 (95)

Abbreviations: ZI, zygomatic implant; CLP, cleft lip/cleft palate; RT IAN, right inferior alveolar nerve; NA, not applicable.

temporary paresthesia, epistaxis, gingival inflammation, and orbital penetration/injury.\textsuperscript{17,24,25} The low incidence of these complications is described in Table 1.

Postoperative concerns regarding difficulty with articulation and hygiene caused by the palatal emergence of the zygomatic implant and its effect on the prosthesis suprastructure have been reported due to the emergence of the zygomatic implant platform.\textsuperscript{15,26}

Although the palatal emergence of the implant does add to the difficulty of maintaining oral hygiene, minimal long-term phonetic sequelae from the prosthesis design have been reported.\textsuperscript{24,28}

**SURGICAL TECHNIQUE**

The surgical technique for placing the zygomatic implants includes exposure of the lateral aspect of the maxilla, with exposure of the orbital rim and zygomatic process. Traditionally, the sinus membrane is elevated to prevent trapping the membrane between the implant and the bone. The implant site is developed by drilling a hole through the alveolus and entering the zygoma from within the sinus, exiting through the posterior aspect of the zygoma. The length of the implant is then chosen, and the implant is placed. Implant integration requires 6 months, followed by exposure and cross arch stabilization of the implants, in combination with anteriorly placed dental implants.\textsuperscript{24}

**SUMMARY OF REPORTED ZYGOMATIC IMPLANT EXPERIENCE**

Table 1 provides a summation of the published data documenting the success and failure with zygomatic implants. The success rate of zygomatic implants placed in atrophic edentulous posterior maxillas is reported to be 90% to 100%. Brånemark et al\textsuperscript{24} reported a long-term study of 52 zygomatic implants placed in 28 consecutive patients with a minimal follow-up of 5 years and a maximal follow-up of 10 years. Of the 52 zygomatic implants, 3 failed, for a 94% success rate.

Kahner et al\textsuperscript{1} reported 145 zygomatic implants with 3 years of follow-up. Of the 145 implants placed, 5 failed, for a success rate of 96.3%. Penarrocha et al\textsuperscript{32} reported 40 zygomatic implants placed in 21 patients, with no failed zygomatic implants and a mean follow-up of 29 months. Boyes-Varley et al\textsuperscript{35} reported 77 zygomatic implants in 45 patients and recorded no failures with a follow-up of 6 to 30 months. Malevez et al\textsuperscript{34} documented a survival rate of 100% with 103 zygomatic implants placed in 55 edentulous patients with a follow-up of up to 48 months. Aparicio et al\textsuperscript{25} placed 131 zygomatic implants in 69 consecutive patients with severe maxillary atrophy during a 5-year period. During a follow-up period of 6 to 60 months, none of the zygomatic implants failed.

As summarized in Table 1, the literature review revealed more than 1,000 zygomatic implants placed in more than 500 patients. Implants placed in severely atrophic and resorbed edentulous posterior maxillas were primarily included in this review of the literature. Most of the implants placed included single bilateral zygomatic implants and 2 to 4 traditional implants placed in the anterior maxilla. One study reported double bilateral zygomatic implants without additional anterior implants. Excluding maxillectomies, tumor ablative reconstructions, cleft palate, and ectodermal dysplasia, zygomatic implants have had a success rate of 98% with 10 months to 10 years of follow-up.

Three reports included the placement of zygomatic implants in smokers, without an increase in the complication or failure rates of the implants.\textsuperscript{11,27-35} Ahlgren et al\textsuperscript{27} reported on 25 zygomatic implants placed in 15 patients; all but 2 were smokers. The success rate of the zygomatic implants was 100% (25 of 25) with a follow-up of 11 to 49 months after loading. Aparicio et al\textsuperscript{25} reported 69 consecutive patients who had received 131 zygomatic implants. Of the 69 patients, 27 smoked 20 or more cigarettes a day, and they reported no failures with a follow-up of 6 months to 5 years.

Duarte et al\textsuperscript{17} reported on immediately loading bilateral zygomatic implants in 12 patients. With a follow-up of 30 months, 2 of the 48 zygomatic implants had failed. The prosthesis was totally zygomatic implant supported with no conventional implants.\textsuperscript{17}

Bedrossian et al\textsuperscript{36} reported on 14 patients who had received bilateral zygomatic implants and 55 premaxillary implants. The premaxillary implants were placed in the area of the canines and central incisors, and the zygomatic implants were placed in the area of the second premolars. The zygomatic implants were immediately loaded. The patient’s pre-existing maxillary denture was converted to a fixed provisional acrylic resin prosthesis within 2 hours of implant placement. None of the implants failed; however, the follow-up was only 12 months.\textsuperscript{36}

Chow et al\textsuperscript{37} immediately loaded 10 zygomatic implants with a follow-up of 10 months and recorded no failures. Similar to traditional dental implants, zygomatic implants also have the restorative option of allowing patients to use their pre-existing/old maxillary denture during the interim healing phase after a reline, which removes pressure over the healing screws.

**PROSTHETIC CONSIDERATIONS**

The splinting of 2 to 4 anterior implants with bilateral zygomatic implants with a rigid bar allows for the equal distribution of occlusal forces along the curvature of the prosthesis. The zygoma absorbs most of
the posterior occlusal forces, and the premaxillary implants absorb the anterior occlusal load, thus effectively reducing the adverse masticatory loading and cantilever effects of the long lever arm of the zygomatic implant. This decreases the excessive lateral and rotational forces, which will increase the chances of implant failure.\textsuperscript{31} Brånemark’s original report advocated the use of cross arch stabilization to distribute the masticatory loads evenly between the bilateral zygomatic arches and the anterior maxillary bone.\textsuperscript{22}

**CONCLUSIONS FOR ZYGOMATIC IMPLANT NONGRAFTING OPTION**

The clinical reports cited in the present report indicate that the zygomatic implant success rate is excellent and at least equal to that for grafting options combined with implants. This option provides the patient with an implant-supported restoration without the need for sinus intervention.

**Angled Implants as Alternative to Sinus Grafting**

Alternatives to bone grafting techniques for prosthetic restoration of the edentulous maxilla include zygomatic implants and, more recently, angled implants, which avoid grafting procedures that some patients might be reluctant to undergo. Although zygomatic implants require more extensive surgical training, the placement of angled implants requires minimal special training other than traditional implant placement methods. For this report, the term “angled implant” refers to implants placed at angles that often are 30 degrees or greater from the traditional vertical or axially directed implants.

The theoretical success of angled implants is based on the following principles:\textsuperscript{42}

1. The use of longer implants, allowing for more implant surface to bone contact.
2. Anchorage of 1 or more cortices, allowing for immediate implant stabilization.
3. Prosthetic rehabilitation can be directed more posteriorly, allowing for a more even load distribution throughout the arch.

The use of tilted implants eliminates the potential complications associated with donor site graft harvest morbidity and the complications directly related to sinus surgery. Nine studies reporting on the use of angled implants for maxillary reconstruction have been critically reviewed and are summarized in Table 2. The number of patients, number of implants, time of loading, number of implants lost, reason for implant loss, overall survival rate of angled versus axial im-

**Table 2. SUMMARY OF ANGLED IMPLANT REFERENCES**

<table>
<thead>
<tr>
<th>Reference</th>
<th>Patients (n)</th>
<th>Angled Implants (n)</th>
<th>Follow-Up</th>
<th>Success Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA</td>
<td>49</td>
<td>44</td>
<td>82</td>
<td>80/82 (97.5)</td>
</tr>
<tr>
<td>NA</td>
<td>48</td>
<td>32</td>
<td>1 y</td>
<td>61/64 (95.3)</td>
</tr>
<tr>
<td>NA</td>
<td>47</td>
<td>18</td>
<td>1 y</td>
<td>40/42 (95.3)</td>
</tr>
<tr>
<td>NA</td>
<td>51</td>
<td>41</td>
<td>82</td>
<td>80/82 (97.5)</td>
</tr>
<tr>
<td>NA</td>
<td>43</td>
<td>15</td>
<td>86</td>
<td>39/42 (92.8)</td>
</tr>
<tr>
<td>NA</td>
<td>50</td>
<td>19</td>
<td>103</td>
<td>100/103 (97)</td>
</tr>
</tbody>
</table>

**Abbreviation:** NA, not applicable.

plants, prosthetic success, and length of follow-up are summarized.

**ANGLED IMPLANT LITERATURE REVIEW**

Nonaxial loading of implants was previously considered to inhibit adequate osseointegration. ten Bruggen et al.\(^4\) described angled implants with tissue-supported overdentures and fixed restorations of the partially edentulous posterior maxilla. Celletti et al.\(^4\) confirmed that nonaxially loaded implants achieved integration and were functional successful after 1 year of loading, with no adverse effect on the surrounding bone or soft tissue.

In 1999, Mattsson et al.\(^4\) described a surgical technique for restoring the severely resorbed edentulous maxilla with a fixed restoration without grafting the alveolus or maxillary sinus. Their study included 15 patients who received 4 to 6 implants, all angled, for a total of 86 implants. The surgical technique involved raising a mucoperiosteal flap and exposing the anterior lateral wall of the maxillary sinus and the nasal piriform aperture. A fenestration was made in the anterior sinus to locate the lateral nasal wall. Bilaterally, posterior implants were placed at an angle parallel to the anterior wall of the sinus. Additional axial implants were placed into the anterior maxilla in a vertical orientation compared with the posterior implants. One or 2 implants were then placed more mesially at an angle to engage the nasal spine or cortical bone of the nasal cavity. The patients were not allowed to wear their removable prosthesis for 2 weeks. The implants were uncovered 6 months after placement, and all patients were restored with a fixed restoration. The patients were followed up for 36 to 54 months. One implant was lost at the time of uncovering owing to poor osseointegration. The overall survival rate of the implants was 98.8%, and the prosthetic success rate was 100%. In their preliminary study, the investigators concluded that the use of angled implants could be a cost-effective alternative to traditional bone grafting techniques for restoring the completely edentulous maxilla.\(^4\)

Krekmanov et al.\(^4\) reported on angled implants in the mandible and maxilla. For the present review, only the maxillary implants were included. Their objective was to modify the traditional method of implant placement in the posterior jaws and still provide distal support for fixed prostheses to avoid cantilevering and grafting. Twenty-two patients received 138 implants, with 40 of the implants placed at an angle. Their study used an open technique with a sinus fenestration to locate either the anterior or posterior wall of the maxillary sinus. The most posterior implants were placed along either the anterior or posterior sinus wall at approximately 30 to 35 degrees of angulation. A 2-stage protocol was used, with implant uncovering 6 months after placement. The implants were loaded 1 day to 3 weeks after abutment placement. Implant bone level measurements were taken at follow-up, ranging from 1 to 5 years after loading. The implants were classified as successful if they remained stable with less than 2 mm of bone loss after loading. The implants were classified as surviving if they remained stable with more than 2 mm of bone loss after loading. One angled implant and 6 axial implants were lost. All the failed implants were lost after loading. The angled implants had an overall success rate of 95.7% and an overall survival rate of 97.5%, and the axial implant had an overall success rate and overall survival rate of 92.5% and 93.8%, respectively. The overall prosthetic success rate was 100%. Complications included early incision dehiscence and less accessibility of the tilted implants. The investigators concluded that the use of tilted implants for the treatment of edentulous arches with posterior resorption eliminated the need for advanced techniques and presented a good alternative to these techniques.

Angled implants have been used engaging both the piriform region and the posterior maxilla. Krekmanov\(^4\) reported on 22 patients who received a total of 75 implants, with 42 implants angled. Two patients were loaded within 2 weeks. The remaining patients were loaded after 4 to 6 months, with abutment placement as a second-stage procedure. Three angled implants before loading and 1 angled implant after loading were lost. No axial implants were lost. The follow-up ranged from 1 to 10 years. The overall survival rate in the angled and straight implants was 92.8% and 100%, respectively. The overall prosthetic success rate was 100%. Krekmanov\(^4\) postulated that cortical bone contact seemed to be directly linked to the survival of the angled implants.

Aparicio et al.\(^4\) used straight and angled implants as a treatment option to sinus grafting in patients with partially edentulous posterior maxillas. They reported on 25 patients with 101 implants, with 42 implants placed at an angle. Six patients were smokers. The angled implants were placed in the tuberosity/pterygoid area, palate, mesial sinus wall, and nasal pyriform areas. The implants were allowed to osseointegrate for 6 to 8 months and then uncovered and loaded with fixed restorations. The patients were followed up for 21 to 87 months. The implants were evaluated clinically, radiographically, and using the Periotest. The success and survival rates were determined as per Albrektsson et al.\(^4\) Two of the axial implants failed before loading. None of the angled implants failed. Three of the axial and 2 of the angled implants were classified as surviving but not successful. The axial implants had a success rate of 95%, and the angled implants had a success rate of 95.2%. On the basis of
their results, the investigators believed that partial edentulism in the posterior maxilla with insufficient bone for traditional implant placement could be restored with a combination of axial and angled implants and that angled implants were a viable alternative to sinus grafting.

Immediate loading of angled implants, combined with axially directed implants, has been reported. Calandriello and Massimiliano reported on 18 patients who had received a total of 60 implants, of which 27 were angled. Immediate loading was used with a screw- retained prosthesis on the same day or within 3 days. One each of the axial and angled implants failed, for an overall survival rate of 97% and 96.3%, respectively. The implants failed because of fractured provisions, which allegedly caused micromotion and prevented osseointegration. The overall survival rate for the implants was 96.7%, and the prosthetic success rate was 100%.

Malo et al evaluated an immediate function protocol for complete maxillary arch reconstruction with a fixed restoration supported by 4 implants. The report included 32 patients who had received 128 implants. Each patient received 2 angled and 2 axial implants, for a total of 64 axial and 64 angled implants. An open surgical technique was used in their study. Each of the posterior implants was placed tangential to the anterior sinus wall at an angle of 30 to 35 degrees. Two anterior implants were placed axially, mesial to the posterior implants. The implants were placed at a torque of 40 N-cm. A provisional fixed acrylic restoration was delivered within 3 hours after implant placement. The first 22 patients also received 51 rescue implants. These implants were not immediately loaded and were used in the case of implant failure or were included in the final prostheses. The patients without rescue implants received their final prosthesis at 6 months after implant placement. The patients who had received rescue implants received their final prosthesis 12 months after initial implant placement. Follow-up examinations were performed 6 months and 1 year after implant placement. Clinical and radiographic examinations were performed. The implants were classified as surviving according to routine implant evaluation methods. Three angled implants failed. None of the axial implants failed. Two of the angled implants failed because of heavy bruxism and one failed owing to poor osseointegration and mobility. The survival rate for the straight and angled implants was 100% and 95.3%, respectively. The overall survival rate was 97.6%. The prosthetic success rate was 100%. Marginal bone loss was 0.9 mm on average, and no difference was found between the axial and angled implants. The investigators believed that immediate loading using 2 angled and 2 axial implants to restore the edentulous maxilla is a viable treatment alternative to sinus grafting. Malo et al confirmed these results in 2006. In this report, 16 of the 44 patients were smokers. Most of the prostheses were supported by 4 implants. A total of 166 implants were placed, with 82 of the implants placed at an angle along the anterior maxillary sinus wall using an open sinus technique. The implants were immediately loaded with provisional acrylic prostheses on the day of surgery. The final fixed restoration was delivered 12 months after implant placement. The patients were followed up for 1 year. Two implant failures were both angled implants. Both failures were replaced with implants that survived and were included in the final prostheses. The survival rate of the straight and axial implants was 100% and 97.5%, respectively, with an overall survival rate of 98.7%. The prosthetic success rate was 100%. No difference was found between angled and axially directed implants regarding marginal bone loss during the observation period.

Rosen and Gynther, using the prosthetic protocol of Mattsson et al, confirmed positive results with smokers. Six patients were smokers. The patients were followed up clinically and radiographically for 8 to 12 years. A total of 3 implants in 2 patients were lost during the follow-up period, for an overall survival rate of 97%. The other patients had all their implants restored with fixed prostheses. The overall prosthetic success rate was 90%. Complications included mucositis with sinusitis, speech problems, and esthetic problems with the restoration. This long-term follow-up provided evidence that the use of angled implants in patients with severely atrophic posterior maxillas is a viable and evidence-based option compared with bone grafting.

Tiziano et al evaluated the treatment outcomes of immediate loaded maxillary full arch fixed restorations with the use of axial and angled implants and compared the clinical success rates of axial versus angled implants in the partially edentulous patient. The patients were evaluated at 1 month, 3 months, 6 months, 1 year, and yearly for up to 5 years. Of the 164 axial implants, 3 failed, for a survival rate of 97.9%. Of the 82 angled implants, 2 failed, for a survival rate of 97.1%. The prosthetic success rate was 100%. No difference was found in the marginal bone loss in the 2 groups at 1 year after placement.

Table 2 lists the references with the clinical data presented. The angled implants had an overall success rate of 96.5% and the straight implants, a 97% success rate. It appears that the published data support the use of angled implants combined with axial (straight) implants for implant supported implant prostheses.
ADVANTAGES TO ANGLED IMPLANTS FOR IMPLANT-SUPPORTED PROSTHETIC REHABILITATION

The data to date strongly suggest that the use of angled implants with or without axially loaded implants for the reconstruction of partially and/or completely edentulous atrophic maxillae presents an excellent treatment alternative to conventional sinus bone grafting. It was believed that nonaxially loaded implants would fail because of the unfavorable forces applied to the implant and surrounding bone. However, this theory has been disproven by Celletti et al. and others, especially when using multiple implants to distribute the load.

Angled implants appear to be successful owing to several factors described in multiple studies. Longer implants can be used, providing more surface area for osseointegration. The longer implants engage more than 1 cortical plate, which allows for excellent initial implant stability. Angled implants also provide more posterior support, avoiding distal cantilevers and allowing for more widespread load distribution throughout the arch. Angled implants eliminate the need for sinus grafting and possible need for a donor site, along with the donor site complications and morbidity. Although all the surgical protocols reviewed in the present study used an open surgical technique with sinus openings, advances in computed tomography-guided technology might eliminate the need for the open surgical technique completely. Although traditional grafting techniques are an excellent treatment option, the use of angled implants provides the clinician with a viable alternative to traditional techniques for those patients with limited resources or those patients who might not be amenable to sinus procedures.

Angled implants can be placed in the office setting with minimal patient morbidity. The use of computerized-guided surgery might allow angled implant placement without the need for incisions or flaps, thus further decreasing patient morbidity compared with grafting options.

DISADVANTAGES TO ANGLED IMPLANTS FOR IMPLANT-SUPPORTED PROSTHETIC REHABILITATION

The placement of angled implants, combined with 2 axially directed implants in the anterior maxilla, requires long implants and proper prosthetic coordination. The clinical evidence found in the literature seems convincing that the forces placed on these 4 implants, with cross arch stabilization, can result in adequate function. The period of follow-up is shorter than that with the zygoma implants. Continued follow-up with 5 to 10 years of follow-up will confirm the early results reported in this discussion.

The placement of endosseous implants into the edentulous severely atrophic/resorbed maxilla is very unpredictable, regardless of the grafting technique used. Zygomatic implants were designed as an alternative to grafting procedures in the severely atrophic maxilla. This literature review has indicated that the nongrafting option of using zygomatic implants as the posterior anchor for an implant-supported prosthesis is very successful and might be greater than that with traditional sinus graft procedures.

References