Maxillary Single-Tooth Replacement Utilizing a Novel Ceramic Restorative System: Results to 30 Months

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Key Words
Tapered screw implants
Ceramic restorations
Single-tooth replacement

This study reports on the first longitudinal results of an alumina (70%)-zirconia (30%) ceramic restorative system for implant-supported, single-tooth replacement in the anterior maxillary jaw. Eighteen patients (9 men, 9 women, mean age = 42.4 years) were treated with 22 implants placed into 19 extraction sockets and 3 residual ridges. Eight implants were immediately loaded with nonoccluding provisional prostheses. All implants were definitively loaded with fully occluding ceramic restorations after osseointegration and soft tissue maturation. Patients were monitored from 7 to 30 months (mean = 18.1 months) after loading. All implants osseointegrated and were successfully restored. One case of abutment screw loosening occurred because of patient parafunction (bruxing), and another patient reported chewing pain attributed to malocclusion. Both problems were successfully resolved without further incidence. Within the context of this study, single-tooth replacement in the anterior maxillary jaw was successfully achieved with alumina-zirconia ceramic single-tooth restorations with up to 30 months of clinical function.

Introduction

Implant-supported, single-tooth restorations in the anterior maxillary jaw have traditionally posed a number of clinical and esthetic challenges. Ridge resorption patterns may necessitate placement of implants with a labial inclination and complicate the ability to achieve an abutment emergence profile that is parallel with adjacent dentition.1 Lower-density maxillary bone traditionally results in approximately a 10% higher implant failure rate compared with the mandible.1 In partially edentulous cases, ceramometal restorations can sometimes appear darker than the adjacent natural dentition.2

Clinical demands for improved esthetics have led to the development of all-ceramic restorative systems as esthetic alternatives to ceramometal restorations.3-5 Their excellent restorative properties include low thermal conductivity and diffusivity, low electrical conductivity,6 and a translucency that minimizes...
gingival shadowing and creates an appearance of tooth vitality.5,7 When used on dental implants, however, titanium abutments can block the transmission of light through all-ceramic crowns and make restorations appear duller than the adjacent dentition.6 Over time, porcelain degradation from toothbrushing may increase this visual disparity.2,8 Implant abutments may also produce an unsightly metallic smile line that can become more pronounced with gingival recession and oxidation.2,9,10

New porcelain veneering techniques can be implemented to help increase the appearance of translucency in restorations with underlying metal, and improved labial margin designs can help mitigate the problem of metallic smile lines.2,9,11 For example, the application of porcelain to the collar region of gold abutments may help preserve esthetics in the event of future gingival recession.1,12 but these restorative techniques require greater time and technical expertise, which can add additional laboratory cost.2

Several manufacturers have introduced ceramic restorative systems for implants, but preparation time and less-than-optimal restorative materials have resulted in slow market growth.13 A new ceramic restorative system (PureForm, Zimmer Dental Inc, Carlsbad, Calif) that enables porcelain to be applied directly to an opaque ceramic base instead of a metal framework has been evaluated for strength and esthetic results, but no longitudinal follow-up data have been reported.13 This prospective study evaluated the clinical performance of the system on tapered screw dental implants placed in the maxillae of humans.

**Materials and Methods**

**Patient selection and evaluation**

Study candidates presented with 1 or more missing or hopeless maxillary teeth in the authors' private dental practices located in Israel (Z.O.) and Italy (G.S.). All patients were subjected to a preliminary evaluation that included careful review of their medical and dental histories, detailed clinical and radiographic examinations, oral hygiene status, and ability to commit to a long-term treatment plan. Those patients who met strict inclusion criteria (Table 1)14-16 were admitted into the study after treatment alternatives were explained and signed informed consent was obtained.

Diagnoses evaluations were performed to assess the volume and location of available bone and the esthetic and functional needs of the case relative to the desires of the patient. A study cast was fabricated and mounted on a semiajustable articulator utilizing a face bow transfer and vertical registration to determine the jaw relationships, available occlusal dimension, proposed implant position, crown-root ratio, and potential complications. This enabled fabrication of a prosthetic wax-up and a surgical template to guide implant placement relative to the planned restoration.

**Implant and restorative components**

This study utilized a tapered screw implant design with a triple external thread pattern and a microtextured (MTX) or hydroxyapatite-coated (HA) surface (Tapered Screw-Vent, Zimmer). Definitive prostheses were fabricated with a ceramic restorative system (PureForm) containing 6 alumina (70%)-zirconia (30%) copings shaped like prepared natural teeth and titanium core abutments that provided a machined interface between the prostheses and implants (Figure 1).

**Surgical procedures**

The patient was prepared for surgery. Anesthesia was accomplished via local infiltration with or without nitrous oxide sedation, depending on the needs of the patient and the preference of the clinician. In cases with hopeless dentition, the periodontal ligament was severed and the tooth wasatraumatically avulsed to preserve the surrounding bony architecture for the immediate placement and stabilization of an implant. In some cases, the tooth was sectioned or filed interproximally to facilitate its dislocation and removal. Soft tissue remnants were carefully debrided from the extraction socket with curettes.
before preparation for implant placement. A mucoperiosteal flap was elevated in most cases but was kept small to preserve the periosteal vascular supply. In other cases, a flapless, transmucosal surgical approach was utilized to preserve the vascular network, natural soft tissue contours, and esthetics of the case.

In cases with preexisting partial edentulism, the surgical template was used as a guide to drill a pilot hole into the residual ridge under copious external irrigation. A sterile, surgical try-in pin (PureForm) was inserted into the guide drill hole, and a plastic try-in coping was placed on the pin to evaluate its emergence profile and location of the proposed restoration relative to the adjacent dentition. The try-in components were removed from the patient’s mouth. In immediate extraction sites, the surgical template and natural dimensions of the socket provided appropriate surgical orientation and thus obviated the need for the component try-in.

The implant receptor site was initially prepared in the tooth extraction socket or residual ridge by sequential cutting with a series of internally irrigated straight drills in progressive diameters. A final-step drill was used to prepare the apical end of the definitive osteotomy 0.2 mm smaller.
in diameter than the tapered apical end of the implant. This allowed approximately one third of the tapered implant to be placed before its self-tapping api
cal threads engaged the lateral walls of the receptor site. As the implant was placed, its tapered body progressively condensed the bone from 0.2 mm at the apex
to 0.3 mm at the crest of the ridge, which completely eliminated any voids around the cervical end of the implant (Figure 2). The fixu
ture mount was oriented toward the buccal aspect according to the manufacturer's recommendations for abutment positioning.

After the implant was placed, the fixture mount was prepared as a transitional abutment, and a nonoccluding, provisional pros
thesis (Figure 3) was immediately delivered in some cases. In other cases, the fixture mount was re
moved and a surgical cover screw was attached. The soft tissues were reaproximated and su
tured around the provisional restoration for 1-stage healing or over the top of the implant for a conventional 2-stage surgical procedure, depending on the case. Sutures were removed after approximately 1 week. Antibiotic prophylaxis (eg, amoxicillin 500 mg) was commenced immediately before surgery and continued for 3 days postoperative.

Healing was approximately 4 months for submerged implants and 2 weeks for immediately provisionalized implants. At the end of this phase, submerged implants were surgically uncover
ed and evaluated clinically and radiographically for osseointe
gration. The implants were im
mediately provisionalized, and the soft tissue was closed around the nonoccluding prosthesis with 3-0 sutures (Vicryl, Ethicon, Som
erville, NJ). The sutures were removed approximately 5 days later, and the soft tissue was allowed to mature for approximately 2 weeks before definitive restorative procedures began.

**Definitive restoration procedures**

The provisional prosthesis was removed, an impression post was attached to the implant (Fig
ure 4), and the screw-access hole in the top of the component was blocked out with utility wax. A full-arch impression was made with an elastomeric material (eg, vinyl polysiloxane) (Figure 5). After setting, the impression was removed from the patient's mouth, and the area surrounding the posthole was lubricated in the impression with petroleum jelly. The impression post was unthreaded from the implant in the patient's mouth and threaded into an implant analog, and the assembly was inserted into the corresponding impression hole. The provisional restoration was reattached to the implant, and the patient was dismissed until del
ivery of the definitive prosthesis.

In the dental laboratory, soft tissue replication material (eg, IPS Express, Ivoclar Williams, Am
herst, NY) was injected around the transfer assembly, the impres
sion was poured in dental stone, and the working cast was sepa
rated after setting. The impression post was removed from the implant analog incorporated within the working cast. A core abutment (PureForm) was select
ed according to its cuff height (0.5 mm or 1.5 mm) based on the depth of the peri-implant sulcus replicated on the working cast. The component was placed on the implant analog in the working cast with its flat side oriented buc
cally, and was stabilized with a retaining screw tightened to 30 Ncm of torque to fully engage the friction-fit connection of the com
ponent (Figure 6). Plastic try-on copings were placed on the core abutment in the working cast to evaluate its shape relative to the adjacent dentition (Figure 7). Af
ter selection of a coping in the optimum dimensions, a corre
sponding ceramic coping was reduced and contoured with high-speed diamond wheels and ex
ternal irrigation to prevent excessive heat generation (Figure 8). The prepared ceramic coping was blasted with aluminum oxide at 38 psi and steam cleaned for 45 seconds. Porcelain with a coefficient of thermal expansion that ranged from 8.1 to 8.3 × 10^-6 (eg, Vitadur Alpha, Vident, Brea, Ca
lif) was applied to the ceramic coping (Figure 9) and finished according to the manufacturer's recommendations and conven
tional laboratory procedures.

In preparation for sterilization, the finished ceramic prosthesis was removed, and the core abutment was unseated from the implant analog in the working cast with a removal tool that dislodged the friction-fit interface between the abutment and implant analog. At the delivery appointment, the provisional prosthesis was removed from the implant, and the sterilized core abutment was delivered to the implant with 30 Ncm of applied torque (Figure 10). Full seating of the core abutment was verified radiographically. The screw-ac
cess hole in the top of the core abutment was occluded with a cotton pellet and composite material to prevent the ingress of cement and to facilitate its future retrieval. The porcelain single
tooth prosthesis was luted onto the core abutment with glass ionomer (eg, Ketac-Cem, 3M Espe
AG, Seefeld, Austria) or resin (eg, Panavia, Kuraray Co Ltd, Osaka, Japan) cement. Excess cement
was removed from the margin area, and the occlusion and bite were adjusted with conventional clinical techniques for porcelain restorations (Figures 11 and 12). Patients were provided with detailed oral hygiene instructions and dismissed. Recall appointments were scheduled for 1 month postrestoration and every 3 months thereafter.

**Patient satisfaction survey**

At the first follow-up appointment, patients were asked to rate their satisfaction with the definitive restoration in 6 different categories: esthetics of prosthesis, comfort of prosthesis, function of prosthesis, length of treatment time, meets my expectations, and cost of treatment.

**RESULTS**

Patient and treatment data are presented in Table 2. A total of 19 implants were placed into immediate extraction sockets, and 3 implants (case nos. 13, 15, and 18) were placed into preexisting edentulous locations. Whereas 8 implants (case nos. 8, 9, 13, 14, and 16–18) were immediately provisionalized at the time of implant placement, the remaining 14 implants (case nos. 1–7, 10–12, and 15) were provisionally restored after a submerged healing period. There were no surgical complications, and all implants clinically osseointegrated. After clinical loading with the definitive restoration,
patients were monitored from 7 to 30 months (mean = 18.1, mode = 18).

Patient health risk factors and adverse events are listed in Table 3. Two patients were habitual smokers. These patients were advised of the higher risk of implant failure and were presented with smoking-cessation options\(^7\) but were included in the study even if they continued smoking. In these 2 patients, smoking did not seem to impair healing, and both restorations continue to function without any adverse clinical manifestations.

One incidence of screw loosening occurred in case no. 3. Examination revealed signs of parafunctional bruxism, which was previously undetected. It was theorized that excessive lateral forces on the implant restoration exceeded the preload value of the abutment screw and caused it to loosen. The definitive prosthesis was removed, and the abutment screw was retightened to 30 Ncm of applied torque. A new ceramic prosthesis was delivered, and a night guard was fabricated for the patient. No further screw loosening occurred.

In case no. 17, the patient presented with a complaint of masticatory discomfort after 13 days of immediate, nonoccluding provisional loading and 1 week after delivery of the definitive prosthesis. Several other teeth were missing, and the patient exhibited signs of malocclusion. The prosthesis was removed and the implant was submerged beneath the soft tissue for 6 months of additional healing. During the submerged healing period, occlusal adjustments were made and additional implants were placed into the remaining edentulous
areas. All implants subsequently osseointegrated and were successfully restored with the ceramic components used in this study but were not included as part of the study. Correct occlusion was fully restored, and the patient reported no further complications.

Patient response to treatment is presented in Table 4. All patients were very satisfied with the esthetics, comfort, and function of the definitive restoration and with how it met their expectations. One patient (case no. 17) was somewhat satisfied with the length of treatment because of the necessary change in treatment protocol required to address the adverse event. Patients whose implants were immediately loaded (case nos. 8, 9, 13, 14, 16, and 18) were very satisfied with length of treatment, and all other patients indicated that they were satisfied with treatment. All patients were satisfied with the cost of treatment.

### Table 2

<table>
<thead>
<tr>
<th>Patients</th>
<th>Location</th>
<th>Surgery</th>
<th>Prosthetic Loading Time</th>
<th>Follow-up (mo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case No.</td>
<td>Sex</td>
<td>Age</td>
<td>Maxillary Quadrant</td>
<td>Tooth</td>
</tr>
<tr>
<td>1</td>
<td>F</td>
<td>38</td>
<td>Left anterior</td>
<td>Central incisor</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>48</td>
<td>Right anterior</td>
<td>Central incisor</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>51</td>
<td>Left anterior</td>
<td>Lateral incisor</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>52</td>
<td>Left posterior</td>
<td>Central incisor</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>58</td>
<td>Right anterior</td>
<td>Lateral incisor</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>59</td>
<td>Right posterior</td>
<td>Second premolar</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>60</td>
<td>Right posterior</td>
<td>Second premolar</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td>61</td>
<td>Left posterior</td>
<td>Second premolar</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>62</td>
<td>Left posterior</td>
<td>Second premolar</td>
</tr>
<tr>
<td>10</td>
<td>F</td>
<td>63</td>
<td>Right posterior</td>
<td>Second premolar</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>64</td>
<td>Left anterior</td>
<td>Central incisor</td>
</tr>
<tr>
<td>12</td>
<td>F</td>
<td>65</td>
<td>Right anterior</td>
<td>Cuspid</td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>66</td>
<td>Right anterior</td>
<td>Central incisor</td>
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<tr>
<td>14</td>
<td>F</td>
<td>67</td>
<td>Left anterior</td>
<td>Central incisor</td>
</tr>
<tr>
<td>15</td>
<td>M</td>
<td>68</td>
<td>Left posterior</td>
<td>First premolar</td>
</tr>
<tr>
<td>16</td>
<td>M</td>
<td>69</td>
<td>Right posterior</td>
<td>First premolar</td>
</tr>
<tr>
<td>17</td>
<td>M</td>
<td>70</td>
<td>Right posterior</td>
<td>First premolar</td>
</tr>
<tr>
<td>18</td>
<td>M</td>
<td>71</td>
<td>Left posterior</td>
<td>First premolar</td>
</tr>
</tbody>
</table>

*MTX indicates microtextured; HA, hydroxyapatite.
†Smoker.
‡See Table 3.

### Table 3

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Category</th>
<th>Description</th>
<th>Cause</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>Health risk factor</td>
<td>Smoker</td>
<td>Nicotine addiction</td>
<td>Presented with smoking-cessation protocol</td>
</tr>
<tr>
<td>18</td>
<td>Health risk factor</td>
<td>Smoker</td>
<td>Nicotine addiction</td>
<td>Presented with smoking-cessation protocol</td>
</tr>
<tr>
<td>3</td>
<td>Adverse event</td>
<td>Abutment screw loosened</td>
<td>Parafunional bruxism</td>
<td>Tightened the abutment screw and fabricated a new prosthesis and night guard</td>
</tr>
<tr>
<td>17</td>
<td>Adverse event</td>
<td>Chewing pain</td>
<td>Malocclusion</td>
<td>Submerged the implant for additional healing and balanced the occlusion by placing more implants</td>
</tr>
</tbody>
</table>

### Discussion

In the present study, the selected implant featured a 1° taper, which has been reported to offer better primary stability than standard straight screw implants without causing any negative bone tissue reactions related to the tapered screw design. The surgical technique for low-density bone was designed to compress the bone progressively from 0.2 mm at the apex to 0.3 mm at the crest of the ridge. Research has shown that when a receptor site is prepared a minimum 0.1 mm smaller in diameter than the implant, the force-fitting stresses generated during placement will increase.


<table>
<thead>
<tr>
<th>Clinical Result</th>
<th>Case No. and Patient Assessment of the Clinical Result*</th>
</tr>
</thead>
</table>
| Esthetics of prosthesis         | A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A 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CONCLUSION

The ceramic system successfully rehabilitated tooth form, function, and esthetics and remained stable without chipping or cracking up to 30 months of clinical follow-up.

ACKNOWLEDGMENT

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