Survival and Mechanical Complications of Posterior Single Implant–Supported Restorations Using Prefabricated Titanium Abutments: A Medium- and Long-Term Retrospective Analysis with up to 10 Years Follow-up

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**Purpose:** To evaluate the survival of implants and abutments and the incidence of mechanical complications of single posterior implant-supported restorations using prefabricated titanium abutments. **Materials and Methods:** This retrospective clinical study analyzed 172 Astra Tech OsseoSpeed internal hexagon implants (Dentsply Sirona) placed in 85 patients with a follow-up between January 2009 and January 2019. All implants were restored with prefabricated titanium abutments and cement-retained metal-ceramic crowns. The clinical outcomes recorded were implant and abutment survival rates and mechanical complications (abutment/implant fractures, screw loosening/fracture, decementation of the superstructure, veneer chipping/fractures) and were analyzed according to age, sex, implant length/diameter, bone graft, arch, implant position, parafunctional habit or dental status, and opposite arch. Kaplan-Meier survival analysis was used to determine whether the distribution of time to event/failure differed based on implant position (premolar or molar), implant diameter (3.5 vs 4 mm), or abutment angles (straight vs 15 degrees).

**Results:** During the observation period (mean: 108 months), implant and abutment cumulative survival rates were 97.7% and 98.3%, respectively, with no statistically significant differences between implant positions (molar/premolar), implant diameters (3.5 vs 4 mm), or abutment angles (straight vs 15 degrees). Of the 172 single posterior implant-supported restorations, 14 mechanical complications (8.2%) were recorded. In particular, 3 abutment fractures (1.7%), 2 screw loosenings (1.2%), 2 screw fractures (1.2%), 1 implant fracture (0.6%), 2 chipping/fractures of veneering materials (1.2%), and 4 decementations of the superstructure (2.3%) occurred. **Conclusion:** The single posterior implant-supported restorations using prefabricated titanium abutments remain a clinically acceptable treatment in terms of prosthetic procedure and cost-effectiveness. Int J Prosthodont 2022;35:278–286. doi: 10.11607/ijp.7669

Implant prosthetics has become a field driven entirely by restoration planning, and it is therefore important to know the design principles for abutment fabrication, as well as the advantages of different designs and their connections with implants. The implant-abutment interface is a critical area, as its accuracy can influence the rate of biologic and mechanical complications and thus the long-term outcome of implant-supported prostheses. Nowadays, implant abutments can be either stock/prefabricated or customized. The use of a prefabricated abutment is indicated when the implant is placed in an almost ideal prosthetic position. The advantages of using prefabricated abutments are time efficiency in the overall treatment and therefore shortening of the technical manufacturing time. Otherwise, customized abutments can play an important role in ensuring maximum precision and mechanical stability.
of abutments and associated prostheses.\(^8\)\(^9\) Currently, the fabrication of more individualized computer-milled abutments is becoming more possible when compared to prefabricated abutments.

In contrast to stock abutments, customized abutments have the potential to accurately reproduce the emergence profile, leaving room for the soft tissue to fill and provide a thicker and more stable mucosal margin. Nevertheless, a recent systematic review by Canullo et al did not find a significant impact of abutment morphology on the soft tissue around implants.\(^10\)

Moreover, another systematic review and meta-analysis by Raee et al that was performed to compare the peri-implant clinical and patient-reported outcomes following the use of CAD/CAM customized vs prefabricated abutments found no evidence to support the superiority of customized abutments over prefabricated ones.\(^11\) Employing stock abutments can still be considered a clinically acceptable treatment. Therefore, the aim of this retrospective study was to evaluate the survival and mechanical complications of posterior single implant–supported restorations using prefabricated titanium abutments.

### MATERIALS AND METHODS

#### Study Protocol

This retrospective case series study aimed to answer the following hypothesis: Posterior single implant-supported restorations using prefabricated titanium abutments have clinically acceptable survival rates and incidence of complications. The reporting of this study was performed following the recommendations of the Institute of Health Economics quality appraisal checklist according to Guo et al.\(^12\) Due to the fact that data collection is part of the routine clinical procedure, consent to use the retrospective data was obtained from each patient.

#### Patient Selection

Eighty-five consecutive patients (55 men, 30 women; mean age: 52 years) referred between January 2009 and January 2019 to the Multidisciplinary Department of Medical, Surgical, and Dental Sciences of Campania University Luigi Vanvitelli for maxillary or mandibular single-tooth extraction in the premolar and molar area followed by implant treatment with Astra Tech OsseoSpeed internal hexagon implants (Dentsply Sirona) were retrospectively evaluated. The exclusion criteria were as follows: Any underlying uncontrolled disease or health condition; severe liver or renal disease; complicated diabetes mellitus; and/or history of recent radiotherapy in the head and neck area or active chemotherapy. The 85 included patients were divided into two groups: The first group, consisting of 40 patients, was treated with single implants in the premolar area (Pm), and the second group, consisting of 45 patients, was treated with single implants in the molar area (M). Tooth extraction was performed in cases of advanced carious, endodontic, or periodontal lesions, root fracture, or a combination thereof. Patients with a history of periodontitis were treated previously, and their disease was considered as under control before commencement of the implant therapy. The patients were then treated 30 days (in the case of early implant placement) or 3 months (in the case of delayed implant placement) following tooth extraction, according to the classification of Hämmerle et al.\(^13\)

#### Surgical Procedures

First, the teeth were carefully extracted to minimize the trauma to the alveolar bone walls, in particular the buccal bone, and the postextraction alveolar ridges were carefully debrided. The characteristics of the placed implants were: 3.5 × 9 mm (65 implants); 3.5 × 11 mm (48 implants); and 4.0 × 9 mm (59 implants). Implant distribution is shown in Table 1. The implants were placed in each patient following early and delayed placement protocols. Full-thickness flaps were raised for all the implants, and these were connected to healing abutments or cover screws at the end of the implant placement. No temporary or removable restorations were connected to the implants. The patients received amoxicillin/clavulanic acid 750/250 mg and ibuprofen 400 mg 1 hour before the surgical procedure and twice a day for the following 4 days. In order to avoid potential sources of bias, all implants were placed by two experienced and calibrated maxillofacial surgeons (F.D. and A.L.) using the same surgical protocol.

#### Prosthetic Procedure

Two to 4 months after the osseointegration period, a pick-up impression technique, single-phase and monocomponent, employing polyether material was

### Table 1 Distribution of Implants (n) Placed in Maxilla and Mandible

<table>
<thead>
<tr>
<th>Implant dimensions</th>
<th>Maxilla</th>
<th>Mandible</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Premolar</td>
<td>Molar</td>
</tr>
<tr>
<td>3.5 × 9 mm</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>3.5 × 11 mm</td>
<td>24</td>
<td>5</td>
</tr>
<tr>
<td>4.0 × 9 mm</td>
<td>10</td>
<td>22</td>
</tr>
</tbody>
</table>
performed. Straight or angled (15 degrees) prefabricated titanium abutments were employed that ranged from 4.0 to 5.0 mm in diameter and 4.5 to 6.5 mm in height. Abutments were tightened to the implants with a titanium screw using a torque of 20 Ncm according to the manufacturer recommendations. All metal-ceramic crowns were cemented with temporary cement (TempBond, Kerr). In order to avoid potential sources of bias, the prosthetic procedures were conducted by two experienced and calibrated prosthodontists (G.D. and C.M.C.) using the same restorative protocol.

Follow-up Evaluation
Follow-up visits were performed every 6 to 12 months for up to 10 years. Unscheduled visits were considered those requested by the patient due to perceiving pain or discomfort from the implant or prosthetic complications. Any clinical problems such as implant failure, screw loosening or fracture, abutment fracture, chipping or fractures of veneering materials, and/or decementation of the superstructure were checked and recorded. Implant failure was defined as implant removal for any reason. The date of implant removal or the last scheduled follow-up visit at which implants were in function was recorded, and the time (in months) elapsed between implant loading and the last visit was defined as the implant survival period. A prosthetic event was considered any clinical problem occurring at the abutment or crown level. Abutment failure was considered if the abutment needed to be replaced for any reason. Implant/restoration failure was considered if an osseointegrated implant needed to be removed due to the impossibility of being restored after prosthetic complications.

Statistical Analysis
The implant, screw, abutment, and restoration survival rates and the incidence of biologic and mechanical complications were recorded and expressed as percentages (%). All data were synthetized in Excel tables and compared and analyzed using OriginLab Pro 2019 software. Kaplan-Meier survival analysis was used to determine whether the distribution of time to event or failure differed based on implant position (premolar or molar), implant diameter, or abutment angulation. Censoring was considered when no event or failure occurred during the observation period or the patient dropped out of the study. For prosthetic survival analysis, censoring was also considered when implants were lost for no prosthetic reason. Log-rank test was conducted to determine whether the survival/complication distribution differed according to implant position (M vs Pm), implant diameter, or abutment angulation. Statistical significance was set at a P value < .05.

RESULTS
During the study period, 172 implants placed in 85 patients, 55 men and 30 women, with a mean age of 52 years (range 20 to 74 years), were analyzed. The 10-year cumulative survival rate (CSR) of the implants was 97.7%, with 168 implants remaining in function. The mean observation period for the implants was 108 months (range 118 months), with 101 implants monitored for 120 months, 31 implants for 108 months, and 36 implants for 84 months. Four implants (2.3%) failed, two of which (3.5 × 11 mm) failed early after 2 and 4 months of loading, and 2 that were removed because of marginal bone loss with peri-implant inflammation at 41 (3.5 × 9 mm) and 52 (4 × 9 mm) months after loading.

The overall 10-year implant survival analysis and distribution according to the implant diameter (3.5 vs 4 mm) and position (M vs Pm) are shown in Fig 1. No statistically significant differences were found regarding implant survival when comparing different implant diameters (log
rank: $\chi^2 = 0.188$, df = 1, $P = .665$) and positions (log rank: $\chi^2 = 0.340$, df = 1, $P = .559$). Among the 172 placed abutments, 45 were angled prefabricated abutments, and all the others were straight. The 10-year CSR of the abutments was 98.3%, with 169 in function at the end of the evaluation period. Of the 172 single posterior implant-supported restorations evaluated, 14 mechanical complications (8.2%) were recorded. In particular, 3 abutment fractures (1.7%), 2 incidences of screw loosening (1.2%), 2 screw fractures (1.2%), 1 implant fracture (0.6%), 2 chipping or fractures of veneering materials (1.2%), and 4 decementations of the superstructure (2.3%) occurred. The distribution of posterior single implant–supported restorations affected by biologic and mechanical complications, relating both to the Pm and M areas, is described in Table 2. There was one implant fracture associated with a screw fracture (Fig 2). The first abutment fracture was located in the neck portion (Fig 3), while the second and third abutment fractures affected the hexagon abutment (Fig 4). Screw fractures were observed in two cases, one of which was associated with an implant fracture (Fig 2), while the second one affected the first molar in the same patient as the abutment fracture occurred (Fig 5). No mechanical complications resulted in implant restoration failures because of the satisfactory extraction of broken fragments in the case of abutment or screw fracture. Implant fracture

<table>
<thead>
<tr>
<th>Implant dimensions</th>
<th>Premolar, n/total</th>
<th>Molar, n/total</th>
<th>Failed implants (peri-implantitis), n</th>
<th>Failed abutments (mechanical complications), n</th>
</tr>
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<tr>
<td>3.5 × 9 mm</td>
<td>3/48</td>
<td>0/17</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3.5 × 11 mm</td>
<td>3/39</td>
<td>0/9</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>4.0 × 9 mm</td>
<td>1/18</td>
<td>7/41</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Fig 2 Radiographs showing implant fracture associated with screw fracture.

Fig 3 Fracture of the abutment (neck portion) in the maxillary second premolar position.
affected the neck portion, and its removal made the osseointegrated implant restoration possible.

The overall 10-year abutment survival analysis regarding implant position (M vs Pm) and abutment angulation is shown in Fig 6. No statistically significant differences regarding abutment survival related to implant position (log rank: $\chi^2 = 0.029$, df = 1, $P = .865$) or angulation (log rank: $\chi^2 = 1.906$, df = 1, $P = .167$) were observed. When analyzing all the mechanical complications related to implant position (M/Pm), implant diameter (3.5 vs 4 mm), and abutment angulation (straight vs angled), no statistically significant differences were observed, as shown in Fig 7. Table 3 shows the patients’ clinical data, including sex, age, parafunctional habits/dental status, opposite arch, and the features of the abutments and implants, such as length, diameter, position, bone graft, and the recorded mechanical complications.

**DISCUSSION**

This retrospective study was carried out to evaluate the medium- and long-term survival of implants and abutments and the incidence of mechanical complications.
Fig 7  Abutment survival related to (a) implant position and (b) abutment angulation.

Table 3  Data of Patients (n = 9) with Mechanical Complications of Posterior Single Implant–Supported Restoration

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age, y</th>
<th>Position (FDI)</th>
<th>Implant diameter/length, mm</th>
<th>Abutment diameter/length, mm</th>
<th>Implant fracture</th>
<th>Screw loosening</th>
<th>Screw fracture</th>
<th>Chipping/fractures of veneering material(s)</th>
<th>Decementations of the superstructure</th>
<th>Antagonist arch</th>
<th>Para-functional habit(s)</th>
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<tbody>
<tr>
<td>Male</td>
<td>56</td>
<td>36</td>
<td>4.0/9</td>
<td>5.0/5.5</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Natural teeth</td>
<td>Bruxism</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>41</td>
<td>24</td>
<td>3.5/11</td>
<td>4.0/5.5</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Implant-supported fixed prosthesis</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>43</td>
<td>25</td>
<td>3.5/9</td>
<td>4.0/5.5</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Tooth-supported fixed prosthesis</td>
<td>No</td>
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<tr>
<td>Male</td>
<td>53</td>
<td>26</td>
<td>4.0/9</td>
<td>5.0/6.5</td>
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<td>No</td>
<td>Yes</td>
<td>Natural teeth</td>
<td>Bruxism</td>
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<td></td>
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<tr>
<td>Female</td>
<td>38</td>
<td>45</td>
<td>4.0/9</td>
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<tr>
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<td>61</td>
<td>46</td>
<td>4.0/9</td>
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<tr>
<td>Male</td>
<td>58</td>
<td>45</td>
<td>3.5/11</td>
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<td>No</td>
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<td>No</td>
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<td>Tooth-supported fixed prosthesis</td>
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<td>Natural teeth</td>
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<tr>
<td>Male</td>
<td>40</td>
<td>45</td>
<td>3.5/9</td>
<td>4.0/5.5</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Tooth-supported fixed prosthesis</td>
<td>Bruxism</td>
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of posterior single–implant-supported restorations using prefabricated titanium abutments.

Cement-retained crowns can be placed on either stock or customized abutments. Stock abutments are manufactured with both the profile and the finishing margin of the crown placed arbitrarily without regard to individual morphology. On the other hand, custom abutments are patient-specific; that is, made especially for the individual case being restored. Stock abutments can only be partially adjusted to clinical requirements, whereas customized abutments can shape the marginal soft tissue more effectively and thus facilitate optimal design of the crown contour and emergence profile.

There are many clinical advantages that customized abutments can offer, such as the possibility of creating an optimal emergence profile, easy and safe removal of excess cement, optimal support and retention of the final prosthesis, and the possibility of correcting excessive implant disparallelisms. Nevertheless, stock abutments are less expensive and more accessible. The aim of the present study was to retrospectively evaluate the long-term survival and complication rates of the use of stock abutments in the Pm and M regions of the maxilla and mandible.

The analyses were performed at the implant level and at the abutment level. The 10-year survival rate at the implant level is in accordance with the values reported by Howe et al in a systematic review and sensitivity meta-analysis (96.4%; 95% CI: 95.2% to 97.5%) and by Jung et al (95.2%; 95% CI: 91.8% to 97.2%). However, long-term comparisons regarding implant and abutment survival between implants placed in the Pm vs M region are still scarce. The present study found no statistically significant differences regarding implant and abutment survival when narrow-diameter (3.5 mm) implants were used, regardless of the occurrence of a single case of an implant fracture (3.5 x 11 mm) with simultaneous screw fracture in a patient with parafunction (bruxism), which was restored after abutment replacement without the need for implant removal. Similarly, the present findings are in accordance with the results obtained by Schiegnitz and Al-Nawas, showing a mean survival rate of 97.5% ± 2.4% after a mean follow-up of 39 ± 24 months for category 3 (3.30–3.50 mm) narrow-diameter implants.
Moreover, no statistically significant differences regarding mechanical complications were observed between molars and premolars for single-implant restorations. This finding is also in accordance with another 10-year retrospective clinical study evaluating single-implant–supported premolar and molar crowns. However, Korsch and Walther showed a significant difference regarding loosening of the superstructure of posterior crowns favoring the use of customized abutments over prefabricated abutments. In the present retrospective study, all of the crowns were cemented with temporary cement on stock abutments, allowing for retrieval of the restoration for monitoring of the abutment and implant conditions. Temporary cement was also used to avoid the risks of peri-implantitis and peri-implant mucositis associated with the difficulty of removing excess cement. Among all the crowns, four incidences of decementation of the superstructure (2.3%) were recorded. It can be assumed that decementation could be associated with the retentive properties of the cement used. In addition, only 4 implants from the total of 172 were lost due to peri-implantitis despite the careful technique used for cementation. These results are in accordance with Kotsakis et al, who found no association between the type of prosthesis retention (cemented vs screw-retained) and the incidence of peri-implant diseases within 192 implants supporting single crowns.

Different studies have shown that a 2-mm increase in height will increase retention by up to 40%, especially when the abutment is only 4 mm in diameter. Indeed, an increase in height from 4 to 7 mm results in a 67% increase in retention. Otherwise, when the height of the implant abutment is less than 5 mm, the diameter of the implant abutment plays a more critical role in the cement retention and resistance characteristics. Moreover, several studies showed that the minimum abutment height necessary to provide adequate retention for narrow-platform (3.5 to 4.0 mm) and wide-platform (4.5 to 5.0 mm) implants for single cement-retained restorations was 3 and 4 mm, respectively. Att et al (in vitro) and Shabanpour et al (in vivo) showed that the weakest part of prefabricated titanium abutments was the abutment screw; however, the present investigation showed that the greatest incidence of fractures was represented by abutment fracture, followed by screw fracture. A systematic review on survival and complication rates of dental implants showed that the fracture of abutments and screws occurred in 1.5% of abutments after a follow-up time of 5 years and in 2.5% after 10 years. These findings are in accordance with the present retrospective analysis, which reported three abutment fractures and two screw fractures, resulting in an incidence of 2.9% after 10 years. Also, when comparing stock and custom abutments, Kim and Shin showed that the abutment type did not have a significant influence on screw loosening in the short term, but the use of custom abutments favored screw loosening in the long term. In the present study, only two incidences of screw loosening (1.2%) were recorded after 10 years when stock abutments were used.

CONCLUSIONS

Posterior single implant–supported restorations using prefabricated titanium abutments showed a high survival rate at up to 10 years of follow-up (mean: 108 months), with no statistically significant differences when comparing implant position, implant diameter, or abutment angulation. The obtained results for the entire evaluation period showed favorable outcomes with the use of prefabricated titanium abutments. Although customized abutments can offer clinical advantages in terms of soft tissue response and abutment design, the use of prefabricated abutments still remains as a clinically acceptable treatment in terms of prosthetic procedure and cost-effectiveness to restore the posterior single implant–supported restorations.

ACKNOWLEDGMENTS

The authors report no conflicts of interest.

REFERENCES

Application of Cryopreservation to Tooth Germ Transplantation for Root Development and Tooth Eruption

Mouse tooth germs were cryopreserved with widely open cervical margins of the enamel organ to overcome difficulties in cryoprotectant permeation and to test their efficacy by transplanting them into recipient mice. The maxillary right first molar germs of 8-day-old donor mice were extracted and categorized into the following four groups according to cryopreservation time: no cryopreservation; 1 week; 1 month; and 3 months. The donor tooth germs were transplanted into the maxillary right first molar germ sockets of the 8-day-old recipient mice. The maxillary left first molars of the recipient mice were used as controls. The outcome of the transplantation was assessed at 1, 2, and 3 weeks after transplantation. Stereomicroscopic evaluation revealed that most of the transplanted teeth erupted by 3 weeks after transplantation. Microcomputed tomography analysis revealed root elongation in the transplanted groups as well as in the controls. There was no significant difference between the cryopreserved and noncryopreserved transplanted teeth, but the roots of the cryopreserved teeth were significantly shorter than those of the control teeth. Histologic examination revealed root and periodontal ligament formations in all the transplanted groups. These results suggest that the transplantation of cryopreserved tooth germ facilitates subsequent root elongation and tooth eruption.

Li X, Nakamura M, Tian W, Sasano Y. Sci Rep 2021;11:9522. References: 23 Reprints: M Nakamura, megumi.nakamura.a6@tohoku.ac.jp —David Ojcius, USA