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**Article** in *Journal of Oral and Maxillofacial Surgery* · February 2018

DOI: 10.1016/j.joms.2018.02.001

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# Fiber-Reinforced Resin Fixed Prostheses on 4 Short Implants in Severely Atrophic Maxillas: 1-Year Results of a Prospective Cohort Study

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**Purpose:** The aim of this study was to report on 1-year outcomes of fixed full-arch fiber-reinforced resin bridges on short implants in atrophic maxillary jaws.

**Materials and Methods:** A prospective cohort study was designed and patients with severely atrophic maxillas, corresponding to Cawood and Howell Classes V and VI, were included. Mesial and distal peri-implant bone levels were assessed on panoramic radiographs that were taken at the time of implant insertion (baseline) and during follow-up visits.

**Results:** Eighteen patients with 72 implants inserted in atrophic maxillary jaws were included in this study. All patients had a follow-up visit 1 year after loading. The cumulative 1-year patient-based implant survival rate was 88.8%, and the cumulative 1-year implant-based survival rate was 97.2%. The marginal bone level (MBL) was  $-0.5 \pm 0.5$  mm at the time of loading ( $n = 72$ ) and  $-0.8 \pm 0.6$  mm ( $n = 72$ ) after 1 year. The MBL depended substantially on the depth at the time of insertion. No prosthetic failure, such as chipping or fracture, occurred within the first year of loading.

**Conclusion:** Prosthetic rehabilitation of atrophic maxillas with prostheses supported by 4 4.0- × 5.0-mm or 3.0- × 8.0-mm implants seems to be a viable and cost-effective treatment option in the short-term.

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*J Oral Maxillofac Surg* ■:1.e1-1.e6, 2018

The concept of supporting a full-arch fixed prosthesis on only 4 implants has proved a reliable treatment option for prosthetic restoration of atrophic jaws.<sup>1</sup> However, in edentulous posterior maxillas, severe bone atrophy, especially as a result of prolonged postextraction crestal atrophy and to a lesser degree from sinus pneumatization, can complicate implant rehabilitation.<sup>2,3</sup> It is the centripetal nature of maxillary atrophy that complicates implant insertion compared with mandibular insertion, because maxillas have a smaller jaw base with knife-edged

ridges. In these cases, various approaches have been described in the literature, ranging from sinus grafting or other bone augmentation procedures to variations of implant lengths, from zygoma implants to ultrashort implants, for successful prosthetic restoration.<sup>4-6</sup> The sinus lift is currently considered the gold standard to increase bone volume in the posterior maxilla to allow for insertion of implants of conventional lengths ( $\geq 10$  mm), providing 75% of patients with a sinus floor below the palatal plane—and thus reaching into the alveolar process—the opportunity

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Conflict of Interest Disclosures: None of the authors have a relevant financial relationship(s) with a commercial interest.

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Received November 8 2017

Accepted February 6 2018

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0278-2391/18/301149

<https://doi.org/10.1016/j.joms.2018.02.001>

for implant insertion.<sup>7</sup> Numerous studies have confirmed the favorable outcomes and excellent long-term results. However, augmentative procedures are time consuming and involve higher costs, higher levels of patient morbidity (especially when autologous bone is used for augmentation), and the risk of complications, such as postoperative sinusitis and graft failure.<sup>8,9</sup> Recently, several studies compared the results of ultrashort implants with implants of conventional length in combination with sinus augmentation procedures for prosthetic restoration of the posterior maxilla, and the implant survival rates of ultrashort implants were found to be comparable to implants of conventional lengths placed in augmented sinuses.<sup>10-12</sup>

The systemic review of the European Association for Osseointegration consensus conference by Thoma et al<sup>11</sup> and a recent meta-analysis by Fan et al<sup>10</sup> concluded that ultrashort implants offer a viable alternative with minimal complications (to the conventional treatment regime of sinus augmentation combined with implants of conventional length). Thus, the European Association of Dental Implantologists published a consensus statement that short implants are a reliable treatment option compared with implants with augmentation.<sup>13</sup> Ultrashort implants allow for cost-effective and time-efficient prosthetic restorations in 1 session with high levels of patient satisfaction.<sup>11,14,15</sup>

The aim of this study was to report on the 1-year outcomes of fixed full-arch fiber-reinforced resin bridges on short implants in atrophic maxillary jaws.

## Materials and Methods

A prospective cohort study according to the Good Clinical Practice Guidelines and the Declaration of Helsinki was designed after approval from the institutional ethical committee was obtained (EK number 018/2011). The results of the present study are reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) criteria.<sup>16</sup>

### INCLUSION AND EXCLUSION CRITERIA

Patients 18 to 80 years of age with severely atrophic maxillas corresponding to Cawood and Howell Classes V and VI (flat or depressed alveolar ridge form, inadequate in height or width) were included in this study after their written consent was obtained.<sup>17</sup>

The following exclusion criteria were defined: uncontrolled diabetes (hemoglobin A<sub>1c</sub>, >6.5%); smoking (>10 cigarettes per day); alcohol abuse; untreated periodontitis of residual teeth; osteomyelitis; rheumatic disease; poor general state of health; bisphosphonate, interferon, or glucocorticoid therapy; untreated tumor

disease; pregnancy; poor compliance; physical limitations interfering with oral hygiene; and participation in other medical studies up to 30 days before implant insertion.

### SURGICAL PROTOCOL

All patients received short (3.0- × 8.0-mm) or ultrashort (4.0- × 5.0-mm) calcium phosphate-coated Bicon implants (Bicon LLC, Boston, MA). The thinner implants were used solely in a knife-edged anterior region. The implant bed preparation differs from the insertion of threaded implants: The drilling is performed at 50 rpm without irrigation or by hand, and all accumulating autogenous bone of the osteotomy is harvested. After preparation, the implants are tapped into the bone using an insertion instrument. The prosthetic well is closed with a polyethylene plug and the implant is covered with the harvested autogenous bone from the osteotomy. When possible, a double-layer wound closure was performed, suturing the periosteum in the first step and the overlying mucosa in the second step.<sup>18</sup>

### PROSTHETIC AND MATERIAL PROTOCOL

Implants were left submerged for a period of at least 6 months of healing before being surgically exposed. In 1 session, the implants were uncovered, and an implant-level transfer impression and an impression of the opposing dentition and an occlusal registration were made. A Trinia (Bicon LLC) frame (metal-free fiber-reinforced hybrid material) was milled using a computer-assisted design and manufacturing process. The restorations were temporarily cemented with TempBond (Kerr GmbH, Rastatt, Germany) to allow for careful de-cementation in the event of prosthetic complications. Final cementation was performed using a carboxylate luting cement (Durelon; 3M ESPE Dental Products, St Paul, MN).

### PATIENT RECALL

Patients were enrolled in a recall program with follow-up visits 6 months after implant insertion followed by a 1-year examination. At each follow-up, the peri-implant soft tissues were inspected and an orthopantomogram was recorded.

### MEASUREMENT PROTOCOL

After calibration of the x-ray device was achieved, 2 of the authors (R.S. and F.W.) assessed the mesial and distal peri-implant bone levels on panoramic radiographs that were taken at the time of implant insertion (baseline) and follow-up visits (6 and 12 months after implant insertion). For this purpose, the following 8 landmarks were digitally assessed for each implant at each radiographic follow-up: implant shoulder and

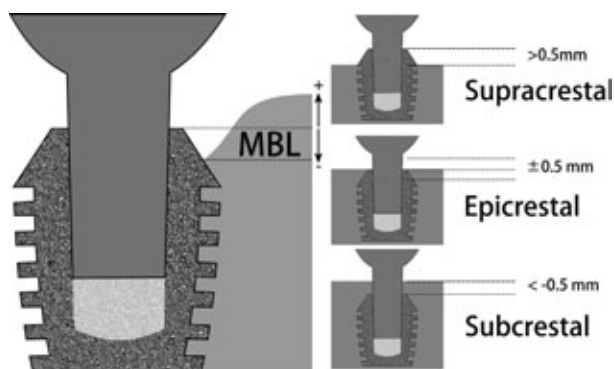
tip, bone level at the widest diameter of the implant (mesial and distal), bone level at the implant (mesial and distal), and end of the abutment neck (mesial and distal). The landmarks are displayed in [Figure 1](#). All measurements were performed twice using a proprietary program created by 1 of the authors (R.S.). In a final session, measurements were checked for plausibility and errors were corrected until consensus was reached.

#### STATISTICAL ANALYSIS

Statistical analysis was performed using the open-source statistical program R 2.15.1 (<http://cran.r-project.org>). Implant-related, patient-related, and prosthetic successes were analyzed separately. A Welch 2-sample *t* test was used to test for relevant differences between male and female patients.

Survival of implants was computed based on patient (patient as unit of interest) and on implant (implant as unit of interest) using the Kaplan-Meier method with a 95% confidence interval (CI). Survival time was defined as the timespan from implant placement to last follow-up or loss of implant. In the same manner, prosthetic survival was computed using the timespan from loading to last follow-up or prosthetic event. Prosthetic events were defined as chipping, fracture, or need for re-fabrication.

Two linear regression models were computed to estimate the mesial (linear regression model 1) and distal (linear regression model 2) attachment levels by implant depth immediately after loading ([Table 1](#), [Figs 2, 3](#)). The attachment level was regressed by bone level and time.



**FIGURE 1.** Schematic drawing of implant and abutment. The MBL was defined as the vertical distance of the implant shoulder to the first contact between bone and implant. Three implant insertion strategies were differentiated: supra-, epi-, and subcrestal. Each implant is classified in the control x-ray after implant insertion. MBL, marginal bone level.

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## Results

Eighteen patients with 72 implants inserted in atrophic maxillas were included in this study (12 women; mean age,  $66.9 \pm 9.0$  yr; range, 54.0 to 79.7 yr; 6 men; mean age,  $67.6 \pm 5.3$  yr; range, 61.4 to 76.5 yr). There was no significant age difference between female and male patients (Welch 2-sample *t* test,  $t = -0.21069$ ,  $df = 15.302$ ,  $P = .8359$ ). All patients attended the 1-year follow-up recall examination. The following results refer to this 1-year follow-up.

Of the 72 implants, 56 had a dimension of  $4.0 \times 5.0$  mm, 14 had a dimension of  $3.0 \times 8.0$  mm, and 2 had a dimension of  $3.5 \times 8.0$  mm. Twelve patients received 4  $4.0 \times 5.0$ -mm implants, 5 patients received 2  $3.0 \times 8.0$ -mm implants in the anterior region, and 1 patient received 4  $3.0 \times 8.0$ -mm implants. In the opposing jaw, 6 patients had partial dentures, 6 had natural teeth, and 6 had full-arch fixed implant bridges.

#### PATIENT-BASED IMPLANT SURVIVAL

Two implants were lost in 2 patients before loading (right distal implant in a 71-year-old woman, right mesial implant in a 72-year-old man) and the 2 implants were replaced. The patient-based 1-year cumulative survival rate (CSR) was 88.8% (95% CI, 75.3-100.0).

#### IMPLANT-BASED IMPLANT SURVIVAL

The 1-year CSR was 97.2% (95% CI, 93.3-100.0).

#### PROSTHETIC-BASED SURVIVAL RATE

The 1-year CSR was 100% (95% CI, 100.0-100.0).

#### MARGINAL BONE LEVEL

Linear regression models of marginal bone levels (MBLs) were computed to estimate the MBL at 1 year of loading. The MBLs at the mesial implant were  $-0.4$  mm for subcrestal,  $-0.7$  mm for epi-crestal, and  $-0.8$  mm for supracrestal placed implants after 1 year. The MBLs at the distal implant were  $-0.2$  mm for subcrestal,  $-0.5$  mm for epi-crestal, and  $-1.3$  mm for supracrestal placed implants after 1 year.

#### SELECTED PATIENT CASE

[Figures 4A](#) and [4B](#) show the orthopantomogram and clinical photograph of a 68.3-year-old man. The patient reported satisfactory chewing abilities, showed stable peri-implant bone, and exhibited no prosthetic complications.

## Discussion

The aim of this study was to report on the preliminary follow-up results of patients restored with fixed fiber-reinforced resin prostheses on  $4.0 \times 5.0$ -mm

**Table 1. LINEAR REGRESSION MODEL OF MARGINAL BONE LEVEL AT MESIAL AND DISTAL IMPLANTS REGRESSED BY INSERTION PROTOCOL (EPI-CRESTAL AS BASELINE; EPI-CRESTAL  $\pm$  0.5 MM, SUBCRESTAL <0.5 MM, AND SUPRACRESTAL >0.5 MM) AND TIME**

Factor	Mesial				Distal			
	Estimate	SE	<i>t</i> Value	Pr(>  <i>t</i>  )	Estimate	SE	<i>t</i> Value	Pr(>  <i>t</i>  )
Intercept (= epi-crestal)	-0.52	0.10916	-4.801	<0.001	-0.48	0.09049	-5.277	<0.001
Subcrestal <-0.5 mm	0.19	0.16923	1.120	0.267	0.28	0.12921	2.160	0.035
Supracrestal >0.5 mm	-0.12	0.16039	-0.750	0.456	-0.77	0.27573	-2.788	0.007
Time	-0.11	0.07358	-1.474	0.145	-0.04	0.06523	-0.581	0.563
<i>R</i> <sup>2</sup>	0.0636				0.1874			

Abbreviation: SE, standard error.

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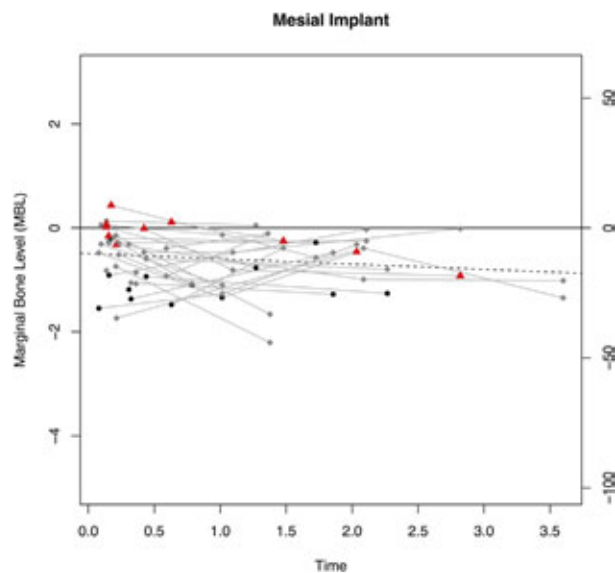
ultrashort and 3.0- × 8.0-mm short implants in severely atrophic maxillas.

The 1-year patient-based CSR was 94.7% and the implant-based CSR was 98.7% at 1-year follow-up. These survival rates are comparable to implant survival rates of conventional lengths and show the feasibility of prosthetic restoration of edentulous maxillas with 4 short implants.<sup>19,20</sup> These data also are in line with recent studies reporting excellent survival rates of ultrashort implants (range, 91.2 to 100%) up to 5 years after loading.<sup>21-24</sup>

The 1-year prosthetic-based CSR in the present study was 100%. This is in line with the findings of

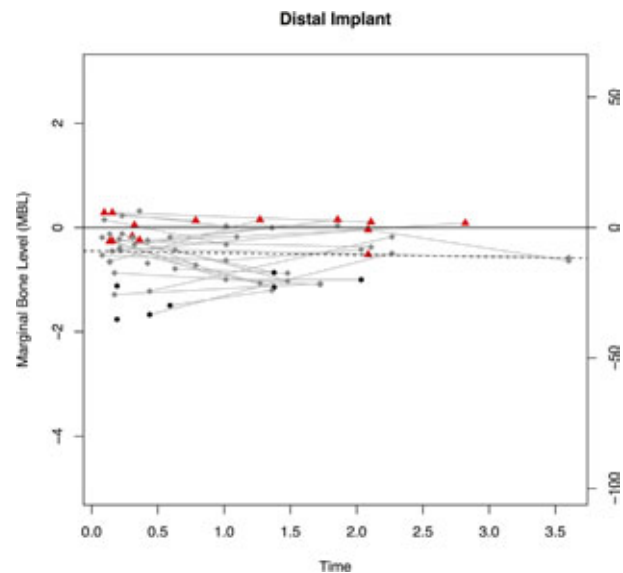
Pieri et al<sup>23</sup> who reported 2 minor prosthetic complications (CSR, 95.8%) in the short implant group: 1 abutment loosening and 1 ceramic fracture. However, these favorable CSRs are from studies with up to 5 years of follow-up. Future follow-up of the present cohort will prove whether prosthetic rehabilitation of edentulous maxillas with 4 short implants is a feasible concept and yields equally high CSRs in the long-term.

The marginal bone loss around implants that was found in the present study compares favorably to the values reported for implants of conventional lengths ( $\geq 10$  mm).<sup>25-27</sup> The present findings also are



**FIGURE 2.** Attachment level of the mesial implant over time in years. The left y-axis labels refer to millimeters and the right y-axis levels refer to percentages of implant length. Red triangles refer to supra-crestal, gray diamonds refer to epi-crestal, and black circles refer to sub-crestal implants. The dashed regression line represents a linear model of epi-crestal insertion depth regressed by time.

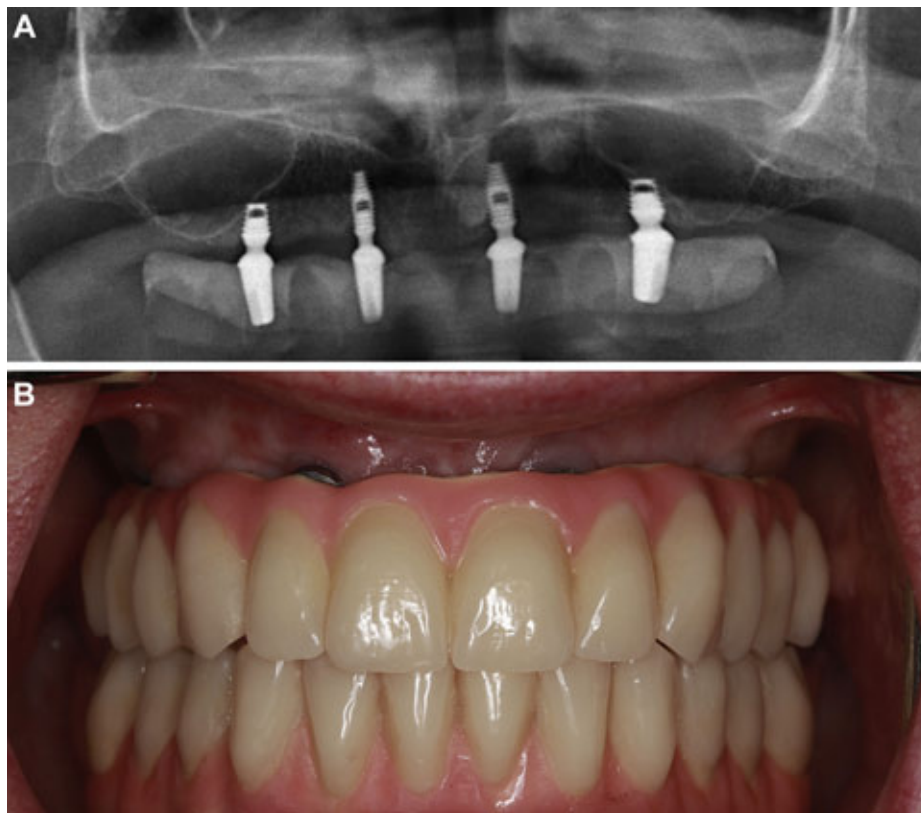
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**FIGURE 3.** Attachment level of the distal implant over time in years. The left y-axis labels refer to millimeters and the right y-axis levels refer to percentages of implant length. Red triangles refer to supra-crestal, gray diamonds refer to epi-crestal, and black circles refer to sub-crestal implants. The dashed regression line represents a linear model of epi-crestal insertion depth regressed by time.

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**FIGURE 4.** Images of a 68.3-year-old man. A, Orthopantomogram. B, Clinical photograph.

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comparable to the results of recent studies reporting changes in MBL around single and splinted ultrashort implants 1 year after implant insertion of 0.74 to 1.41 mm.<sup>22,28</sup> However, several studies have reported the mean annual marginal bone loss after a certain time of follow-up and do not separate the MBL of the first year from the following years.<sup>21,23</sup> Hence, these findings must be assessed critically, because comparison between studies is difficult.

The MBL in the present study depended substantially on the insertion depth: distal implants inserted approximately 0.6 mm below bone level did not lose bone on average 1 year after implantation (Table 1). This is contrary to recent findings reporting on higher MBLs when implants were placed below bone level, which was attributed to greater soft tissue pocket depth and re-establishment of the biological width.<sup>29-31</sup> However, none of the studies evaluating the outcome of ultrashort implants provided data on the MBL in relation to implant insertion depth at baseline.<sup>22,28</sup> In addition, all other studies were of implants that had implant-and-abutment interfaces (IAIs) with threaded fasteners, whereas this study involved implants with a locking taper IAI, which is reported to be bacterially sealed.<sup>32</sup> The authors

hypothesize that an important level also will be found for mesial implants at future follow-up examinations.

Time was not found to have a relevant influence at the mesial and distal implants; the authors hypothesize that the factor of time also will have an important impact at future follow-ups.

The findings of the present study have to be analyzed within its limitations, namely the small study cohort and the short study period. Long-term results of severely atrophic maxillas restored with fixed prostheses on 4 short implants are still scarce; prospective studies with a larger number of inserted implants and longer follow-up times will be needed before general recommendations can be given.

Cementation of the prostheses could cause problems in the future: in the case of prosthetic events, the entire prostheses might have to be destroyed, potentially resulting in a considerable amount of additional costs and temporarily impaired chewing function.

Within the limitations of the present study, the authors conclude that prosthetic rehabilitation of atrophic maxillas with prostheses supported by 4 short implants seems to be a viable and cost-effective treatment option in the short-term.

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