Fixed, Fiber-Reinforced Resin Bridges on 5.0-mm Implants in Severely Atrophic Mandibles: Up to 5 Years' Follow-Up of a Prospective Cohort Study

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Purpose: The aim of this study was to evaluate the midterm outcomes of fixed, full-arch, fiber-reinforced resin bridges on ultrashort implants in terms of marginal bone loss and overall implant survival.

Patients and Methods: Patients with severely atrophic mandibles, corresponding to Cawood and Howell class V and class VI, were included in this prospective temporal cohort study. Mesial and distal peri-implant bone levels were measured on panoramic radiographs taken at the time of implant insertion (baseline) and at follow-up visits.

Results: A total of 17 patients with atrophic mandibular jaws with an average follow-up period of 2.9 ± 1.5 years were included. The cumulative 1-, 3-, and 5-year patient-based implant survival rates were 94.1%, and the cumulative implant survival rates were 98.5%. The marginal bone level (MBL) of the mesial implants was 0.0 ± 0.3 mm at the time of loading (n = 33), −0.1 ± 0.3 mm (n = 20) after 1 year, −0.4 ± 0.5 mm (n = 10) after 3 years, and −1.5 ± 1.0 mm (n = 4) after 5 years. The mesial bone level depended significantly on time and insertion depth. The MBL of the distal implants was −0.4 ± 0.4 mm (n = 34) at the time of implantation, −0.4 ± 0.6 mm (n = 20) after 1 year, −0.5 ± 0.5 mm (n = 10) after 3 years, and −2.2 ± 1.7 mm (n = 4) after 5 years. The distal bone level depended significantly on time and insertion depth.

Conclusions: Fixed, full-arch, fiber-reinforced resin bridges retained by 4 ultrashort implants provide a comparatively cost-effective, safe, stable alternative for prosthetic restoration of the severely atrophic mandible. The overall implant survival rate and the MBL after 5 years are equivalent to those of threaded implants of conventional lengths.

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The all-on-4 concept is considered a safe treatment option for the restoration of atrophic mandibles with predictable outcomes; implant success rates are in the high nineties, and long-term survival rates show satisfactory results.[1-3] As a result of the cost-effective use of only 4 implants to fix the prosthesis, as well as

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the possibility of immediate loading, patient satisfaction is generally high.[4] In severely atrophic mandibles (Cawood and Howell class V and class VI), however, rehabilitation with dental implants may prove to be challenging.[5] Especially in the posterior atrophic mandible, the position of the alveolar nerve may limit the insertion of dental implants with standard lengths (≥8 mm) and limit the insertion to their classic location, the interforaminal mandibular body.[6] In these cases, a wide range of preprosthetic treatment options exist, and bone augmentation and/or distraction procedures and lateralization of the inferior alveolar nerve have been attempted, leaving the interforaminal implant insertion as the gold standard for most dental surgeons, because these procedures are technically demanding, time-consuming, and expensive and may result in substantial complications.[7-9] Short implants have gained in popularity during the past decade and represent a viable alternative to these procedures.[10] Short implant survival rates are comparable with those of long implants inserted into augmented bone sites and therefore may be a preferable, less traumatic treatment option for restoration of severely atrophic mandibles.[9,11-14] Recently, the European Association of Dental Implantologists reached a consensus that short implants in atrophic sites are a reliable treatment option whose risks are comparable with those of standard-dimension implants in combination with augmentation procedures.[6] Still, evidence on short implants in an all-on-4 setting is limited.[12,15]

In a recent pilot study, we reported preliminary results of fiber-reinforced hybrid-material bridges, fixed on 4 ultrashort 5.0-mm implants.[15] The aim of the current study was to evaluate the midterm outcomes of splinted ultrashort implants in terms of marginal bone loss and overall implant survival.

Patients and Methods

After approval of the institution's ethical committee was obtained (No. 018/2011), a prospective study was designed according to the Declaration of Helsinki, as well as the Good Clinical Practice guidelines. The results are reported according to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) criteria.[16]

INCLUSION CRITERIA

Patients aged between 18 and 80 years with severely atrophic mandibles, corresponding to Cawood and Howell class V and class VI, were included in this study after their written consent was obtained.

EXCLUSION CRITERIA

The following exclusion criteria were adopted: presence of diabetes (hemoglobin A_{1c} level >6.5%); smoking (>10 cigarettes per day); alcoholism; untreated periodontitis in the opposing jaw; history of bacterial endocarditis; reduced general state of health; bisphosphonate, interferon, or glucocorticoid intake; rheumatic disease; untreated tumor disease; osteomyelitis; pregnancy; poor patient compliance; and physical limitations interfering with oral hygiene; as well as participation in other medical studies 30 days before implant insertion.

The detailed surgical and prosthetic protocols were reported together with the preliminary results.[15] The implants healed while submerged and were uncovered after 3 months. Impressions were taken on the day of uncovering, and implants were loaded about 2 weeks later.

IMPLANT RECALL

Patients were invited to participate in the implant recall 6 months after loading, followed by annual examinations. At each follow-up visit, the peri-implant tissues were examined and a panoramic radiograph was taken.

MEASUREMENT PROTOCOL

Mesial and distal peri-implant bone levels were measured on panoramic radiographs taken at the time of implant insertion (baseline) and follow-up visits (6 months after implant placement and then annually). Eight landmarks were digitally placed around each implant at each radiographic follow-up. Landmarks were placed at the implant tip and shoulder, mesially and distally at the widest diameter of the implant, at the bone level at the implant, and at the end of the abutment neck (Fig 1). All of the measurements were performed using a proprietary program that was specifically created by 1 of the authors (R.S.) for this purpose. Two of the authors (R.S. and F.W.) measured each image twice, and all of the measurements were checked for plausibility and corrected until a consensus was reached.

STATISTICAL ANALYSIS

Statistical analysis was performed using the open-source statistical program R (version 2.15.1; R Foundation for Statistical Computing, Vienna, Austria, http://cran.r-project.org). Implant and prosthetic successes were analyzed separately. A Welch 2-sample *t* test was used to test for significant differences in age distribution between male and female patients. Linear regression models (lm) were computed to estimate the attachment level by implant depth immediately after loading for mesial (lm 1) and distal (lm 2) implants. The attachment

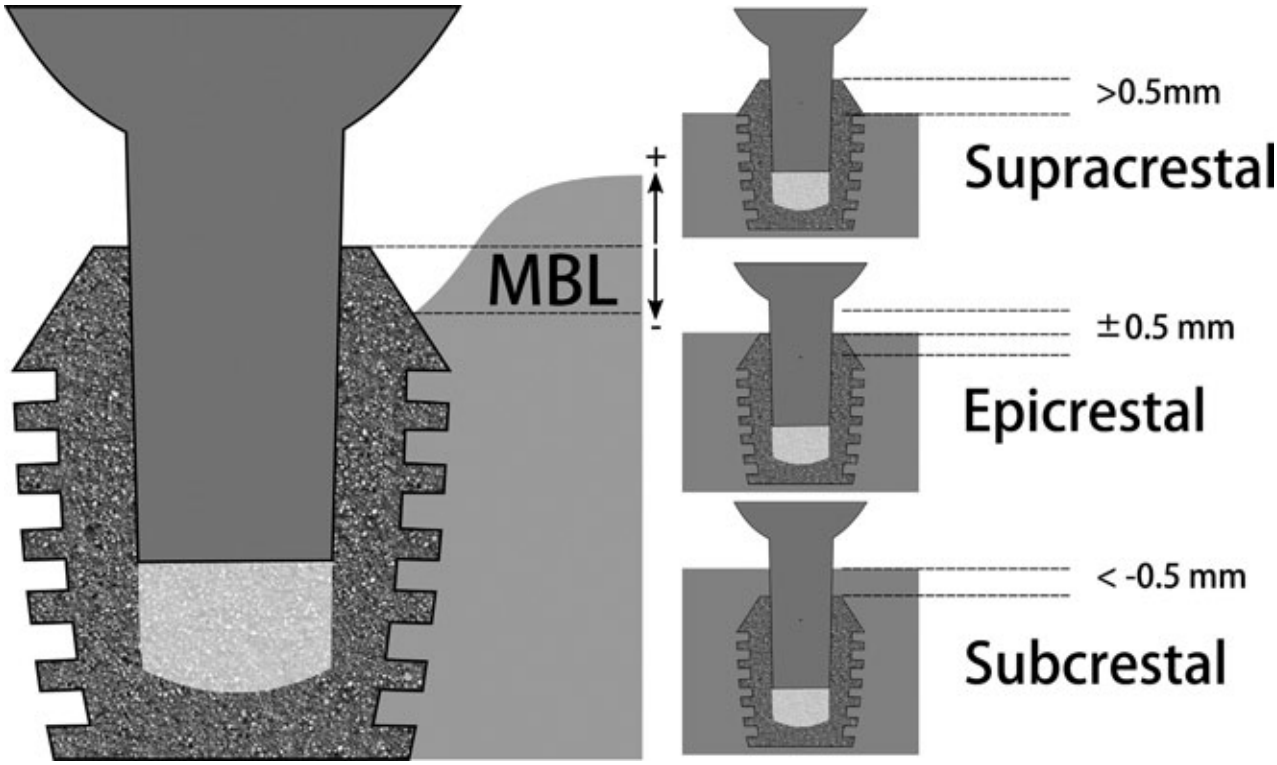

FIGURE 1. Schema of implant and abutment. The marginal bone level (MBL) was defined as the vertical distance of the implant shoulder to first bone implant contact. Three implant insertion strategies were discriminated: supracrestal, epicrestal, and subcrestal. Each implant was classified using the control radiograph after implant insertion.

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level was regressed by bone level, abutment level, and time (Table 1; Figs 2, 3).

Results

A total of 17 patients with atrophic mandibles were included in this study (14 women ranging in age from 40.7 to 73.9 years [mean, 62.1 ± 9.6 years] and 3 men ranging in age from 45.4 to 73.5 years [mean, 62.6 ± 15.1 years]). There was no significant age difference between female and male patients (Welch 2-sample *t* test: $t = -0.061$ days, $df = 2.36$, $P = .9561$). The follow-up period was on average 2.9 ± 1.5 years, ranging from 1.1 to 5.6 years.

Table 1. LINEAR REGRESSION MODEL OF MARGINAL BONE LEVEL OF MESIAL AND DISTAL IMPLANTS REGRESSED BY INSERTION PROTOCOL AND TIME

	Mesial				Distal			
Factor	Estimate	Standard Error	*t* Value	P_r (>|*t*|)	Estimate	Standard Error	*t* Value	P_r (>|*t*|)
Intercept (ie, epicrestal)	−0.21	0.12318	−2.394	.036*	−0.28	0.10292	−2.704	.008*
Subcrestal	0.31	0.12340	2.461	.002*	0.32	0.13489	2.407	.018*
Supracrestal	—	—	—	—	−0.66	0.17529	−3.744	<.001*
Time	−0.17	0.0323	−5.206	<.001*	−0.17	0.04222	−4.038	<.001*
R^2	0.3258				0.3597			

Note: Regarding the insertion protocol, epicrestal was defined as baseline (epicrestal ±0.5 mm), subcrestal was defined as less than 0.5 mm, and supracrestal was defined as greater than 0.5 mm.

* Statistically significant.

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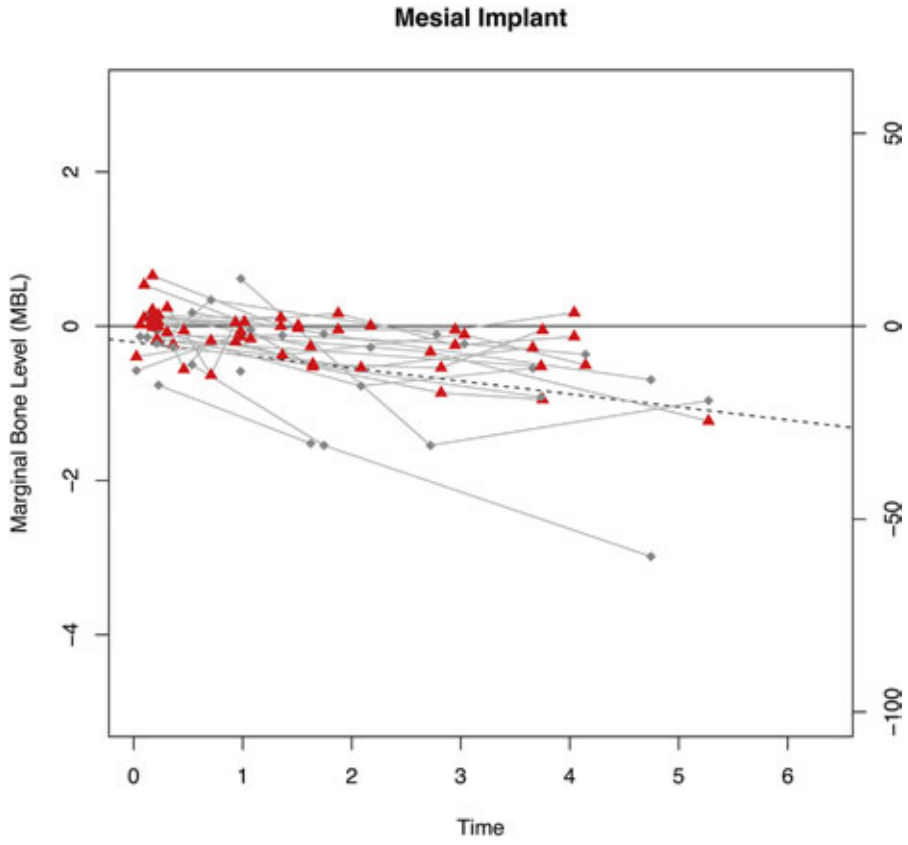

FIGURE 2. Attachment level of mesial implants over time (in years). The *left y-axis* labels refer to millimeters, and the *right y-axis* labels refer to percentage of implant length. The *red triangles* indicate supracrestal implants, and the *gray diamonds* indicate epicrestal implants. The *dashed regression line* represents a linear model of epicrestal insertion depth regressed by time.

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PATIENT-BASED IMPLANT SURVIVAL

One left mesial implant in a 55.4-year-old woman, out of 64 implants in total, was lost 174 days after placement and just before loading, resulting in an overall success rate of 94.1%. This patient underwent restoration with 3 implants without replacement of the implant. The cumulative 1-, 3-, and 5-year implant survival rates were 94.1% (95% confidence interval, 83.6 to 100.0%).

IMPLANT-BASED IMPLANT SURVIVAL

One implant failure resulted in an overall success rate of 98.5%. The cumulative 1-, 3-, and 5-year implant survival rates were 98.5% (95% confidence interval, 95.7 to 100.0%).

PROSTHETIC-BASED SURVIVAL

All patients underwent restoration with a fiber-reinforced hybrid-material bridge (TRINIA; Bicon, Boston, MA). In the opposing jaw, 7 patients had a denture, 6 had an all-on-4 ultrashort prosthesis, 2 had a partial denture with remaining anterior teeth, 1 had an implant-borne denture, and 1 had an implant-borne fixed bridge on 10 ultrashort implants. In only 1 patient, a 40.7-year-old woman who smoked, one 27.8-mm distal cantilever of the bridge prosthesis fractured after 4.8 years of loading, resulting in an overall prosthetic survival rate of 94.1%. In the opposing jaw, this patient had a fixed bridge on 10 implants. The cumulative 1-, 3-, and 5-year prosthetic survival rates were 100.0% (n = 15), 100.0% (n = 7), and 50.0% (n = 2).

MARGINAL BONE LEVEL

The marginal bone level (MBL) of the mesial implants was 0.0 ± 0.3 mm (range, −0.8 to 0.7 mm; n = 33) at the time of loading, −0.1 ± 0.3 mm (n = 20) after 1 year, −0.4 ± 0.5 mm (n = 10) after 3 years, and −1.5 ± 1.0 mm (n = 4) after 5 years. The mesial bone level depended significantly on time and insertion depth, whereby the epicrestally placed implants lost additional bone to the time depended loss whereas the subcrestally placed implants did not (Table 1). The MBL of the distal implants was -0.4 ± 0.4 mm (range, -1.4 to 0.3 mm; n = 34) at the time of loading, -0.4 ± 0.6 mm (n = 20) after 1 year, - 0.5 ± 0.5 mm (n = 10) after 3 years, and -2.2 ± 1.7 mm (n = 4) after 5 years. The distal bone level depended significantly on time and insertion depth, whereby

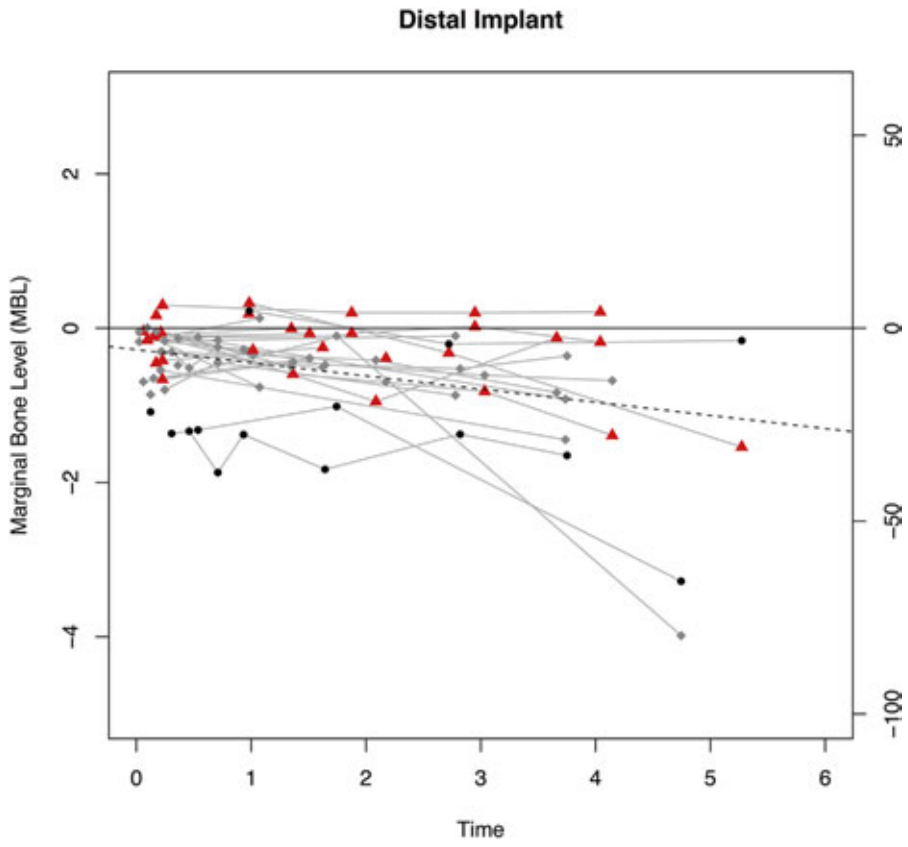

FIGURE 3. Attachment level of distal implants over time (in years). The *left y-axis* labels refer to millimeters, and the *right y-axis* labels refer to percentage of implant length. The *red triangles* indicate supracrestal implants; *gray diamonds*, epicrestal implants; and *black circles*, subcrestal implants. The *dashed regression line* represents a linear model of epicrestal insertion depth regressed by time.

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the epicrestally placed implants and supracrestally placed implants lost additional bone (Table 1).

SELECTED PATIENT CASE

Figure 4 shows a panoramic radiograph and clinical photograph of a 53.1-year-old patient at 4.3 years' follow-up. The patient showed healthy gingiva without bleeding on probing, reported cleaning with an interdental brush, and had satisfactory chewing function. In the opposing jaw, a hybrid denture was fixed on 3 short implant-borne locators.

Discussion

The aim of this study was to evaluate the 5-year follow-up results of fixed, fiber-reinforced hybrid-material bridges on 4.0 × 5.0–mm implants in severely atrophic mandibles. The cumulative 5-year implant-based success rate in this study was 98.5%, which is in line with a recent study reporting excellent results of implant-fixed prostheses on ultrashort implants.[12] These results also compare favorably with the results of prostheses fixed on implants of conventional lengths.[3] Recent studies have reported that 4 implants were sufficiently stable to support an overdenture in the short-term and that the tilting of implants did not alter the peri-implant MBLs compared with conventional, axially inserted implants.[17-19]

In 1 female patient in our study, the left mesial implant was lost 174 days after its insertion, just before loading, resulting in a 5-year patient-based survival rate of 94.1%. Three implants were restored in this patient without replacing the implant. Duyck et al[17] have shown that the observed occlusal forces on each implant increase with a decreased number of implants supporting a fixed prosthesis in the mandible. When the number of supporting implants was gradually reduced from 6 to 3 implants, the highest bending forces were found when only 3 implants were supporting the prosthesis. However, 3 years after insertion and 2.6 years after loading, the remaining 3 implants in our patient showed an uneventful follow-up.

The prosthetic-based survival rate was 100% at the 3-year follow-up and 4-year follow-up and dropped to 50% at the 5-year follow-up. However, only 2 patients

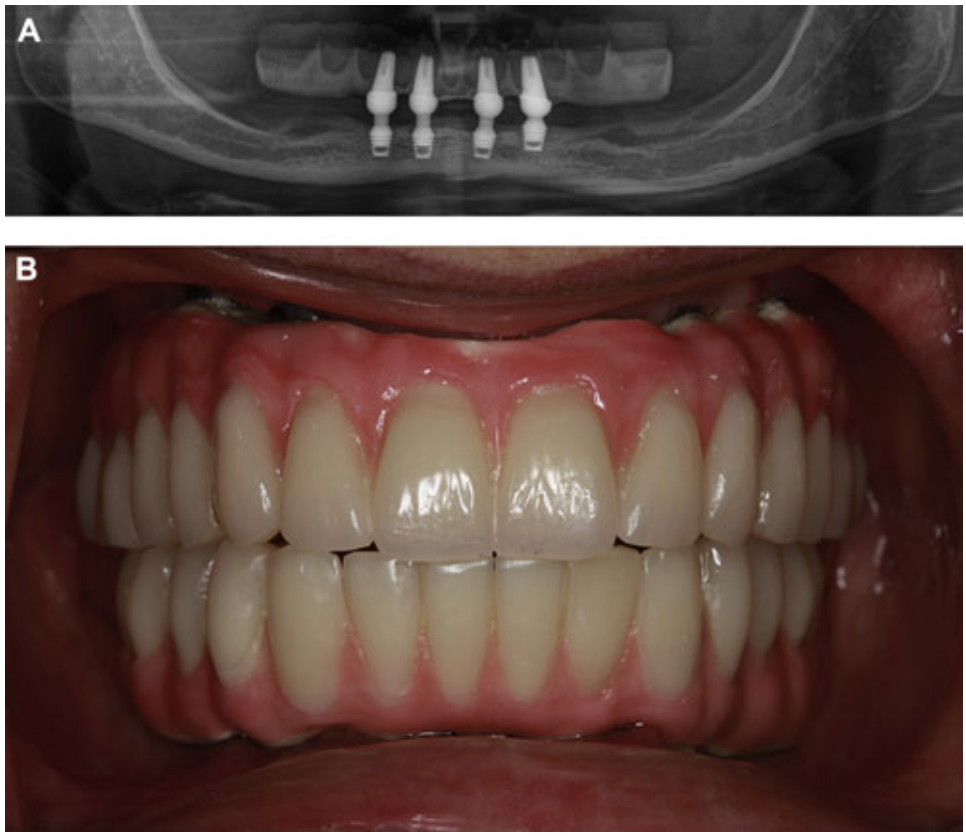

FIGURE 4. Panoramic radiograph (*A*) and clinical photograph (*B*) of a 53.1-year-old female patient at 4.3 years' follow-up.

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were followed for 5 years. The patient in whom the distal cantilever fractured did not participate in the annual implant recall and only returned as problems occurred.

In this study, the mean MBL values in the first year remained stable for both mesial and distal implants. These values are comparable with those of implants of conventional lengths: Mean vertical marginal bone loss of around 0.5 mm during the healing period, followed by annual bone loss of 0.2 mm, is nowadays considered physiological.[20-22] Our findings exceed the good results of a recent study by Esposito et al[12] reporting the 3-year follow-up results of the prosthetic rehabilitation of posterior atrophic mandibles with prostheses supported by 5.0-mm-long implants. They evaluated 26 implants in 15 patients and found the mean MBL 1 year after implant loading to be −1.20 mm, followed by an annual loss of 0.12 mm; 2 short implants failed in 1 patient, accounting for an overall 3-year implant success rate of 92.3%.

The MBL of mesial and distal implants was significantly influenced by the insertion depth (Figs 2, 3; Table 1). Contrary to recent findings, implants performed better when they were placed in a slightly subcrestal position (bone level to implant shoulder).[21,23,24] In contrast to threaded implants, Morse taper implants, which were placed slightly subcrestally, showed stable MBL values (Table 1).

The factor of time, however, did have a significant effect on the peri-implant marginal bone loss around mesial and distal implants (Table 1). Mesial and distal implants lost an average of 0.17 mm per year, which is presently considered to be in the physiological range.[20-22]

Fixed, full-arch, fiber-reinforced resin bridges retained by 4 ultrashort implants provide a comparatively cost-effective, safe, stable alternative for prosthetic restoration of the severely atrophic mandible. The overall implant survival rate and the MBL after 5 years are equivalent to those of implants of conventional lengths. The results of this study imply that ultrashort implants (eg, Bicon implants) should be placed in a slightly subcrestal position to achieve optimal results.

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