

Immediate Loading of Fixed Partial Dental Prostheses on Extra-Short and Short Implants in Patients with Severe Atrophy of the Posterior Maxilla or Mandible: An Up-to-4-year Clinical Study

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Purpose: The goal of this study was to evaluate the cumulative survival rate and marginal bone loss (MBL) of extra-short (5- and 6-mm-long) and short (6.5-mm-long) implants inserted into severely atrophic, partially edentulous posterior maxillae and mandibles that were immediately restored with provisional fixed dental prostheses. **Materials and Methods:** Between October 2013 and December 2017, partially edentulous patients with severe vertical bone atrophy in the posterior area in need of replacement of premolars and/or molars with fixed prostheses were enrolled in the study. Analysis of cumulative survival rate and MBL was determined with respect to implant length at the longest, biannual follow-up period (38 ± 10 months; range: 25 to 48 months). **Results:** Fifty-five patients were included in the study. A total of 62 extra-short (5 and 6 mm), 15 short (6.5 mm), and 69 standard-length (≥ 10 mm) implants were immediately placed and loaded. Cumulative survival rates were similar for all implants (99.3%). One mandibular extra-short implant failed and was removed but was replaced 2 months later with another implant of the same length and diameter and successfully reloaded. Implant length did not impart any significant differences in MBL, though the presence or absence of platform switching was influential. **Conclusion:** The cumulative survival rate and MBL reported in this study encourage the use of short and extra-short implants to immediately restore with fixed prostheses partially edentulous patients with severe vertical bone atrophy in posterior areas. Thus, it could be an alternative treatment to vertical bone augmentation. *Int J Oral Maxillofac Implants* 2020;35:607–615. doi: 10.11607/jomi.7943

Keywords: immediate restoration, implant-supported prosthesis, occlusal loading, posterior edentulism, short implants

Dental implants have long been used to replace missing or “hopeless” teeth.¹ However, anatomical limitations such as inadequate posterior bone height may limit their use.^{2,3} In the past, 10 to 12 mm of residual alveolar bone height has been considered to be the minimum amount of bone necessary to enable predictable implant treatment.⁴ When dental implants were first introduced, an assumption was made that longer implants would not only prove more advantageous than shorter implants due to an improved crown-to-implant ratio,⁵ but also offer greater implant surface area available for osseointegration.¹ A viable standard implant was considered to be 4 mm in diameter and 10 mm in length because these dimensions

could ensure sufficient bone-to-implant contact and adequate crown-to-implant ratios for implant restorations.^{6–9}

Frequently, posterior bone height is insufficient to allow for the use of such standard implants^{2,10,11} unless invasive surgical procedures such as sinus elevations, vertical bone augmentation,^{12–14} or alveolar nerve transposition have been undertaken. Risks of intraoperative and postoperative complications, infection, or graft resorption have been reported for these procedures, along with increased duration and cost of treatment.^{15–18} Advancement in textured surfaces enabled increases of implant surface areas that presumably compensated for the shorter length of bone contact when using short implants. As a consequence, the use of short dental implants was suggested as an alternative to regenerative procedures in atrophic posterior ridges, where the presence of the maxillary sinus or the mandibular inferior alveolar canal often reduces available bone height.^{19–21} In 1991, implants shorter than 10 mm (8 and 9 mm) were defined as “short.” Since then, the definition of short implants has been controversial, with studies and reviews lacking consensus about the meaning of that term.²² The present study adheres to a

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recent classification scheme based on the frequency of reporting, which designated “extra-short” for implants shorter than or equal to 6 mm and “short” for implants between 6 and 10 mm long.²³

The present study aimed to investigate the cumulative survival rate and marginal bone loss (MBL) of extra-short (5 and 6 mm) and short (6.5 mm) implants immediately loaded in severely atrophic posterior mandibles and maxillae of partially edentulous patients. In addition, statistical analysis was determined for the effect of platform switching on MBL.

MATERIALS AND METHODS

The present study included partially edentulous patients in need of replacement of teeth in the posterior area. All the dental procedures were performed at one clinic between October 2013 and December 2017 after obtaining informed consent signatures from patients in accordance with the Declaration of Helsinki for investigations in human subjects.

Inclusion criteria were as follows: (1) partially edentulous patients in the posterior area (premolars and molars); (2) 5-mm bone height or more above the alveolar canal in the mandible and 4 mm or more bone height inferior to the floor of the maxillary sinus in the maxilla; (3) patients of 20 years of age or older; (4) absence of periodontal disease or parafunctional habits.

Exclusion criteria were as follows: (1) less than 5 mm bone height above the mandibular alveolar canal; (2) less than 4 mm bone height inferior to the floor of the maxillary sinus or presence of any sinus pathology; (3) severe maxillomandibular discrepancies; (4) the presence of periodontal disease; (5) irradiated patients or patients taking medications that could interfere with bone metabolism (ie, bisphosphonates); and (6) smoking was not considered to be an exclusion criterion, nor was the presence of a periapical lesion. However, implant placement was postponed if any one of the following occurrences existed in the extraction site: (1) an abscess; (2) draining fistula; (3) pus; or (4) exudate. Uncontrolled diabetes or any other systemic condition that was a contraindication to surgery was also considered an exclusion criterion, as was the presence of pathology involving the adjacent teeth.

All implants were manufactured with a microroughened surface (T3, Zimmer Biomet).

Treatment

To aid in the making of the prosthesis, alginate impressions were taken, study casts were mounted on an articulator, and diagnostic wax patterns were created for optimal crown positions. The intended implant sites for each patient were identified by fabricating a

radiographic-surgical template and a provisional prosthesis of metal-reinforced acrylic resin with perforations in the central fossae areas. Occlusal analysis and a complete intraoral clinical and radiographic examination, including cone beam computed tomography (CBCT), was performed prior to and immediately after implant insertion with subsequent biannual follow-up periods (25 to 48 months) for every patient.

Surgical Procedure

Prior to surgery (2 to 3 days), professional tooth cleaning for plaque and calculus removal was administered to each patient and 0.20% chlorhexidine rinse was prescribed (3 times a day for 14 days). At 12 hours before surgery, all patients began a 6-day course of amoxicillin (1 g tablets, bi-daily). On the day of surgery, local infiltration of 4% articaine with 1:100,000 epinephrine was delivered into the vestibular and lingual/palatal areas. The same local anesthetic was used on the incision lines with 1:50,000 epinephrine. In cases where it was determined by CBCT that the bone crest was less than 7 mm wide (buccal to lingual) or when the band of keratinized gingiva was inadequate, a full-thickness mucoperiosteal flap was raised to expose the crestal bone and increase the amount of keratinized gingiva buccally; in the maxillary arch, this was achieved by moving the incision line toward the palate and repositioning the flap buccally; in the mandibular arch, a subepithelial gingival graft was harvested from the palate and placed buccally. Though ridge augmentation was not performed, Endobon Xenograft material (Zimmer Biomet) was mixed with autogenous bone (50%/50%), harvested with the burs during drilling in all immediate extraction placement sites, filling the facial gaps between the implant and the alveolar walls. In the maxillary arch, where the available bone height was less than 5 mm, a crestal approach sinus elevation with osteotomes without any particulate graft insertion was performed to allow the placement of a short or extra-short implant at the crestal bone level. Whenever a flap was raised, resorbable sutures were used to close it. Based on both the CBCT analysis and the amount of resistance encountered during drilling, bone quality was assessed and recorded. For Type I and II bone, osteotomies were performed according to the manufacturer's protocol. In maxillary Type III and IV bone, care was taken to underprepare the osteotomies by using osteotome bone expanders (Steri-Oss, Osteotome Kit). In mandibular Type III bone, drills of the same length but one size smaller in width were used. In Type IV mandibular bone, the final drill was the same length as the implant but two sizes smaller in width. All implants were inserted using a drill unit, and final seating was achieved with a torque caliper hand-ratchet (High Torque Indicating Ratchet Wrench, Zimmer Biomet);

Fig 1 (a) Lateral view of a partially edentulous area. (b) Radiographic image that demonstrated sinus floor proximity and minimal vertical bone height distal to the second premolar. The maxillary premolars were not restorable.

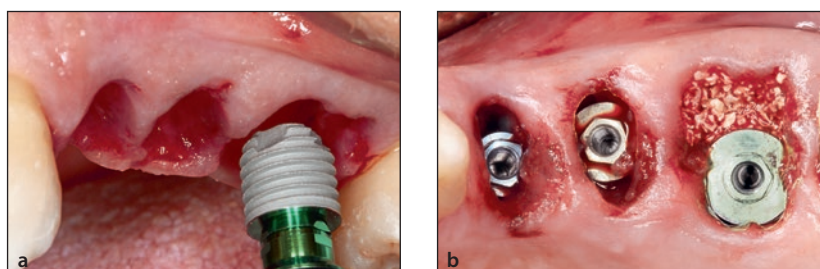
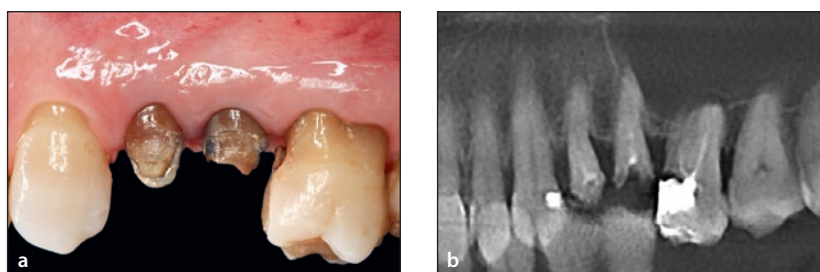


Fig 2 (a) Clinical image of a wide-diameter, extra-short implant (6.0 × 6.0 mm) being placed in the extraction socket of the maxillary left first molar. The first and second premolar extraction sockets are also apparent. (b) Clinical occlusal image after placement of the implants with the inclusion of a xenograft material along the buccal aspect (Endobon, Zimmer Biomet). (c) Hand-ratchet that demonstrated an insertion torque of 80 Ncm. (d) Clinical image of the screw-retained provisional prosthesis immediately postinsertion. This restoration had centric occlusal contacts; no contacts were permitted in lateral excursions. (e) Postoperative radiograph showing the fixed provisional prosthesis with a splint. The abutments for short/extra-short implants were designed for platform switching.



the insertion torque was then recorded. Implant insertion and surgical sites are illustrated with clinical and radiographic images (Figs 1 to 6). The distribution of implant types with respect to diameter (Fig 7) and bone quality (Fig 8) as well as insertion torque values (ITV) versus bone type (Table 1) are depicted for all implants.



Provisional Prostheses

In all cases, provisional abutments (Titanium Temporary Cylinders, Zimmer Biomet) were chosen, adjusted for length and angulation, and then inserted. The provisional abutment platforms were one size smaller than the short/extra-short implant platforms, and thus, platform-switched. The 4-mm-diameter standard-length implants were not platform-switched. Periapical radiographs were taken to verify complete seating of each abutment. The abutment screws were torqued to 10 Ncm using a torque driver (Low Torque Indicating Ratchet Wrench, Zimmer Biomet). The intaglio surfaces of the provisional fixed prostheses were relieved, and openings were prepared to allow the temporary cylinders to seat without interference. The screw-access areas were blocked to prevent light-cured composite resin (Tetric-Flow, Ivoclar Vivadent) from flowing in when luting the cylinders to

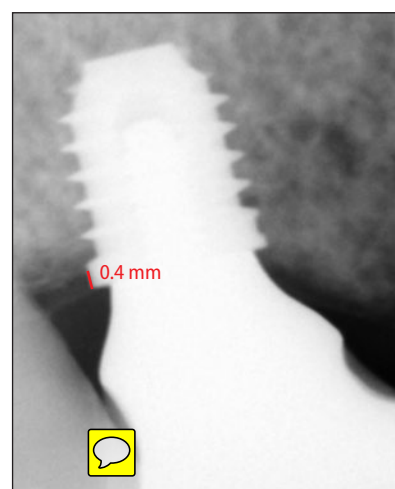


Fig 3 Example measurement of the medial crestal bone level referenced from the most coronal aspect of the implant to the crest of the bone.



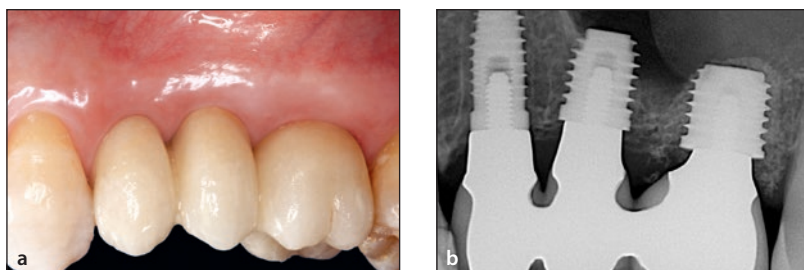


Fig 4 (a) Clinical image of the definitive restoration 3 years postinsertion. (b) Periapical radiograph 3 years postinsertion, which demonstrated stable crestal bone levels adjacent to the implants.

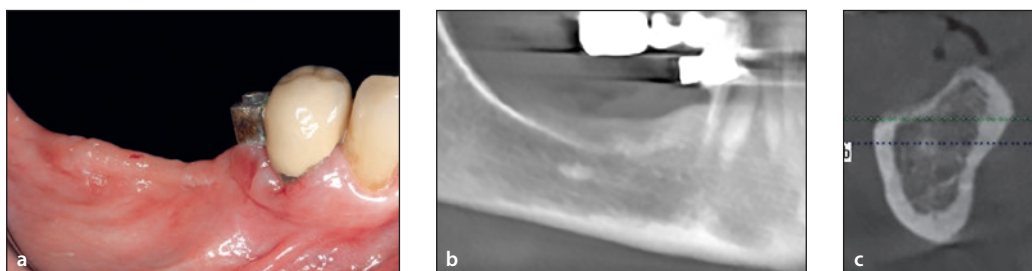


Fig 5 (a) Lateral view of a partially edentulous area in the mandible. (b) Radiograph and (c) CBCT image demonstrating minimal vertical bone height. (d) Clinical occlusal image after placement of the implants. (e) Clinical image including the xenograft material along the buccal aspect (Endobon, Zimmer Biomet). (f) Clinical image of the screw-retained provisional prosthesis immediately postinsertion. (g) Postoperative radiograph showing the fixed provisional prosthesis with a splint. The abutments for short/extra-short implants were designed for platform switching.

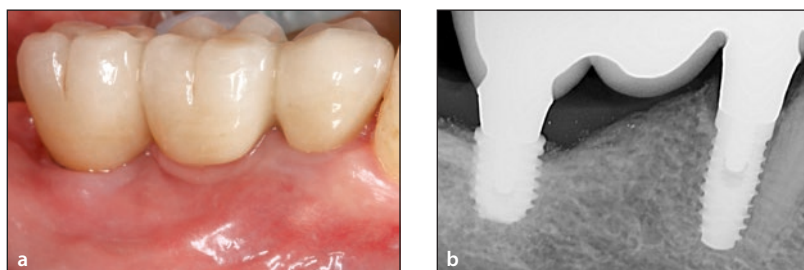
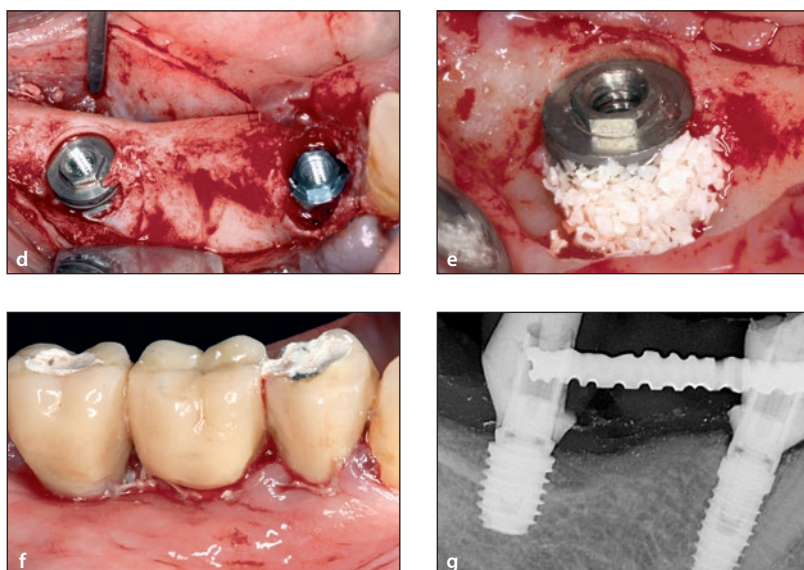


Fig 6 (a) Clinical image of the definitive restoration 4 years postinsertion. (b) Periapical radiograph 4 years postinsertion, which demonstrated stable crestal bone levels adjacent to the implants.

the fixed provisional prostheses. Once the resin set, the prostheses were adjusted to achieve proper contact points in centric occlusion and no contact in excursive or protrusive movement, which was determined with

thin foil articulating paper. The block-out material was removed, and the retaining screws were loosened to remove the provisional prostheses with the luted cylinders. Further adjustments were made with respect

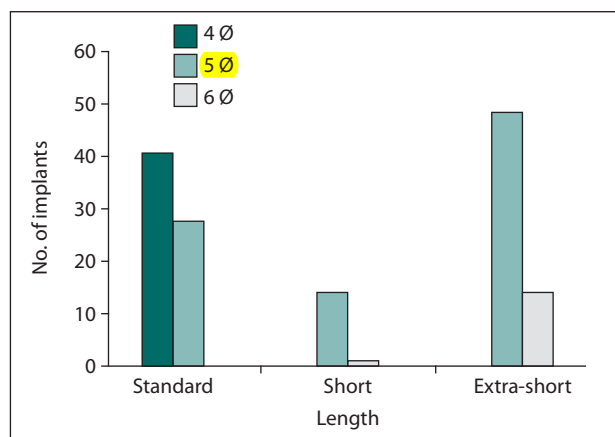


Fig 7 Quantification of implants by diameter and length.

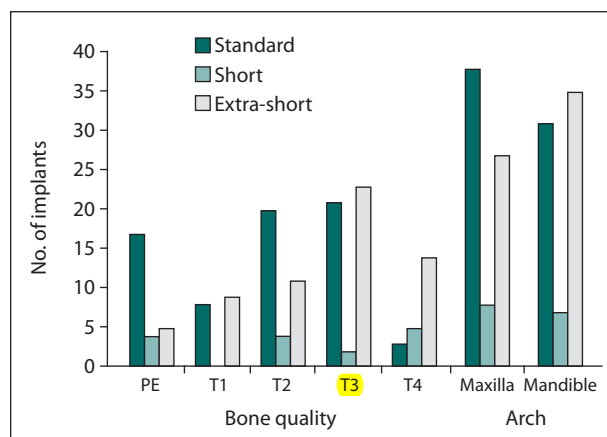


Fig 8 Distribution of implants by length, bone quality, and arch. PE = postextractive.

to the emergence profile: contour of the crown, refinement, and polishing. The fixed provisional prostheses were reinserted, and the screws were torqued to 20 Ncm using a manual wrench for final seating. Periapical radiographs were taken at baseline and at 6-month intervals to determine and compare implant marginal crestal bone level using an individualized film holder. Mesial and distal crestal bone level measurements were taken from the most coronal part of the implant collar to the crestal bone level using VixWin Platinum Software calibrated measurement (Fig 3). Clinical and radiographic images at implant insertion and placement of a provisional prosthesis are illustrated (Figs 2 and 5). All patients were given an NSAID analgesic and anti-inflammatory medication to take immediately after surgery and repeat after 8 hours, if needed. They were instructed to consume only liquids for 1 week and after that to chew soft food for 2 months. Patients were seen for hygiene maintenance once a week for the first month and then monthly up to 6 months.

Restorative Prostheses

Four to 6 months later, implant-level definitive impressions were made using anatomical custom trays and pick-up impression copings (Zimmer Biomet) placed onto the implant platforms. Low-viscosity polyether impression material was used for the definitive impressions (Impregum Penta, 3M ESPE). To minimize the potential for peri-implant bone resorption, abutments narrower than the short/extra-short implant platforms were selected, and thus, platform-switched. All standard-diameter implants (4 mm) were not platform-switched. Gold UCLA abutments (Zimmer Biomet) were used in all cases. Abutment screws (Gold-Tite, Zimmer Biomet) were torqued to 32 Ncm according to the manufacturer's protocol using a calibrated torque driver (Contra Angle Torque Driver Body, Zimmer Biomet). To provide for both esthetics and function, porcelain-fused-to-metal,

Table 1 Number of Implants (ITV vs Bone Quality)

Bone type	ITV (Ncm)			
	A: > 90	B: 70–90	C: 50–69	D: < 50
PE	2	1	3	2
Type I	4	3	2	
Type II	10	4	1	
Type III	6	11	4	4
Type IV	3	6	3	8

PE = postextractive; ITV = insertion torque value.

screw-retained restorations were utilized. Periapical radiographs were taken using an individualized film holder for crestal bone level measurements and comparisons (Fig 3). The bone at implant level was calibrated at the day of implant surgery and then thereafter at the recheck appointments. Clinical and radiographic images at restoration and final follow-up are illustrated (Figs 4 and 6). Where applicable, data are presented as the mean \pm SD, and statistical significance ($P < .05$) was calculated with the open source R Project for Statistical Computing (The R Foundation). An effect of platform switching on MBL was determined across each implant length by repeated-measures analysis of variance (ANOVA) followed by a pairwise post hoc *t* test of the fit to a linear mixed-effect model.

RESULTS

The study consisted of 55 partially edentulous patients (women: 38; men: 17) including 16 smokers. Patients had severe vertical bone atrophy in the mandibular and/or maxillary premolar and molar areas and received 146 implants (maxilla = 73; mandible = 73) consisting of a combination of 62 extra-short (5 and 6 mm),

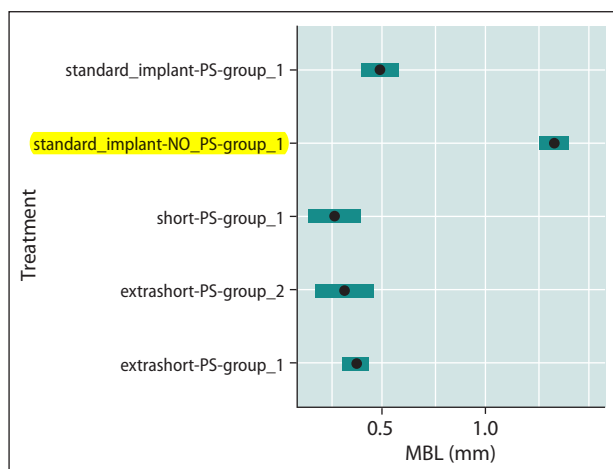


Fig 9 Distal marginal bone loss (MBL) for different groups and treatments.

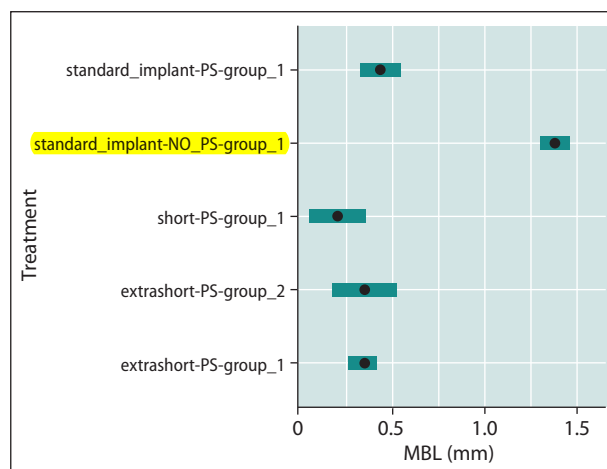


Fig 10 Mesial marginal bone loss (MBL) for different groups and treatments.

15 short (6.5 mm), and 69 standard (≥ 10 mm) lengths; 120 were inserted in healed bone and 26 in fresh extraction sockets. In the maxillary arch, 20 implants were inserted with simultaneous sinus floor elevation. The median age of the subjects was 63 years (minimum: 30; maximum: 86).

In 55 patients (group 1), extra-short (5 and 6 mm) and/or short (6.5 mm) implants were splinted to standard implants (≥ 10 mm). In five patients (group 2), only extra-short (5 and 6 mm) and/or short (6.5 mm) implants were splinted. These two groups were also categorized according to arch site and the poorest bone quality within each splint. Fifty patients received only one fixed provisional prosthesis; five patients received two. The total fixed prostheses amounted to 60, with 30 each located in the maxillae and mandibles.

Postrestoration follow-up occurred from a minimum of 24 up to 48 months biannually. At each follow-up visit, clinical and radiographic inspections were taken, and no adverse signs or symptoms were noted apart from one 6-mm extra-short implant that failed in the mandible. The affected patient functioned with the provisional restoration for 8 months. Two of the three abutment screws came loose; only the mesial screw retained the prosthesis and subsequently became mobile. Thus, the mesial implant was removed and replaced 8 weeks later with an implant of the same length and diameter. This implant osseointegrated and was successfully loaded with a new definitive prosthesis.

Cumulative survival rate and MBL were determined at an average follow-up period of 38 ± 10 months for each implant type.

The bone at implant level was calibrated at the day of implant surgery and then thereafter at the recheck appointments. Changes in the mesial and distal crestal bone levels were determined by the use of VixWin

Platinum software measurements of periapical radiographs (Fig 3) and averaged for MBL. Data for groups 1 and 2 were pooled together, as independent sample sizes were insufficient to provide statistical power for comparisons. Due to the combined groups, the effect of platform switching on MBL was determined with respect to implant length. Platform switching and implant length were treated as one independent variable in repeated-measures ANOVA, which resulted in an overall effect. This was followed by a pairwise post hoc analysis using a *t* test to determine the fit of a linear mixed-effect model for each independent variable. Consequently, MBL was found to mainly depend upon the absence (1.36 ± 0.19 mm; $P < .05$) versus the presence of platform switching (0.36 ± 0.25 mm) as opposed to splinting of extra-short implants with (0.37 ± 0.28 mm) or without (0.34 ± 0.18 mm) larger implant lengths.

Cumulative survival rates for all implants (99.3%) were similar across implant lengths: standard length (100%), extra-short (98.4%), and short (100%) with one failure. The small number of distributed implants according to length and bone quality (Fig 8) did not permit adequate assessment of the latter on measured outcomes. MBL for extra-short (0.35 ± 0.24 mm; range: 0.0 to 0.8 mm) and short (0.25 ± 0.17 mm; range: 0.0 to 0.9 mm) implants was significantly different from standard-length implants (0.92 ± 0.26 mm; $P < .05$). As all extra-short and short implants were platform switched, it was determined that the difference resulted from the absence (1.36 ± 0.19 mm; range: 1.1 to 1.7 mm; $n = 43$; $P < .05$) or presence (0.48 ± 0.32 mm; $n = 26$) of platform switching in standard-diameter implants (Figs 9 and 10). No difference was noticed between implants inserted in healed bone, in fresh extraction sockets, or with crestal approach sinus floor elevation.

DISCUSSION

In clinical practice, patients often find it uncomfortable to wear removable provisional prostheses during the initial implant-integration phase. The potential to receive a fixed prosthesis immediately after implant placement has been described as a major advantage.²⁴ The ability to place short implants in areas with minimal bone height precludes the need for bone regeneration that would delay the use of a fixed prosthesis. The introduction of short implants (< 10 mm in length) has made it possible to deliver favorable outcomes at efficient speeds by reducing the need to perform techniques that enhance available bone.²⁵

When short implants were introduced, the use of a staged approach for placement was suggested. The implants were first submerged below the gingiva prior to introducing restorations to protect the initial phases of osseointegration and avoid the risk of implant failures due to micromovement or contamination.²⁶ Current practice often follows a single-stage approach based on several studies showing no significant differences in survival rate between immediate and delayed loading of implants depending on bone height and quality.²⁷ Some differences occurred in success variables, but the benefits of reduced time and patient comfort outweighed any small changes observed.²⁷ Recent studies have additionally shown that the implant length does not play a relevant role in the achievement of implant primary stability. Anitua et al (2010) conducted a finite element analysis of the influence of implant length, diameter, and design on implant surface stress distribution.²⁸ Stress distribution on the implant surface was localized on the first six threads of the implant, independent of its length, diameter, or design. They also reported that at a constant length, wider implants reduced the maximum von Mises stress in bone by 20% to 30%.²⁸ Furthermore, a number of clinical studies show no significant difference in survival rates between short and standard-length implants independent of the need to perform sinus floor elevation.^{6,29–34}

Short implants placed in select patients using high insertion torque values (> 40 Ncm) and immediately loaded have shown comparable survival rates to those placed using staged procedures, even in the presence of poor bone quality.²¹ Recent studies have further assessed the effects of splinting short implants to each other or to longer implants for support of fixed partial prostheses without any significant difference in survival rate.³⁵ The present study investigated the effect of prosthetic support by extra-short, short, and standard implants by determining cumulative survival rate and MBL in relation to bone quality and arch site.

The data collected show no significant differences for cumulative survival rate and MBL, respectively:

extra-short (98.4%), short (100%), and standard (100%). In addition, the excellent outcome of cumulative survival rate and MBL (< 0.5 mm) at an average of 38 ± 10 months follow-up for extra-short and short implants indicated that these provided an added advantage for patients with severe vertical bone atrophy. Despite the even distribution of implants with respect to bone quality and arch site, a trend toward larger MBL resulted, particularly for standard-length implants. The presence of platform switching resulted in MBL differences; this has been shown to reduce or minimize bone resorption at the top of the implant, increasing support to facial gingival marginal tissue and papillae.³⁶ The lack of platform switching in all the 4-mm-diameter standard implants may have accounted for their losses.

Indeed, many factors can contribute to the adequate dispersion of load across splinted implants.³⁷ The present study analyzed each implant separately for ease of study comparisons and to prevent vague associations that arise from fitting survival data to a statistical model. Two studies using similar patient demographics and surgical techniques^{38–40} accounted for the interdependency across splinted implants. In one study,^{38,40} short Brånemark implants (6 to 8.5 mm; Nobel Biocare) were used in posterior sites of the maxilla and/or mandible with a mean follow-up period of 5 years. Comparisons were made between splinted implants and single crowns. In measurements of cumulative survival rate and MBL, implants supporting single crowns were not significantly different compared with two groups of splinted implants, though it was not clear how many single implants were located in the maxilla, where larger bone losses occurred. A 51-year systematic review up to 2016⁴¹ showed similar ranges in marginal bone loss between implants restored with nonsplinted and splinted restorations. Interestingly, Naert et al⁴⁰ showed a significantly higher hazard rate as well as larger, insignificant bone loss in the first 6 months for shorter implants, but these results were not categorized with respect to single or splinted groups. Moreover, all implants tested (< 10 mm in length) would be considered short by some investigators.^{34,42}

The data of the present study show similar cumulative survival rate values for splinted implants compared with the aforementioned studies, with the exception of the increased hazard rate or implant loss for short implants^{38,39} accompanied by insignificant increases in bone loss.⁴⁰ MBL was a better indicator of differences and indeed showed variability across studies. Nevertheless, the changes in MBL that did occur were very small (0.015 mm/year after 6 months) compared with the present study (median $0.5 \pm$ SE mm). The MBL values in the present study correspond more closely to the data involving splinted, standard implants.^{35,39} The fact that standard-diameter implants resulted in the largest MBL



was probably related to the absence of platform switching in the implant-abutment connection. However, it is also possible that the lack of platform switching performed for standard implants resulted in susceptibility to influences of bone quality.

The microroughened implant surfaces used in the present study and the high insertion torque values obtained (> 50 Ncm) may account for the achievement of success rates comparable to standard implants. The roughened surface allows for faster integration and significantly increases the surface area, allowing for greater bone-to-implant contact. The use of high insertion torque values for placement of an implant results in closer contact between the implant and surrounding bone, thus improving the primary stability.⁴³ To achieve high insertion torques, the osteotomies were underprepared in accordance with the bone quality at each site.^{37,43} Many studies report similar outcomes with the placement of single, short, and standard implants following two types of sinus floor elevation procedures^{31,44} or in the absence of sinus floor elevation for single, short implants.²⁵ Likewise, immediate and delayed loading procedures do not impart any substantial differences in survival and success variables for implants.²⁷ Therefore, other factors excluding surgical procedures may be at play with regard to success variables for short versus standard implants. Some of these factors include proper surgical planning and restoration, longer follow-up, implant design (machined versus textured), and comparisons with regard to bone quality and/or location of insertion. One study⁴⁴ noted that surgical time and cost were significantly higher in patients who received standard implants versus those that received short implants. Indeed, one of the main advantages of using short implants is faster and less-expensive treatment due to the lack of invasive surgical procedures required. The results of the present study add support for the immediate loading of extra-short and short implants, with only minor influences in splinting with standard implants when not platform-switched. The only limiting factor was an initial learning curve for the underpreparation technique and immediate loading procedures. Occlusal control, patient selection, and dietary compliance present additional elements for achievement of satisfactory clinical results.

CONCLUSIONS

The results of this study potentially support the use of extra-short (5 and 6 mm) and short (6.5 mm) implants splinted or not to standard-length implants (≥ 10 mm) for immediate loading in cases of severe posterior bone atrophy, both in the maxilla and the mandible.

Cumulative survival rates and MBL were comparable to those obtained from similar studies with standard-length implants. Larger sample sizes and longer follow-up periods are needed to further validate these conclusions. Using extra-short and/or short implants may be considered a valid alternative to performing regenerative procedures, one that offers patients the advantages of shorter treatment times, minimal invasiveness, and lower morbidity and costs.

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The authors reported no conflicts of interest related to this study.

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