

CLINICAL RESEARCH

Three-year clinical and radiographic outcomes of splinted versus nonsplinted extrashort implants in atrophic mandibles: A split-mouth randomized clinical trial

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Atrophy of the posterior mandible often presents a challenge in treatment with implant-supported prostheses, as resorption of the alveolar crest after tooth loss can hinder the appropriate positioning of adequately sized implants.¹ Advanced surgical techniques such as bone grafting,² distraction osteogenesis,³ and mandibular nerve lateralization⁴ can be used to allow the placement of longer implants but have been associated with longer treatment durations.¹ Furthermore, while guided bone regeneration has been reported to have high clinical success rates and long-term bone stability,^{5,6} distraction osteogenesis and mandibular nerve lateralization have been linked to increased morbidity⁷ and a higher risk of permanent neurosensory disorders.⁸

ABSTRACT

Statement of problem. Whether the unfavorable crown-to-implant ratio of extrashort implants and the use of splinted versus nonsplinted crowns affects marginal bone loss and implant survival remains unclear.

Purpose. The purpose of this split-mouth randomized clinical trial was to evaluate the effect of splinting on survival rates and clinical and radiographic parameters associated with prostheses supported by extrashort implants in the posterior region of atrophic mandibles over a 3-year follow-up period.

Material and methods. Sixty extrashort implants (5 mm in length) were placed in 10 participants. Prosthesis type for each hemimandible was randomly assigned to 1 of 2 groups (n=30): Group NS, nonsplinted crowns and Group S, splinted crowns. Modified plaque index (mPI), modified sulcus bleeding index (mBI), probing pocket depth (PPD), and vertical marginal bone loss (vMBL) were assessed immediately after prosthesis installation (T0) and at 6 (T1), 24 (T2), and 36 months (T3). A custom-made acrylic resin device was used to standardize radiographic images over time, and vMBL was measured by using an image processing software program. Survival rates were analyzed by using the Kaplan-Meier method and the log-rank test. The Mann-Whitney and Friedman tests were used for mPI and mBI, while 2-way repeated-measures ANOVA was applied for PPD and vMBL ($\alpha=.05$).

Results. No significant difference was observed between groups in terms of survival rates, which were 100% and 96.6% for Groups S and NS, respectively ($P=.309$). The mPI was significantly higher in Group S than in Group NS at T1 ($P<.001$) and T3 ($P=.006$). At T3, Group S also exhibited a significantly higher mBI than Group NS ($P=.012$). PPD was significantly lower in Group S than in Group NS at all time points ($P=.038$). No significant difference was found between groups regarding vMBL ($P=.498$). In both groups, vMBL was significantly higher at T1 than at T3 ($P=.035$).

Conclusions. Extrashort implants with nonsplinted crowns exhibited similar survival rates and vMBL compared with those with splinted crowns over a 3-year follow-up period. Extrashort nonsplinted implants were associated with more effective biofilm control. (J Prosthet Dent xxx;xxx:xxx-xxx)

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Clinical Implications

After a 3-year follow-up period, prostheses supported by extrashort implants (5 mm in length) and nonsplinted prosthetic crowns in the posterior region of atrophic mandibles seemed to have improved oral hygiene and resulted in clinical and radiographic outcomes comparable with those of prostheses with splinted crowns.

Short implants (6.0 to 8.5 mm in length) and extrashort implants (<6.0 mm in length) have been indicated in patients with mandibular atrophy.^{9–11} Their survival rates and bone remodeling levels have been reported to be comparable with those of long implants,^{12–15} particularly after advancements in surface treatments and the macrogeometry of extrashort implants.^{16,17} However, a systematic review and meta-analysis has also reported lower survival rates for extrashort implants compared with implants longer than 6 mm.¹⁸ The increased interocclusal space resulting from alveolar resorption combined with the use of extrashort implants has been reported to lead to an unfavorable crown-to-implant ratio^{19,20} and a limited bone-to-implant contact area, which may pose a biomechanical risk.^{19,21,22} Pascoal et al²³ reported similar survival rates for splinted and nonsplinted crowns, while Al Amri and Kellesarian²⁴ reported no significant difference between them regarding crestal bone loss. In contrast, De Souza Batista et al²⁵ concluded that splinted crowns were associated with relatively lower implant failure rates.

Biomechanical studies^{25–28} have suggested that splinting prostheses supported by extrashort implants helps distribute occlusal loads across prosthetic components, reducing stress on the cortical bone and minimizing prosthetic complications. Conversely, non-splinted crowns have been reported to facilitate oral hygiene, lowering the prevalence of peri-implantitis, and improving the passivity of the substructure, allowing for an improved emergence profile and cervical contour.^{9,29–32}

Thus, this randomized split-mouth clinical study aimed to evaluate the influence of the prosthetic splinting of extra-short implants on the survival rate of implant-supported prostheses in the posterior region of atrophic partially edentulous mandibles, as well as on the clinical parameters of modified plaque index (mPI), modified sulcus bleeding index (mBI), and probing pocket depth (PPD) and the radiographic parameter of vertical marginal bone loss (vMBL). The null hypothesis was that no significant difference would be observed between splinted and nonsplinted prostheses regarding implant survival and associated clinical and radiographic parameters after a 3-year follow-up period.

MATERIAL AND METHODS

This study had been approved by the local research ethics committee (CAAE: 64381317.4.0000.5147) and followed the CONSolidated Standards of Reporting Trials (CONSORT) 2010 guidelines.³³ Sample size was calculated by using repeated-measures ANOVA and a split-mouth design with 2 time points. A pilot study involving 3 participants estimated an effect size of 0.204. Considering a 5% significance level and 85% power, it was determined that 56 implants would be required. Calculations were made with a software program (G*Power v.3.1.5; Heinrich-Heine-Universität Düsseldorf).³⁴

Twenty-six participants were enrolled in the study after signing the informed consent form. All participants had at least 2 missing mandibular molars on each side and met the following inclusion criteria: Kennedy Class I arches, healthy according to the American Society of Anesthesiologists system,³⁵ aged 18 or older, residual bone height of less than 8 mm, and the presence of teeth or fixed prostheses in the opposing arch. Exclusion criteria included gingival thickness of less than 2 mm, smoking more than 10 cigarettes per day, pregnancy, systemic disease, parafunctional habits, chronic periodontal disease in teeth adjacent to the implant sites, and a history of bone grafting. Based on these criteria, 10 participants were excluded. Among the remaining 16 participants, 3 were excluded during the study because of death, treatment abandonment, or relocation. Thus, 13 participants (4 men [30.8%] and 9 women [69.2%]) were evaluated, with a total of 60 implants placed.

At least 2 adjacent extrashort implants were placed in each hemimandible. Two participants received 8 implants, while the others received 4. Prostheses were randomly assigned to 1 of 2 groups: nonsplinted single prostheses (Group NS) and splinted prostheses (Group S). In each participant, the treated side and prosthesis type were randomly determined by using the sealed envelope method, with the contralateral side assigned to the opposite group.

All participants received a preoperative dose of 2 g amoxicillin (Glaxo Wellcome) and 40 mg prednisone (Brainfarma Indústria Química e Farmacêutica), administered orally 1 hour before surgery. One participant reported an allergy to amoxicillin and was therefore administered 300 mg clindamycin (Pfizer Brasil) instead. Nerve block and infiltration anesthesia were conducted by using 2% lidocaine with 1:100 000 epinephrine (Alphacaine; Nova DFL). Crestal and intrasulcular incisions were made, and a full-thickness flap was elevated. The osteotomy procedure was guided by a prefabricated surgical guide to ensure optimal 3-dimensional implant positioning at bone level (epicrestally). The drilling protocol was conducted according to the manufacturer's instructions at 900 rpm.

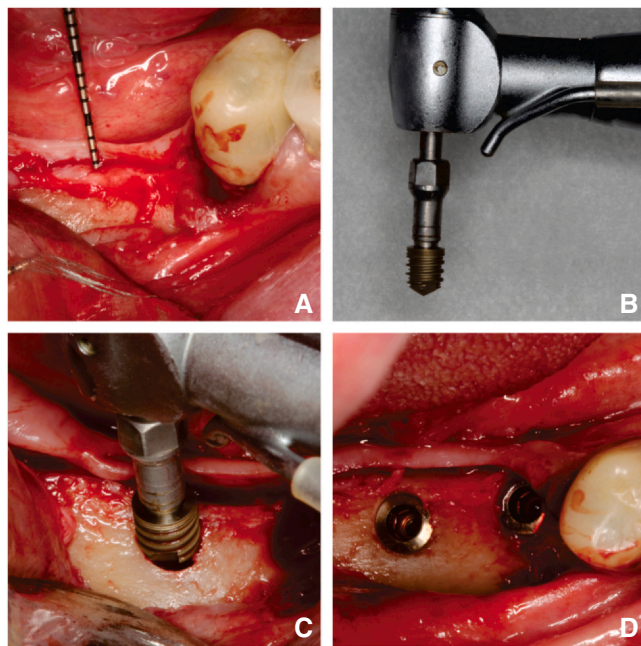


Figure 1. Representative images of surgical procedures. A, Elevation of full-thickness mucoperiosteal flap, followed by confirmation of minimum gingival thickness required for inclusion in study. B, Extrashort implant with tapered internal connection used with all prostheses, measuring $\varnothing 4 \times 5$ mm (Unitite Compact; S.I.N. Implant System). C, Implant placement. D, Installed implants.

All implants were $\varnothing 4 \times 5$ mm (UCMC 4005 N; S.I.N. Implant System), with a cylindrical macrogeometry in the cervical portion and conical toward the apex, with microthreads in the cervical region and a conical prosthetic platform featuring a 4-degree internal angle. The surface treatment extended to the top of the platform. Primary stability was achieved in all implants, with torque values exceeding 35 Ncm. Continuous scalloped sutures were placed by using 5-0 mononylon thread (Ethicon; Johnson & Johnson). All surgical procedures were performed by the same surgeon (B.S.S.M.) and are illustrated in Figure 1.

In the postoperative period, participants were prescribed 875 mg amoxicillin (Nortis Farmacêutica) every 12 hours for 7 days, 40 mg prednisone (Brainfarma) at 8 and 16 hours after surgery, and 1 g sodium dipyrone (Sanofi Medley Farmacêutica) as needed for pain. After 24 hours, participants were instructed to use a 0.12% chlorhexidine gluconate mouthwash (Periogard; Colgate Palmolive) for 10 days. Sutures were removed between the seventh and tenth postoperative day.

Reopening was conducted after a 4-month healing period, and healing caps (CIC 4004 or CIC 4006; S.I.N. Implant System) were installed. Twenty-one days after the reopening surgery, the healing caps were removed, and mini-abutments (MAC 4802 or 4803; S.I.N. Implant System) were selected for Group S, while universal

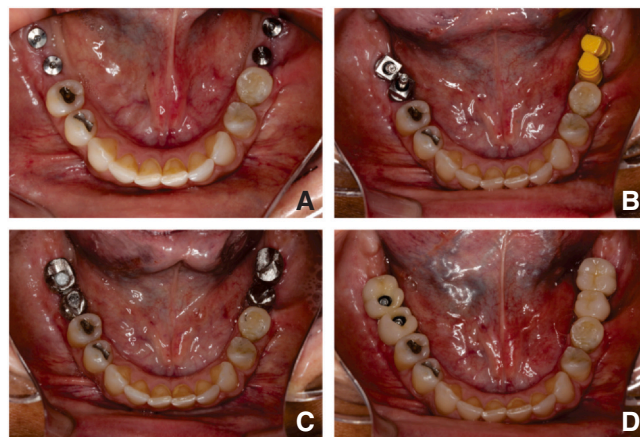


Figure 2. Representative images of prosthetic procedures. A, Healing caps in place. B, Impression copings positioned. C, Trial of metal framework, with splinting in right hemimandible and no splinting in left hemimandible. D, Metal-ceramic crowns splinted and screwed on right side, and nonsplinted and cemented on left side.

abutments (AIMC 45402 or 45602; S.I.N. Implant System) were used for Group NS. All abutments were tightened to 20 Ncm according to the manufacturer's recommendations. Impressions were made by using addition silicone (Adição Express XT; 3M do Brasil), and casts were fabricated with Type IV dental stone (Durone; Dentsply Sirona) and artificial gingiva (Gingifast Elastic; Zhermack). The casts were mounted in a semi-adjustable articulator (A7 Plus; Bio Art) and sent to the dental laboratory for fabrication of the implant-supported crowns.

Before crown installation, all participants underwent oral environment stabilization and supragingival scaling. Occlusal adjustment was conducted to eliminate premature contacts and occlusal interferences. Participants received detailed instructions on oral hygiene and prosthesis maintenance, along with a care kit containing a toothbrush, interdental brush, floss threader, and toothpaste. The prosthetic procedures are illustrated in Figure 2.

Implant survival was determined in accordance with previously reported criteria,³⁶ that is, the implant remained in place throughout the entire observation period, without pain, mobility, or suppuration. Clinical peri-implant conditions, based on mPI, mBI, and PPD indices, were assessed by a previously trained examiner (A.F.) at the time of prosthesis installation (T0) and at 6 (T1), 24 (T2), and 36 months (T3) after installation.

The mPI and mBI indices were evaluated by using the visual scales modified by Mombelli et al,³⁷ with scores ranging from 0 to 3, where "0" indicated no detectable plaque and no bleeding when the tip of a periodontal probe was swept along the gingival margin adjacent to the implant; "1" indicated bacterial plaque detected only after running a probe across the free

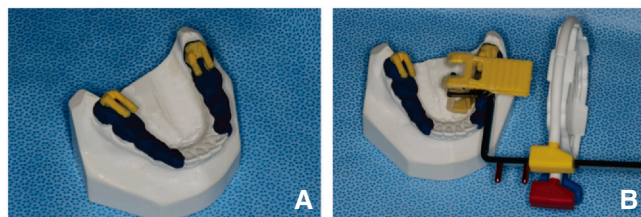


Figure 3. Custom acrylic resin device fabricated to standardize radiographic images and ensure consistent assessments over time. A, Devices positioned on cast, demonstrating adaptation to occlusal surfaces and adjacent teeth. B, Positioning ring and arm kit attached to digital sensor holder and acrylic resin device.

gingival margin on the implant surface, with visible isolated bleeding spots; "2" indicated clinically visible bacterial plaque and bleeding forming a confluent red line at the gingival margin; and "3" indicated abundant bacterial plaque and profuse bleeding.

PPD was assessed by calculating the mean of the values recorded at 4 sites around each implant (mesial, buccal, distal, and lingual). A periodontal probe (PCPUNC15; Hu-Friedy Manufacturing) was introduced parallel to the implant axis until it reached the deepest point within the peri-implant sulcus, allowing the measurement of the distance from the peri-implant mucosal margin to the sulcus base. At the end of each assessment session, participants received additional instructions on oral hygiene and a fresh hygiene kit.

The radiographic periapical status was assessed by using the paralleling technique,⁹ a digital device (765 DC; Gendex), and a CCD-type intraoral sensor (Visualix eHD; Gendex). To standardize radiographic images and ensure consistent assessments of vMBL over time, a custom acrylic resin device was fabricated and fixed to the occlusal surface of the implants and adjacent teeth, with 2 pins positioned in its upper posterior region serving as an attachment for the radiographic positioner (Rinn XCP-DS Fit; Dentsply Sirona) (Fig. 3).

Measurements were conducted by using a software program (ImageJ v. 1.8.0; National Institutes of Health),³⁸ with the implant width used for calibration. On the radiographic image, the most coronal points of bone-to-implant contact were identified mesially and distally. The shortest distances between these points and the implant-abutment junction were then measured, generating 2 straight vertical lines tangent to the implant platform (Fig. 4).³⁹ The vMBL was determined by subtracting the mean of the mesial and distal measurements in each radiographic assessment from the mean of the same measurements obtained from the initial periapical radiograph (T1).

Implant survival data were analyzed by using the Kaplan-Meier method and compared with the Log-rank test. The Mann-Whitney and Friedman tests were applied to compare the groups with respect to the mPI and

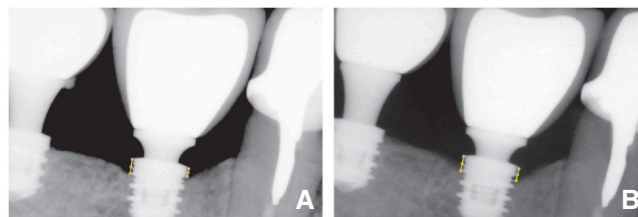


Figure 4. Marking reference points and procedure for measuring vertical marginal bone loss. A, Measurement immediately after prosthesis installation (T0). B, Measurement 36 months after prosthesis installation (T3).

mBI variables, while 2-way ANOVA for repeated measures was used for the PPD and vMBL variables. Statistical analyses were conducted by using a software program (IBM SPSS Statistics, v23; IBM Corp) ($\alpha=.05$).

RESULTS

At T3, no significant difference was observed in survival rates, which were 100% and 96.6% for Groups S and NS, respectively ($P=.309$). One implant failed in Group NS because of significant mobility, bleeding, suppuration, and radiolucency. No other implants showed signs of compromised osseointegration or any biomechanical complications—such as prosthetic screw loosening, screw fracture, or porcelain chipping—at any time point.

No significant difference was found between groups with respect to mPI ($P>.999$) at either T0 or T2. However, mPI scores were significantly higher in Group S than in Group NS at T1 ($P<.001$) and T3 ($P=.006$) (Table 1). In Group S, no significant difference was found between T1, T2, and T3 with respect to mPI values, but these were significantly higher than those observed at T0 ($P<.001$) (Table 1). In contrast, in Group NS, no significant difference was found between T0, T1, and T3 regarding mPI values, but these were significantly lower than those observed at T2 ($P<.001$).

No significant difference was found between groups with respect to mBI, either at T0 ($P>.999$), T1 ($P=.255$) or T2 ($P=.391$). However, at T3, Group S showed significantly higher mBI scores than Group NS ($P=.012$) (Table 1). In group S, mBI was significantly higher at T3 than at T0 ($P<.001$), whereas, in Group NS, it was significantly higher at T2 than at T0 ($P=.033$) (Table 1).

Group S showed significantly lower PPD values than Group NS at all assessment time points ($P=.038$) (Table 1). Neither group showed significant intragroup PPD variation over time ($P=.448$). No significant difference was found between groups with respect to vMBL at any of the assessment time points ($P=.498$) (Table 1). In both groups, vMBL was significantly higher at T1 than at T3 ($P=.035$).

Table 1. Median values (min–max) of modified sulcus bleeding index (mBI) and modified plaque index (mPI), mean values $\pm$ standard deviation of probing pocket depth (PPD), and vertical marginal bone loss (vMBL) associated with prostheses used in study groups according to assessment time points

	Time Point	mPI*	mBI*	PPD (mm)**	vMBL (mm)**
Group NS	T0	0 (0 - 0)	0 (0 - 0)	2.0 $\pm$ 0.4	0.0 $\pm$ 0.4
	T1	0 (0 - 1)	0 (0 - 1)	2.1 $\pm$ 0.4	0.0 $\pm$ 0.3
	T2	1 (0 - 2)	1 (0 - 2)	2.0 $\pm$ 0.7	-0.1 $\pm$ 0.3
	T3	0.5 (0 - 1)	0 (0 - 1)	1.8 $\pm$ 0.4	-0.1 $\pm$ 0.4
Group S	T0	0 (0 - 0)	0 (0 - 0)	1.7 $\pm$ 0.4	-0.1 $\pm$ 0.3
	T1	1 (0 - 1)	0 (0 - 1)	1.9 $\pm$ 0.5	0.0 $\pm$ 0.2
	T2	1 (0 - 2)	0 (0 - 2)	1.8 $\pm$ 0.4	-0.2 $\pm$ 0.3
	T3	1 (0 - 2)	1 (0 - 1)	2.0 $\pm$ 0.7	-0.2 $\pm$ 0.4

Group NS, prostheses with nonsplinted crowns; Group S, prostheses with splinted crowns; mBI, modified sulcus bleeding index; mPI, modified plaque index; PPD, probing pocket depth; T0, at prosthesis installation; T1, after 6 months; T2, after 24 months; T3, after 36 months; vMBL, vertical marginal bone loss.

* Mann-Whitney and Friedman tests ($P < .05$);

** 2-way ANOVA for repeated measures ($P < .05$).

DISCUSSION

The results of this study indicated that prosthetic splinting did not influence the survival of extrashort implants in the posterior region of atrophic mandibles, as both groups showed similar survival rates and vMBL values after 3 years of follow-up. Thus, the null hypothesis was accepted for these variables, consistent with previous studies.^{23,29,31}

However, higher mPI scores at T1 and T3 and higher mBI scores at T3 in Group S suggested that nonsplinted crowns facilitated oral hygiene, leading to the rejection of the null hypothesis for these variables. These results were consistent with previous studies indicating that nonsplinted crowns promote improved hygiene conditions.^{7,9,14,16,24}

All participants underwent supragingival scaling and received standardized oral hygiene instructions and a hygiene kit at each follow-up visit. Additionally, randomization of Groups S and NS ensured that side preference (left- or right-handedness) did not influence oral hygiene effectiveness, a factor not accounted for in previous studies.

The increase in mPI and mBI scores at T2 and/or T3 compared with T0 in both groups suggested the need for closer clinical monitoring and periodic prophylaxis sessions. The importance of these measures was confirmed in a long-term follow-up study, which showed that participants who did not adhere to preventive protocols after implant placement exhibited more evident signs of bleeding upon probing.³²

PPD values were significantly lower in Group S than in Group NS at all assessment time points, including T0, leading to the rejection of the null hypothesis for this variable. However, this finding should be interpreted cautiously, as it may simply indicate that the initial periodontal status measured by PPD remained stable over time, without necessarily being influenced by splinting. This finding is further supported by the absence of significant intragroup variation in PPD values. Accordingly, Al-Sawaf et al²⁷ reported no significant

difference in probing depth between splinted and nonsplinted groups.

Regarding vMBL, no significant difference was observed between Groups S and NS at any time point, with extrashort implants demonstrating minimal bone remodeling regardless of prosthesis type. This was consistent with Clelland et al,³⁰ who reported no significant differences in peri-implant bone loss between splinted and nonsplinted crowns supported by 6-mm implants, despite the high crown-to-implant ratio.

The mean vMBL values obtained in the present study were similar to the MBL values of -1.2 ± 0.2 mm and -1.3 ± 0.2 mm reported for splinted and nonsplinted restorations, respectively, in a 10-year prospective study conducted in the maxilla by Vigolo et al.²⁹ Although the difference reported by these authors was significant, they considered it clinically irrelevant because of the prolonged time elapsed since implant placement.

A previous systematic review and meta-analysis of 19 studies, including 4215 implants placed in 2185 participants with follow-up periods ranging from 12 to 264 months, reported no significant differences between these 2 types of prostheses regarding MBL and the rate of prosthetic complications.²⁵ Another systematic review of 6 studies, comprising 1187 implants with follow-up periods of 1 to 22 years, reported that mean MBL ranged from -0.50 ± 0.8 mm to -1.22 ± 0.95 mm for splinted restorations and from -0.3 ± 0.65 mm to -1.30 ± 0.2 mm for nonsplinted restorations.²⁴

One of the key concerns regarding the use of extrashort implants is their unfavorable crown-to-implant ratio.^{15,28} The high stresses caused by the lever effect of the prosthetic crown may lead to higher MBL values when nonsplinted crowns are used, potentially reducing success rates.^{20,22,26} Splinting can help distribute occlusal forces more homogeneously, thereby promoting improved biomechanical behavior. This could explain the higher PPD values observed for nonsplinted crowns at all assessment time points in the present study.

Notably, however, these higher PPD values were not associated with a greater risk of osseointegration failure or higher MBL values.

A recent systematic review with meta-analysis by Pascoal et al.²³ in the posterior region of both arches concluded that the splinting variable could not be correlated with the rate of biological complications, consistent with the results of the present study. However, it revealed that nonsplinted crowns were associated with a higher likelihood of reversible mechanical complications.

Limitations of the present study included the predominance of female participants in the sample and the fact that PPD values measured at T0 differed among groups, precluding a reliable comparison for this variable. Another limitation involved variations in periodontal phenotype among participants, which could have affected the reliability of the results given the small sample size. Additionally, because a complete line of abutments for extrashort implants was unavailable from the supplier at the time of the study, screw-retained abutments were used for splinted prostheses and cement-retained abutments for nonsplinted ones. However, care was taken to select abutments for both retention types that could be maintained at a maximum subgingival depth of 2 mm. Excess cement was meticulously removed to prevent biofilm accumulation, and all installed crowns underwent periapical radiographic examination to confirm the absence of residual cement. Further studies with larger sample sizes are needed to address these and other methodological limitations, as well as to explore the effects of alternative implant and prosthetic connection designs on the success rates of extrashort implants.

CONCLUSIONS

Based on the findings of this split-mouth randomized clinical trial, the following conclusions were drawn:

1. Extrashort implants supporting nonsplinted versus splinted crowns achieved comparable clinical success.
2. Peri-implant bone loss was minimal throughout the analyzed period and comparable among groups, whereas peri-implant sulcus depth was significantly greater around nonsplinted crowns, suggesting the inferior biological performance of this type of prosthesis.
3. Lower biofilm accumulation and gingival bleeding rates suggested that the prostheses with nonsplinted crowns provided better oral hygiene conditions.

REFERENCES

1. Pieri F, Forlivesi C, Caselli E, Corinaldesi G. Short implants (6mm) vs. vertical bone augmentation and standard-length implants (≥9mm) in atrophic posterior mandibles: A 5-year retrospective study. *Int J Oral Maxillofac Surg.* 2017;46:1607–1614.

2. Leong DJ, Oh TJ, Benavides E, Al-Hezaimi K, Misch CE, Wang HL. Comparison between sandwich bone augmentation and allogenic block graft for vertical ridge augmentation in the posterior mandible. *Implant Dent.* 2015;24:4–12.
3. Menezes DJ, Shibli JA, Gehrke SA, Beder AM, Sendyk WR. Effect of platelet-rich plasma in alveolar distraction osteogenesis: A controlled clinical trial. *Br J Oral Maxillofac Surg.* 2016;54:83–87.
4. Pimentel AC, Sanches MA, Ramalho GC, Roman-Torres CV, Manzi MR, Sendyk WR. Lateralization technique and inferior alveolar nerve transposition. *Case Rep Dent.* 2016;2016:4802637.
5. Jepsen S, Schwarz F, Cordaro L, et al. Regeneration of alveolar ridge defects. Consensus report of group 4 of the 15th European Workshop on Periodontology on Bone Regeneration. *J Clin Periodontol.* 2019;46:277–286.
6. Soldatos N, Weltman R. Vertical ridge augmentation (VRA): success and predictability. *Curr Oral Health Rep.* 2022;9:197–204.
7. Lemos CAA, Verri FR, Santiago Junior JF, et al. Splinted and nonsplinted crowns with different implant lengths in the posterior maxilla by three-dimensional finite element analysis. *J Healthc Eng.* 2018;2018:3163096.
8. Buser D, Weber HP, Lang NP. Tissue integration of non-submerged implants: 1-year results of a prospective study with 100 ITI hollow-cylinder and hollow-screw implants. *Clin Oral Implants Res.* 1990;1:33–40.
9. Mendonça JA, Franchiscone CE, Senna PM, Matos de Oliveira AE, Sotto-Maior BS. A retrospective evaluation of the survival rates of splinted and nonsplinted short dental implants in posterior partially edentulous jaws. *J Periodontol.* 2014;85:787–794.
10. Peixoto HE, Camati PR, Faot F, Sotto-Maior BS, Martinez EF, Peruzzo DC. Rehabilitation of the atrophic mandible with short implants in different positions: A finite elements study. *Mater Sci Eng C Mater Biol Appl.* 2017;80:122–128.
11. Lizio G, Pellegrino G, Felice P. Posterior jaws rehabilitation with < 7mm-short implants: A review. *J Stomatol Oral Maxillofac Surg.* 2022;123:e45–e56.
12. Felice P, Pistilli R, Barausse C, Piattelli M, Buti J, Esposito M. Posterior atrophic jaws rehabilitated with prostheses supported by 6-mm-long, 4-mm-wide implants or by longer implants in augmented bone. Five-year post-loading results from a within-person randomized controlled trial. *Int J Oral Implantol ((Berl)).* 2019;12:57–72.
13. Leighton Y, Carpio L, Weber B, Dias FJ, Borie E. Clinical evaluation of single 4-mm implants in the posterior mandible: A 3-year follow-up pilot study. *J Prosthet Dent.* 2022;127:80–85.
14. Mendoza-Azpur G, Lau M, Valdivia E, Rojas J, Muñoz H, Nevins M. Assessment of marginal peri-implant bone-level short-length implants compared with standard implants supporting single crowns in a controlled clinical trial: 12-month follow-up. *Int J Periodontics Restorative Dent.* 2016;36:791–795.
15. Anitua E, Alkhraist MH, Piñas L, Begoña L, Orive G. Implant survival and crestal bone loss around extra-short implants supporting a fixed denture: The effect of crown height space, crown-to-implant ratio, and offset placement of the prosthesis. *Int J Oral Maxillofac Implants.* 2014;29:682–689.
16. Lombardo G, Pighi J, Marincola M, Corrocher G, Simancas-Pallares M, Nocini PF. Cumulative success rate of short and ultrashort implants supporting single crowns in the posterior maxilla: A 3-year retrospective study. *Int J Dent.* 2017;2017:8434281.
17. Fabris V, Manfro R, Reginato VF, Bacchi A. Rehabilitation of a severely resorbed posterior mandible with 4-mm extra-short implants and guided bone regeneration: Case report with 3-year follow-up. *Int J Oral Maxillofac Implants.* 2018;33:e147–e150.
18. Xu X, Hu B, Xu Y, Liu Q, Ding H, Xu L. Short versus standard implants for single-crown restorations in the posterior region: A systematic review and meta-analysis. *J Prosthet Dent.* 2020;124:530–538.
19. Sotto-Maior BS, Senna PM, da Silva-Neto JP, de Arruda Nóbilo MA, Del Bel Cury AA. Influence of crown-to-implant ratio on stress around single short-wide implants: A photoelastic stress analysis. *J Prosthodont.* 2015;24:52–56.
20. Toniollo MB, Macedo AP, Pupim D, Zapparoli D, da Gloria Chiarello de Mattos M. Finite element analysis of bone stress in the posterior mandible using regular and short implants, in the same context, with splinted and nonsplinted prostheses. *Int J Oral Maxillofac Implants.* 2017;32:e199–e206.
21. Fathi A, Rismanchian M, Khodadadi R, Dezaki SN. Does the crown-implant ratio affect the survival and complications of implant-supported prostheses? A systematic review. *J Prosthet Dent.* 2024;131:819–825.
22. Blanes RJ, Bernard JP, Blanes ZM, Belser UC. A 10-year prospective study of ITI dental implants placed in the posterior region. II: Influence of the crown-to-implant ratio and different prosthetic treatment modalities on crestal bone loss. *Clin Oral Implants Res.* 2007;18:699–706.
23. Pascoal ALB, Paiva KRG, Marinho LCN, Bezerra AS, Calderon PS. Impact of splinting implant-supported crowns on the performance of adjacent posterior implants: A systematic review and meta-analysis. *J Prosthet Dent.* 2025;133:402–410.
24. Al Amri MD, Kellesarian SV. Crestal bone loss around adjacent dental implants restored with splinted and nonsplinted fixed restorations: A systematic literature review. *J Prosthodont.* 2017;26:495–501.
25. De Souza Batista VE, Verri FR, Lemos CAA, Cruz RS, Oliveira HFF, Gomes JML, et al. Should the restoration of adjacent implants be splinted or nonsplinted? A systematic review and meta-analysis. *J Prosthet Dent.* 2019;121:41–51.

26. Rodrigo D, Cabello G, Herrero M, et al. Retrospective multicenter study of 230 6-mm SLA-surfaced implants with 1- to 6-year follow-up. *Int J Oral Maxillofac Implants*. 2013;28:1331–1337.
27. Al-Sawaf O, Tuna T, Rittich A, Kern T, Wolfart S. Randomized clinical trial evaluating the effect of splinting crowns on short implants in the mandible 3 years after loading. *Clin Oral Implants Res*. 2020;31:1061–1071.
28. Sotto-Maior BS, Senna PM, da Silva WJ, Rocha EP, Del Bel Cury AA. Influence of crown-to-implant ratio, retention system, restorative material, and occlusal loading on stress concentrations in single short implants. *Int J Oral Maxillofac Implants*. 2012;27:e13–e18.
29. Vigolo P, Mutinelli S, Zaccaria M, Stellini E. Clinical evaluation of marginal bone level change around multiple adjacent implants restored with splinted and nonsplinted restorations: A 10-year randomized controlled trial. *Int J Oral Maxillofac Implants*. 2015;30:411–418.
30. Clelland N, Chaudhry J, Rashid RG, McGlumphy E. Split-mouth comparison of splinted and nonsplinted prostheses on short implants: 3-year results. *Int J Oral Maxillofac Implants*. 2016;31:1135–1141.
31. Bregagnol RB, Coltro MPDL, Villarinho EA, et al. Long-term clinical performance of short 6-mm implants supporting single crowns in the posterior region: A 10-year cohort study. *Clin Implant Dent Relat Res*. 2024;26:158–169.
32. Monje A, Galindo-Fernández P, Nart J. Supportive therapy following peri-implantitis treatment: A retrospective study on compliance. *Clin Oral Implants Res*. 2024;35:621–629.
33. Schulz KF, Altman DG, Moher D. CONSORT Group. CONSORT 2010 statement: updated guidelines for reporting parallel group randomized trials. *Ann Intern Med*. 2010;152:726–732.
34. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*. 2007;39:175–191.
35. Abouleish AE, Leib ML, Cohen NH. ASA provides examples to each ASA physical status class. *ASA Monitor*. 2015;79:38–49.
36. Papaspyridakos P, Chen CJ, Singh M, Weber HP, Gallucci GO. Success criteria in implant dentistry: A systematic review. *J Dent Res*. 2012;91:242–248.
37. Mombelli A, Van Oosten MA, Schurch E, Jr, Land NP. The microbiota associated with success or failing osseointegrated titanium implants. *Oral Microbiol Immunol*. 1987;2:145–151.
38. Schneider CA, Rasband WS, Eliceiri KW. NIH Image to ImageJ: 25 years of image analysis. *Nat Methods*. 2012;9:671–675.
39. Sinjari B, D'Addazio G, De Tullio I, Traini T, Caputi S. Peri-implant bone resorption during healing abutment placement: The effect of a 0.20% chlorhexidine gel vs. placebo-A randomized double-blind controlled human study. *Biomed Res Int*. 2018;2018:5326340.

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