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Short vs. Standard Laser-Microgrooved Implants Supporting Single and Splinted Crowns: A Prospective Study with 3 Years Follow-Up

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Keywords
Laser-microgrooved collar; marginal bone loss; short implants; survival rate.

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Abstract

Purpose: The aim of this study was to compare survival rates, marginal bone loss (MBL), and peri-implant soft tissue parameters between short and standard laser-microgrooved implants supporting single or splinted crowns 3 years after loading.
Materials and Methods: 30 subjects received 1 short ($\leq$ 7 mm) and 1 standard length ($\geq$ 9 mm) laser-microgrooved implant in adjacent sites of the premolar and molar regions of the mandible or maxilla. Peri-implant soft tissue parameters and intraoral radiographs were recorded at the delivery of definitive crowns (baseline) and 3 years later. Cumulative survival rate (CSR) and marginal bone loss (MBL) in relation to crown/implant (C/I) ratio, implant length, location, type of antagonist, and type of prosthetic design (single or splinted), were evaluated.
Results: CSR of short implants was 98%, compared to 100% for standard implants, without significant statistical difference. MBL was not significantly different over the observation period, with an average of 0.23 $\pm$ 0.6 mm and 0.27 $\pm$ 0.3 mm for short and standard implants, respectively. No statistical differences were found between short and standard implants regarding plaque (14.7% vs. 15.7%), number of sites BOP (8.3% vs. 5.9%), probing depth (1.13 $\pm$ 0.6 mm vs. 1.04 $\pm$ 0.8 mm), and mean mucosal recession (0.18 $\pm$ 0.3 mm vs. 0.22 $\pm$ 0.3 mm). Analyzing MBL in relation to the C/I ratio, implant length, location, type of antagonist, and type of prosthetic design, no statistically significant differences were found.
Conclusion: Regardless of C/I ratio, implant length, location, type of antagonist, and type of prosthetic design, short and standard laser-microgrooved implants had similar survival rates, MBL, and peri-implant soft tissue conditions over the observation period of 3 years.

Several surgical techniques have been proposed to overcome the limitations for standard length implants in atrophic jaws with insufficient vertical bone height.[1,2] However, these surgical techniques are still associated with several disadvantages, such as increased postoperative morbidity, longer treatment time and cost, and higher risk of complications.[3,4] In clinical situations with limited vertical bone height, placement of short implants could be an alternative to advanced surgical bone augmentation techniques.[5-8] Some studies have reported high success rates for short implants,[2,9,10] while others have reported low success rates.[11,12] Low success rates have been associated with low-density atrophic jawbones where primary stability was more difficult to achieve with short implants due to decreased bone-to-implant contact.[13,14] Additionally, a crown-to-implant (C/I) ratio >1 could act as a lever arm creating a bending moment and transferring stress to peri-implant crestal bone.[15,16] Few studies have compared outcomes of short and standard implants placed in adjacent sites of the premolar and molar regions of the mandible or maxilla. The aim of this prospective study was to evaluate cumulative success rates, (CSR), marginal bone loss (MBL), plaque score (P), number of sites bleeding on probing (BOP), probing depth (PD), and mean mucosal recession (REC), of short ($\leq$ 7 mm) and standard ($\geq$ 9 mm) laser-microgrooved implants supporting single or splinted crowns.

Materials and methods

Thirty patients (14 females, 6 males) were screened to participate in this prospective study and received at least one short and one standard laser-microtextured implant in adjacent sites of the mandibular or maxillary premolar/molar regions. The

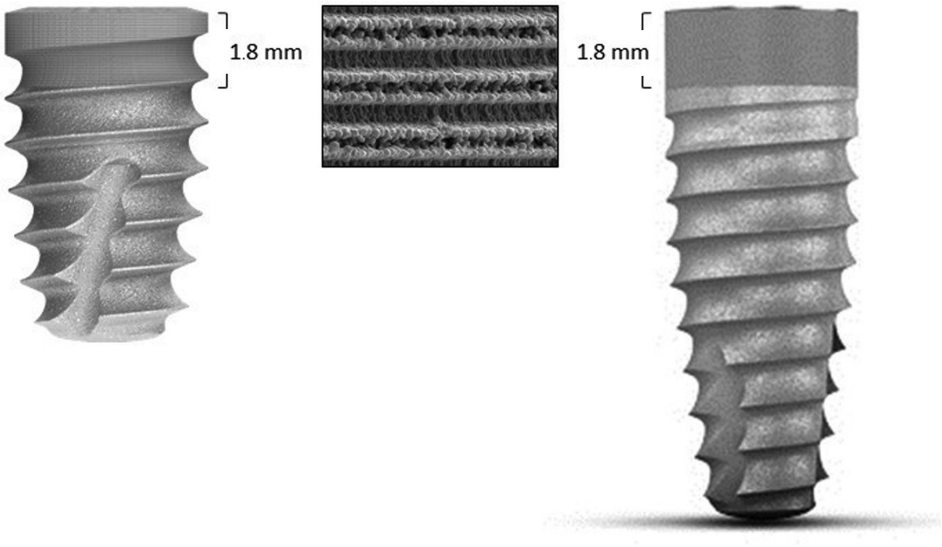

Figure 1 Implants investigated in the study. On the left, short tapered, on the right, tapered internal. In the center, laser-microtextured collar (700×). (Image originally published in Guarnieri R, Belleggia F, Grande M: Immediate versus delayed treatment in the anterior maxilla using single implants with a laser-microtextured collar: 3-year results of a case series on hard- and soft-tissue response and esthetics. J Prosthodont 2016;25:135–145)



Figure 2 For the radiograph procedure, an individualized acrylic device was fixed to the residual dentition, and a radiograph holder was constructed for each patient.

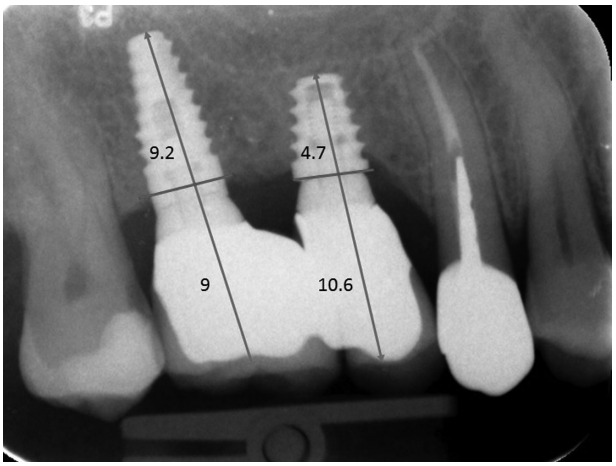

Figure 3 Radiograph measurements used to evaluate the C/I ratio.

study was approved by the Research Ethics Committee of La Sapienza University of Rome (#4597). Patients gave written consent, and the study was conducted according to the principles outlined in the Helsinki Declaration for biomedical research involving human subjects. A total of 68 dental implants (30 short, 38 standard) were placed. The mean age of patients was 51 years (range: 21 to 82 years).

Inclusion criteria were: age ≥ 18 years, good general health, without contraindications to implant surgery, and presence of at least two adjacent edentulous sites requiring implant therapy.

Exclusion criteria were: implants placed into regenerated bone, lack of a periodontal chart and periapical radiograph at the beginning and at the end of follow-up period, alcohol and drug abuse, pregnancy, uncontrolled metabolic disorders, tobacco smoking (> 10 cigarettes/day), full mouth plaque score (FMPS) and full mouth bleeding score (FMBS) ≥25%, periodontally compromised patients (with attachment loss ≥3 mm and/or radiographic bone loss ≥30% of root length in ≥30% of sites), or teeth adjacent to the implant area (mesial and distal) affected by untreated periodontal and/or endodontic infections.

To perform a complete presurgical evaluation, full-mouth intraoral radiographic examinations, cone beam computed tomography (CBCT) scan examinations, diagnostic wax patterns, and a surgical template were conducted for each patient.

Implants

Two implants (Fig 1) were used:

1. Short implants: the implant had a 1.8 mm laser microgrooved coronal design; 4.6 mm in diameter and 6.0 mm

in length (Tapered Short Laser-Lok; Biohorizons, Birmingham, AL) and 4.6 mm diameter; 7.5 mm length (Tapered Internal Laser-Lok; Biohorizons)
2. Standard implants: this implant was a tapered internal connection with a 1.8 mm laser micro-grooved coronal design; 4.6 mm diameter, 9.0 to 12.0 mm length (Tapered Internal Laser-Lok)

Each patient received at least two adjacent implants: short implants were placed in areas with less than 9 mm from the alveolar crest to the superior wall of the inferior alveolar canal or to the inferior wall of the maxillary sinus. Standard implants were placed in areas where this distance exceeded 9.5 mm. All implants were installed by two operators (RG, LT) and were placed according to the manufacturer's recommendations, with 0.9 mm of the laser-microgrooved surface subcrestal and 0.9 mm supracrestal.

Patients scheduled for surgery were prescribed systemic amoxicillin/clavulanic acid (Augmentin; GlaxoSmithKline, Verona Italy), 1 g, twice a day for 7 days, and a chlorhexidine digluconate solution 0.12% (Dentosan 0.12%; Johnson & Johnson, New Brunswick, NJ) rinse (twice daily for 1 minute). After local anesthesia by infiltration using articaine/epinephrine (Ecocain 20 mg/ml; Molteni Dental, Milan, Italy), surgical access was gained with a full-thickness flap at the level of keratinized mucosa with a minimally extended release incision, to expose the crest and the vestibular limit of the bone. Utmost care was taken to preserve the periodontal integrity of adjacent teeth. Following implant placement, the flap was sutured without tension using 4.0 or 5.0 monofilament sutures, which were left in place for 10 days. Patients were instructed to have a liquid or semiliquid diet for the first 3 days and gradually return to a normal diet. An analgesic (ibuprofen, 600 mg) was prescribed to take immediately after surgery and after 8 hours. The second-stage surgery for placement of healing abutments was performed after 4 to 6 months, and the prosthetic restoration 4 weeks later. Definitive crowns were delivered 1 month after second-stage surgery. Allocations for the splinted crown group or single crown group were randomly assigned to each implant by a computer-generated random number table. The randomization codes were stored in password-protected portable computers and enclosed in sequentially numbered, identical, opaque, sealed envelopes.

Radiographic examinations

Radiographs were taken using a film holder at the time of data collection by means of long cone technique. For the radiograph procedure, an individualized acrylic resin device was fixed to the residual dentition, and a radiograph holder was constructed for each patient (Fig 2). This technique ensured that the same position of the radiograph film could be reproduced at each visit, and the angle of the radiograph would not deviate. Radiographically, the crown length was considered as the distance from the occlusal part to the collar of the implant. The length of the implant was considered as the distance from the collar to the tip of the implant. According to the C/I ratios, implants were divided into three groups: A c/i ratio <1, >1 or <1.5, and ≥ 1.5 (Fig 3).

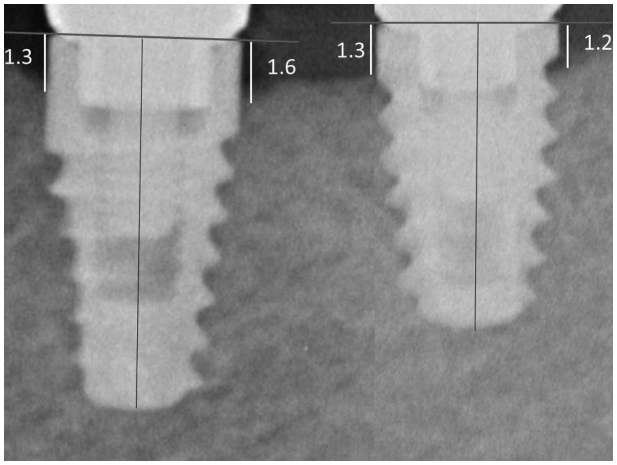

Figure 4 Radiographic MBL at the delivery of definitive crowns.

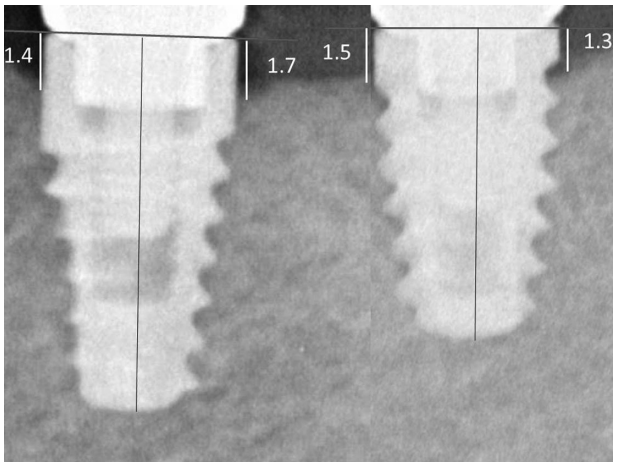

Figure 5 Radiographic MBL at the 3-year follow-up.

Taking as reference the collar of the implant, radiographic MBL was assessed at the mesial and the distal sides by subtracting MBLs at definitive crown delivery (Fig 4) from marginal bone levels at 3-year follow-up (Fig 5). Radiograph measurements were calculated using a software program (VixWin Platinum Imaging Software; Gendex, Des Plaines, IL).

Follow-up

Patients were recalled every 6 months for professional oral hygiene. At the delivery of definitive crowns (baseline) and every 6 months, the following parameters were considered: number of sites with plaque, number of sites BOP, PD, and mucosal recession (REC).

Statistical analysis

Public domain online software (Raosoft, http://www.raosoft.com/samplesize.html) was used to calculate the minimal number necessary for statistical evaluation. Data were analyzed using SPSS software v.13.0 (SPSS Inc., Chicago, IL). Mean values, medians, and standard deviations (SD) were calculated for each parameter. One-sided P-values were calculated

Table 1 Characteristics and treatment specifications of 28 patients treated with 64 implants

Total implants (N = 64)	Short (n = 28)	Standard (n = 36)
Patient (N = 28) age[a]	51 ± 19.8 (21-82)	51 ± 19.8 (21- 82)
Male (M)/female (F) ratio	14/14	14/14
Implant per quadrant		
2 adjacent short/standard	20 patients (10M/10F)	
3 adjacent (short/standard/ standard)	8 patients (4M/4F)	

[a](years), mean ± SD (min–max).

and corrected according to Sidak's method for multiple hypotheses testing. Kruskal Wallis and Mann-Whitney tests were used. Results of the linear mixed effects were used to calculate the difference between short and standard implants and their 95% confidence intervals. Since more than one dependent variable (C/I ratio, implant length, implant location, antagonist, and restoration design) were present simultaneously with other variables, multivariate analysis was performed in each implant group (short and standard) using the multiple linear regression test. The standardized regression coefficient was used to determine the impact of each variable on MBL.

Results

At baseline a total of 68 implants in 30 patients were evaluated. At the 3-year recall visit, two patients with four implants were dropped from the study due to change of address. As a result, the sample size comprised a total of 64 implants (28 short, 36 standard) placed in 28 patients. Characteristics and treatment specifications of the 28 patients treated with 64 implants are summarized in Table 1. Sixteen and 12 short implants were placed in the maxilla and mandible, respectively, while 20 and 16 standard implants were placed in the maxilla and mandible, respectively. In the short group, 14 implant restorations were single, and 14 splinted, while in the standard group 18 implant restorations were single, and 18 splinted. Two short implants were in the mandibular premolar area, and 10 implants were in the mandibular molar area, while 6 and 10 short implants were in maxillary premolar and molar area, respectively. Twelve standard implants were in the mandibular premolar area, and four were in molar mandibular area, while 14 and 6 standard implants were in the maxillary premolar and molar area, respectively (Table 2). Seven short implants (four 6.0 mm long, three 7.5 mm long) were splinted with one standard implant, whereas 7 short implants (four 6.0 mm long, three 7.5 mm long) were splinted with 2 standard implants.

The CSR of short implants was 98% compared to 100% for standard implants with no statistically significant difference. One short implant (7.5 mm length) placed in the maxillary molar area was not osseointegrated at the second stage surgery. Table 3 lists patient- and implant-based variables for short and standard implants. No statistically significant differences were found between short and standard implants in terms of patient sex, age, smoking habit, prosthetic design (splinted/nonsplinted), location, and region. MBL was not significantly different over the observation period, with an average of 0.23 ± 0.6 mm and 0.27 ± 03 mm, for short and standard implants, respectively (Table 4). No statistical differences were found between short and standard implants regarding presence of plaque (14.7% vs. 15.7%), number of sites BOP (8.3% vs. 5.9%), probing depth (1.13 ± 0.6 mm vs. 1.04 ± 0.8 mm), and mean mucosal recession (0.18 ± 0.3 mm vs. 0.22 ± 0.3 mm) (Tables 5–7). Analyzing MBL in relation to the C/I ratio and the implant length, no statistically significant differences were found. No statistically significant differences were found between MBL and the implant's location, type of antagonist, and type of prosthetic design (single or splinted) (Table 8). Furthermore, the multivariate analysis and the multiple linear regression model used to evaluate the relationship between C/I ratio, implant length, location, antagonist, and restoration design with MBL, indicated no statistically significant correlation (Table 9).

Discussion

There is no consensus in the literature on the performance of short implants placed in posterior atrophic jaws. Several studies[11,12,17-23] reported a higher failure rate for short implants compared to standard implants, while other studies[9,24,25] found that implant length had no negative influence on the survival rate. It should be stressed that most of the studies that showed an increased failure rate for short implants were performed with machined-surface implants. More recent studies with textured implants reported similar survival rates between short and standard implants. These differences could be linked to the process of osseointegration and the greater bone-to-implant contact documented around textured surfaces compared to machined surfaces.[26] There is no general consensus on the definition of a short dental implant.[27] Some authors have defined as "short" any implant < 7 mm in height; others, any implant < 10 mm.

Table 2 Distribution of short and standard implants, location, and prosthetic restoration

	Short implants (n = 28)		**Standard implants (n = 36)**	
	Posterior mandible (n = 12)	Posterior maxilla (n = 16)	Posterior mandible (n = 16)	Posterior maxilla (n = 20)
Splinted	6	8	8	10
Single	6	8	8	10
Premolar	2	6	12	14
Molar	10	10	4	6

Table 3 Analysis of patient- and implant-based variables of short and standard implants

	Short				Standard			
Patient-based variables	N	Failure	Survival rate (%)	*p*	N	Failure	Survival rate (%)	*p*
Sex				>0.05				>0.05
M	14	1	92.8		14	0	100	
F	14		100		14	0	100	
Age				>0.05				>0.05
≤50	8	0	100		8	0	100	
>50	20	1	95		20	0	100	
Smoking status				>0.05				>0.05
Nonsmokers	6	0	100		6	0	100	
smokers≤10	22	1	99.5		22	0	100	
Implant-based variables	**N**	**Failure**	**Survival rate (%)**	***p***	**N**	**Failure**	**Survival rate (%)**	***p***
Implant length				>0.05				>0.05
6 mm	14	0	100					
7.5 mm	14	1	92.8					
9 mm					18	0	100	
10.5 mm					10	0	100	
12 mm					8	0	100	
Location				>0.05				>0.05
Maxilla	16	10	93.7		20	0	100	
Mandibule	12		100		16	0	100	
Region				>0.05				>0.05
Premolar	8	0	100		26	0	100	
Molar	20	1	95		10	0	100	

Table 4 Mean radiographic Marginal Bone Loss ± SD (mm) at 3-year examination

MBL	Short implants	Standard implants	Significance
Mesial	0.22 ± 0.9	0.25 ± 0.5	0.326
Distal	0.25 ± 0.6	0.27 ± 0.3	0.249

Table 5 Number of sites with plaque and BOP Number of sites with plaque

	Baseline	3 years
Short implants	1	5
Standard implants	2	6
Significance	0.243	0.221
Number of sites with BOP		
Short implants	1	10
Standard implants	1	9
Significance	0.081	0.247

Although some recent literature reviews[5,7,27,28] indicated no statistically significant differences in failure rates between short (<10 mm) and standard (≥10 mm) implants, implants shorter than 7 mm had lower success rates. Results of the present study showed no statistically significant difference between the CSRs of 6.0/7.5 mm implants (98%) and 9/12 mm implants (100%) with laser-microtextured collars 3 years after loading. The results were independent of patients' sex, age, smoking habit, prosthetic design (splinted/nonsplinted), implant location, and implant region. This suggested that, in clinical situations with limited maxillary and/or mandibular vertical bone height, treatment with short laser-microgrooved implants is as reliable a treatment as standard laser-microgrooved implants.

Implant body design is another factor that has been reported to contribute to survival rates of short implants.[6,29-32] It has been documented that a tapered implant design can increase the primary stability in low-density bone by creating pressure in cortical areas with reduced bone quality.[33] Laser-microgrooved short tapered implants used in the present study are characterized by a tapered design, and reverse buttress threads were shown to distribute load effectively.[34] Implant features might have favored results of the present study. Few findings have been reported in recent literature on MBL around short implants.[7,35-39] Reported results of MBL around short implants do not exceed the criteria accepted for standard implants (i.e., 1.5 mm for the first year and 0.2 mm of additional bone loss each subsequent year). It should be noted that 3 years after loading, almost 2 mm of bone loss around a 6.5 mm implant corresponds to nearly one third of the entire implant length and should be interpreted differently on clinical grounds. In the present study, at the 3-year follow-up, the mean MBL around short laser-microgrooved implants was 0.23 ± 0.6 mm with no statistically significant difference compared to standard-length laser-microtextured implants. Results of the current study agree with published data on MBL around laser-microgrooved implants[40,41] and confirmed that the presence of

Table 6 Probing depth (mm) on four aspects at baseline and at 3-year examination (mean ± SD)

	Mesial	Buccal	Distal	Oral
Short Implants				
Baseline	0.86 ± 0.8	080 ± 0.6	0.98 ± 0.5	0.94 ± 0.6
3-year	1.14 ± 0.6	1.10 ± 0.4	1.16 ± 0.7	1.12 ± 0.3
Significance	0.001	0.001	0.001	0.001
Standard Implants				
Baseline	0.78 ± 0.8	0.72 ± 0.6	0.70 ± 0.3	0.75 ± 0.2
3-year	1.04 ± 0.1	1.08 ± 0.7	1.02 ± 0.8	1.01 ± 0.09
Significance	0.001	0.001	0.001	0.001

Table 7 Mucosal recession (mm) on four aspects at 3-year examination (mean ± SD)

REC	Mesial	Buccal	Distal	Oral
Short Implants	0.18 ± 0.4	0.22 ± 0.2	0.17 ± 0.6	0.15 ± 0.2
Standard Implants	0.24 ± 0.1	0.28 ± 0.3	0.20 ± 0.2	0.18 ± 0.9
Significance	0.274	0.386	0.725	0.312

Table 8 Bivariate statistical analysis of MBL

	Mean	Median	SD	*P*
C/I ratio				
0 to <1	0.22	0.17	0.3	0.362*
1 to <1.5	0.25	0.19	0.5	0.193*
≥1.5	0.23	0.16	0.2	0.256*
Implant length (mm)				
Short				
6.0	0.23	0.18	0.4	0.417*
7.5	0.22	0.19	0.2	0.339*
Standard				
9	0.23	0.21	0.2	0.292*
10.5	0.24	0.20	0.3	0.412*
12	0.22	0.19	0.5	0.315*
Restoration design				
Single	0.21	0.16	0.2	0.253#
Splinted	0.24	0.18	0.4	0.419#
Implant location				
Posterior maxilla	0.22	0.17	0.3	0.247#
Posterior mandible	0.25	0.22	0.4	0.613#
Type of antagonist				
Natural teeth	0.22	0.18	0.4	0.451*
Fixed prosthesis	0.25	0.22	0.2	0.372*
Denture	0.21	0.17	0.3	0.443*
Implant-supported prosthesis	0.22	0.16	0.4	0.192*

*Mann-Witney test (#) Kruskal-Wallis test.

laser-microgrooved surface on implant collars may counteract MBL. This has been explained by the capacity of laser-microgrooved collars that influence peri-implant soft-tissue response. Contrary to what has been shown in human histological data for implants with machined/smooth collars, laser-microgrooved implants exhibited perpendicular/functional orientation of connective tissue fibers around the implant collars that allowed the protection of peri-implant bone by the oral environment.[42]

The results of the present study showed no significant difference in MBL between short and standard implants regardless of the C/I ratio and the prosthetic design. Assumptions were that a high C/I ratio[6,43] and a nonsplinted prosthetic design[18,44] might lead to less favorable conditions for stress distribution around the implants, which could eventually influence MBL.

Published data on the influence of C/I ratio on MBL around short implants are inconsistent. Some authors[43,45,43] found no correlation between C/I ratio and MBL, while others[46,47] reported higher values of MBL with increased C/I ratios. The authors of this article recognize that the sample size reported in this study is insufficient to demonstrate the influence of C/I ratio on MBL around short implants. A recent review on biological and technical complications of splinted and nonsplinted implants[48] indicated that, although there should not be any difference in the ease of performing proper oral hygiene between both restorations if the prosthesis is designed correctly, nonsplinted implant-supported restorations are indicated for patients with decreased manual dexterity and poor oral hygiene. Splinted implant-supported restorations present less technical complications in the long term. Furthermore, to avoid excessive occlusal forces on the prosthetic components, splinted short implants could be recommended for patients with a history of bruxism.

Investigating peri-implant bone levels around splinted and nonsplinted implants, Clelland et al[49] reported that splinting short implants (<6 mm) might limit MBL. In contrast, Rokni et al[50] reported that splinted short implants (5/7 mm) had significantly greater MBL than nonsplinted short implants. Results of the present study showed no statistically significant differences in MBL between splinted or single short implants (6/7.5 mm); however, it is important to consider the different physiology of bone remodeling around implants next to other implants or next to natural teeth. Therefore, the influence of splinting factor on MBL around short implants should be considered for future investigations. It has been reported that short implants placed in the posterior maxilla are associated with increased MBL.[51,52]

Table 9 Multivariate analysis of MBL

Multiple linear regression					
	Unstandardized coefficients		Standardized coefficients	t	Sig.
Constant	B	Error tip.	Beta	B	Error tip.
C/I ratio	−0.01986248	0.018912534	−0.1575987632	−1.05276427	0.29757211
Implant length	−0.02935997	0.032476941	−0.1412801325	−0.91516272	0.37952324
Restoration design	−0.00019423	0.023691696	−0.0009231554	−0.08568564	0.95189264
Implant location	−0.0272992	0.063848617	−0.051984364	−0.41873253	0.68448316
Type of antagonist	−0.06318766	0.049732118	−0.1825247624	−1.35948815	0.18346963

Results of the present study, showing similar mean values of MBL around short and standard implants in the maxilla and mandible, contradict published data. This may be attributed to the tapered implant design of short implants allowing a high primary stability in predominantly low-density maxillary bone tissue.

Another variable considered in the present study was the nature of antagonist. In both implant types, short and standard, results showed no correlation between MBL and the type of opposing arch (natural teeth, fixed prosthesis, denture, implant-supported prosthesis). To the authors' knowledge, only two studies have reported on the influence of antagonist on MBL. Herzberg et al[52] failed to show a positive correlation, whereas Caceres La Torre et al[47] indicated that implants with fixed prostheses as antagonists have a greater MBL compared to dentures. Further studies are needed to evaluate the influence of antagonists on MBL.

The clinical results of short implants should be compared not only with those of longer implants placed in native jawbone, but with results obtained using advanced surgical techniques necessary to place standard implants in resorbed posterior jaws. A review of the literature by Chiapasco et al[1] reported that survival rates of implants placed in maxillae/mandibles reconstructed with onlay bone, in augmented maxillary sinuses, with vertical distraction osteogenesis procedures, and in guided bone regeneration technique protocols were 87.1%, 95%, 95.9%, and 96%, respectively. These data, compared to those obtained in the present study, indicate that priority should be given to simpler approaches.

One limitation of the present study is related to the population size, and one might question the value of the results when only a limited number of implants and patients have been observed. Another limitation is the short follow-up. Accordingly, further studies with an increased number of implants and patients and longer follow-up are needed.

Conclusions

1. Short and standard laser micro-grooved implants had comparable survival rates, marginal bone loss, and peri-implant soft tissue conditions over the observation period of 3 years, regardless of the prosthetic design (splinted/nonsplinted), the location (maxilla/mandible), or region (premolar/molar).
2. In clinical situations of limited maxillary and/or mandibular vertical bone height, treatment with short laser microgrooved implants is as reliable a treatment as standard laser micro-grooved implants.

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