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Scientific Letters

Research Article

Four-millimeter implants supporting unsplinted metal-ceramic screw-retained crowns in posterior jaw areas: a retrospective case series

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Abstract: Little is known about the clinical performance of unsplinted crowns supported by 4-mm implants. The objective of this investigation was to evaluate the clinical performance of extra-short implants supporting single restorations. A retrospective cross-sectional study design was used and included patients treated with 4-mm implants between 2014 and 2017. The influence of crown-to-implant ratio (CI ratio), age, sex, bleeding on probing, type of arch, implant diameter, occlusion antagonist and functional loading time on mesial and distal marginal bone loss around the implants were analyzed using univariate and multivariate linear regression models. A total of 27 cone morse dental implants with 4 mm in diameter was evaluated after a minimum post-loading time of 12 months. One implant was lost after loading, leading to an implant survival percentage equal to 96,3%. No other failure conditions were observed. From the variables analyzed herein, only CI ratio, functional loading time and sex were significantly associated with marginal bone loss on the mesial site of implants; and only CI ratio, functional loading time and bleeding on probing were associated with marginal bone loss on the distal site of implants. The present results suggest that 4-mm implants placed in the posterior maxilla and mandible to support unsplinted metal-ceramic screw-retained crowns may be a very promising alternative in order to enable the rehabilitation of posterior edentulous patients, who are unable or unwilling to undergo bone grafting procedures with high morbidity. However, further prospective long-term studies should confirm if this is a viable treatment option.

Keywords: case series; osseointegration; retrospective study; single crowns; short implants

Received: 14 February 2024; Accepted: 25 March 2024; Published: 08 April 2024

Introduction

Edentulous areas with alveolar bone loss commonly have limited vertical height between the bone crest and adjacent anatomical structures, such as the maxillary sinuses and the mandibular canal. In these areas, placement of long implants is a challenge and may demand other procedures, such as maxillary sinus floor augmentation, guided bone regeneration or onlay bone grafts [1]. One less invasive alternative, however, is the use of short and extra-short implants [2].

The predictability of extra-short implants loaded with fixed prostheses was initially controversial, especially in cases of unsplinted crowns. Nevertheless, the introduction of this type of implants has proven to be an important replacement treatment modality [3]. Furthermore, the use of shorter implants also reduces the complexity of surgical treatment, as it eliminates the need for additional procedures, such as lateralization of the inferior alveolar nerve and bone grafting, associated with morbidity of the patient [4].

Recently, previous articles have shown satisfactory survival rates for extra-short (< 6 mm) implants, indicating that these implants were as reliable as longer ones (≥ 10 mm) for supporting splinted restorations in posterior jaw areas [5,6]. Nevertheless, information on the use of extra-short implants to support single-tooth unsplinted restorations is still lacking in the literature.

Studies that recommend extra-short implants to support splinted prostheses, mainly in the posterior region, are commonly found in the literature. This is done to increase the area of functional distribution of the load applied to them, to reduce the overload on the peri-implant bone tissue. Only a few studies have assessed the clinical outcome of unsplinted restorations in the maxilla and mandible supported by 4-mm implants [7-9].

Therefore, the objective of this retrospective study was to assess the clinical outcome of 4-mm extra-short implants, placed in 23 patients who were evaluated after a minimum post-loading time of 12 months, supporting unsplinted metal-ceramic screw-retained crowns.

Materials and Methods

Study design

This article is a retrospective study that followed the guidelines of STROBE [10]. The project was approved by an Ethics Committee (#83973717.4.0000.5509), and included patients treated consecutively between 2014 and 2017 at the Military Hospital of the São Paulo Area, Brazil.

The patients included fulfilled the following criteria: patients needing at least one extra-short implant (Straumann® Roxolid SLActive RN SP 4.1 mm of diameter × 4.0 mm of length or Straumann® Roxolid SLActive WN SP 4.8 mm of diameter × 4.0 mm of length, Basel, Switzerland) inserted in the posterior area of the maxilla or mandible by the same surgeon (OHPB) in all cases. Implants were loaded 2 months after their insertion surgeries, with unsplinted metal-ceramic screw-retained crowns, and with a minimum functional time of 12 months.

Patients with systemic diseases that could impair osseointegration or with neoplastic diseases, use of corticosteroid drugs, smoking, alcoholism or drug abuse were considered as exclusion criteria.

Envisaging an adequate gingival and periodontal health, patients underwent dental scaling before implant surgery. 2 months later, the restorations were placed. Occlusion was always checked after the definitive installation of the metal-ceramic crowns, where the maxillo-mandibular relationship was checked both in the centric position and in lateral excursion. The contact points during the distribution of axial loads were adjusted in all cases, in order to provide the most favorable occlusion possible. Patients were instructed how to continue a good dental hygiene around implants.

Clinical assessments

The following assessments were selected for the evaluation of the extra-short implants supporting unsplinted metal-ceramic screw-retained crowns. All the information and analysis of radiographs were gathered and calculated by the same calibrated observer (FMS). *Implant survival rate:* determined by the absence of implant mobility and/or continuous radiolucency around the implant; by the absence of infection around the implants; absence of pain or loss of the implant. If one of the aforementioned conditions was present, the implant was considered a failure [11]. *Marginal bone loss (MBL):* peri-implant bone levels were measured on digital periapical radiographs taken at two moments: 1. the immediate post-operative stage of each implant insertion and 2. with a minimum time of 12 months post-loading (Fig. 1). The analysis and measurements on the intraoral radiographs were performed with a computer software (SIDEXIS 1.12, Sirona Dental System GmbH, Bensheim, Germany), distally and mesially to the alveolar bone around implants. The periapical radiographs were always taken using film holders, following the paralleling technique. The marginal bone level recorded on the initial radiograph immediately after surgical insertion of the implant was used as the baseline value for comparison of subsequent measurements. A calibration was performed prior to taking measurements on digital periapical radiographs. This calibration took into account the known measurements of the 4-mm extra-short implant, an object common to all images, whose body measurements are known (4 mm), and its polished prosthetic platform (1.8 mm). The methodology used to obtain measurements of marginal bone loss was based on a previously published study [12].

Figure 1. Radiographic assessment of marginal bone loss. **(a)** Implant platform line on immediate postoperative periapical radiograph. **(b)** Implant length on immediate postoperative (PO) clinical exam (perpendicular line from implant apex to prosthetic platform line). **(c)** Distal measurement from the most coronal bone/implant contact point

to the line of the implant prosthetic platform on immediate PO clinical exam. **(d)** Mesial measurement from the most coronal bone/implant contact point to the line of the implant prosthetic platform on immediate PO clinical exam. **(e)** Implant platform line on immediate postoperative periapical radiograph. **(f)** Implant length in the last PO clinical exam (perpendicular line from implant apex to prosthetic platform line). **(g)** Mesial measurement from the most coronal bone/implant contact point to the line of the implant prosthetic platform in the last PO clinical exam. **(h)** Distal measurement from the most coronal bone/implant contact point to the line of the implant prosthetic platform in the last PO time.

Peri-implant soft tissue health was determined based on the presence of bleeding-on-probing, plaque index or probing pocket depth and *crown-to-implant (CI) ratio*. In this study, we used the Anatomical CI ratio measurement that, according to previous literature [13], is determined by measuring the crown from its highest cuspid, in the molar and/or premolar occlusal surface, to the implant platform along a perpendicular line, followed by the measurement at the centre from the platform to the tip of the apex (Fig. 2).

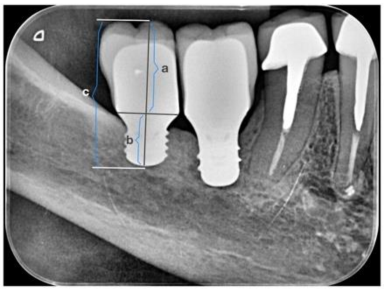

Figure 2. Radiographic crown-to-implant (CI) ratio measurements**. (a)** Anatomical crown length. **(b)** Anatomical implant length. **(c)** Anatomical CI ratio.

Statistical analysis

Descriptive statistics were carried out by assessing mean and dispersion values for the quantitative variables. The influence of age, sex, CI ratio, implant diameter, occlusion antagonist, functional loading time, type of arch and bleeding on probing on the mesial and distal MBL were analyzed using linear regression models (univariate and multivariate models). The SPSS v15.0 for Windows statistical software package (SPSS Inc., Chicago, IL, USA) was used for the statistical analyses.

Results

The values of the absolute and relative frequencies of all variables analyzed are shown in Table 1. A total of twenty-seven 4-mm implants inserted in the maxilla and mandible of 23 patients were evaluated after a minimum time of twelve months and a maximum time of thirty-three months post-loading. One implant was lost after loading; therefore, the statistical analysis was performed with the remaining twenty-six implants. Twenty implants were of female patients (mean age of 61.7 years at insertion time) and six implants were of male patients (with a mean age of 60.85 years at insertion time), as shown in the descriptive statistics in Table 1.

Table 1. Absolute and relative frequencies of all variables analyzed.

Variable	Specifications	Absolute Frequency			Relative Frequency	
		Male	Female	TOTAL	Male	Female
SAMPLE		6	20	**26**	23%	77%
Average Age	*Years*	60.85	61.7	**n/a**	n/a	n/a
Implant Diameter	*4.1 mm*	2	3	**5**	40%	60%
	4.8 mm	4	17	**21**	19%	81%
Occlusion Antagonist	*Natural*	4	15	**19**	21%	79%
	Other	2	5	**7**	29%	71%
Average Loading Time	*Months*	19.42	20.85	**20.13**	n/a	n/a
Average CI Rotation	-	1.67	1.73	**1.70**	n/a	n/a
Type of Arch	*Maxilla*	5	10	**15**	33%	67%
	Mandible	1	10	**11**	9%	91%
Bleeding on Probing	*Yes*	3	5	**8**	38%	63%
	No	3	15	**18**	17%	83%
Mesial Marginal Bone Loss	*Yes*	4	13	**17**	24%	76%
	No	2	7	**9**	22%	78%
	Average	0.428	0.221	**n/a**	n/a	n/a
Distal Marginal Bone Loss	*Yes*	4	14	**18**	22%	78%
	No	2	6	**8**	25%	75%
	Average	0.25	0.269	**n/a**	n/a	n/a

CI: crown-to-implant; n/a: not applicable

The average follow-up time, after loading, was 19.42 and 20.85 months for the implants placed in male and female patients, respectively. Fig. 3 shows the operative moment and the intraoral digital radiographs taken at the immediate post-operative period of implant insertion and after a minimum time of 12 months post-loading.

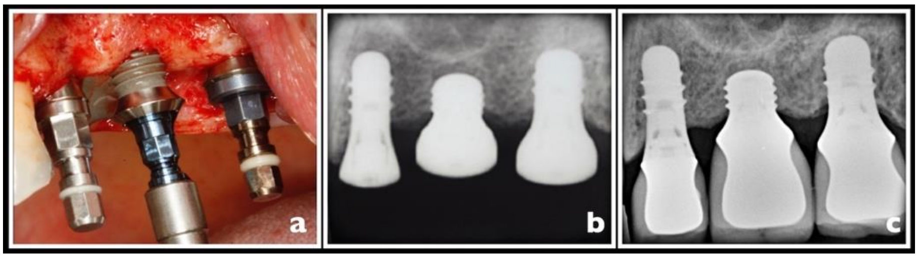

Figure 3. One of the 4-mm implants placed in the left maxilla of a male patient. **(a)** Operative moment. **(b)** Intraoral digital radiograph taken at the immediate post-operative period of implant insertion. **(c)** After a minimum time of 12 months post-loading with unsplinted metal-ceramic screw-retained crowns.

None of the implants were submitted to an immediate loading protocol. All were loaded two months after implant placement. The mean/standard deviation values of mesial and distal bone loss measured on intraoral digital radiographs after a minimum time of 12 months of implant loading are shown in Table 2.

Table 2. Mean/standard deviation (SD) values of mesial and distal bone loss measured in millimeters on intraoral digital radiographs after a minimum time of 12 months of implant loading.

Bone marginal loss (mm)	Mesial	Distal
Mean	0.270	0.257
SD	0.333	0.255

Univariate and multivariate analyses were used to evaluate whether the amount of bone loss on the mesial or distal site of the implants were related to implant diameter, CI ratio, age, bleeding on probing, sex, type of arch (maxilla/mandible), type of occlusion antagonist or to the functional loading time. The three variables significantly associated with MBL on the mesial site of implants in the univariate analysis were CI ratio, sex and functional loading time. In turn, the three variables significantly associated with MBL on the distal site of implants in the univariate analysis were CI ratio, distal bleeding on probing and functional loading time, as shown in Table 3.

Table 3. Univariate linear regression analysis of the variables significantly associated with marginal bone loss on the mesial and distal sites of the implants.

1	**Mesial MBL (Y)**	**Coefficient**	**Standard Error**	$\mathbf{R^2}$	***P* value**
	Intersection (β0)	0.5820	0.3175	0.0403	0.0156
	CI Ratio (X)	-0.1808	0.0388		0.0006
2	**Mesial MBL (Y)**	**Coefficient**	**Standard Error**	$\mathbf{R^2}$	***P* value**
	Intersection (β0)	0.4333	0.1338	0.0747	0.0035
	Sex (X) (Female = 1, Male = 0)	-0.221	0.1525		0.0177
3	**Mesial MBL (Y)**	**Coefficient**	**Standard Error**	$\mathbf{R^2}$	***P* value**
	Intersection (β0)	0.8794	0.2133	0.2700	0.0004
	Functional Loading Time	-0.0289	0.0090		0.0077
1	**Distal MBL (Y)**	**Coefficient**	**Standard Error**	$\mathbf{R^2}$	***P* value**
	Intersection (β0)	0.5899	0.2383	0.078	0.0208
	CI Ratio (X)	-0.1928	0.1352		0.0167
2	**Distal MBL (Y)**	**Coefficient**	**Standard Error**	$\mathbf{R^2}$	***P* value**
	Intersection (β0)	0.2033	0.0581	0.1043	0.001
	Distal bleeding on probing (X) (Yes = 1, No = 0)	0.1754	0.1049		0.0107
3	**Distal MBL (Y)**	**Coefficient**	**Standard Error**	$\mathbf{R^2}$	***P* value**
	Intersection (β0)	0.5926	0.1753	0.1412	0.0024
	Functional Loading Time	-0.0160	0.0080		0.0500

CI: crown-to-implant; MBL: marginal bone loss

In the multivariate linear regression analysis including all studied variables for the mesial MBL, the three variables that were significantly associated with MBL in the univariate analysis maintained their significance in the multivariate model (Table 4). In the multivariate analysis for the distal MBL, only two of the three variables that were significantly associated with MBL in the univariate analysis maintained their significance: functional loading time and distal bleeding on probing. The variable CI ratio lost its significance in the multivariate model, as shown in Table 5.

Table 4. Multivariate linear regression analysis including all the studied variables for the mesial marginal bone loss. $R^2 = 0.5989$; $*p < 0.05$.

Mesial marginal bone loss (Y)	Coefficient	Standard error	*P* value
Intersection	2.1431	1.4322	0.1529
Crown-to-implant (CI) Ratio	-0.3389	0.1639	0.0500*
Functional Loading Time	-0.0398	0.0102	0.0012*
Age	-0.0081	0.0060	0.1933
Bleeding on Probing	-0.1422	0.1265	0.2764
Sex	-0.2952	0.1331	0.0404*
Type of Arch	-0.1770	0.1199	0.1580
Diameter	0.1202	0.2265	0.6025
Occlusion Antagonist	-0.1998	0.1216	0.1189

Table 5. Multivariate linear regression analysis including all the studied variables for the distal marginal bone loss. $R^2 = 0.6700$; $*p < 0.05$.

Distal marginal bone loss (Y)	Coefficient	Standard error	*P* value
Intersection	0.9789	1.4392	0.5055
Crown-to-implant (CI) Ratio	-0.1777	0.1647	0.2955
Functional Loading Time	-0.0160	0.0103	0.0138*
Age	-0.0012	0.0060	0.8424
Bleeding on Probing	0.1606	0.1271	0.02203*
Sex	0.0701	0.1337	0.6070
Type of Arch	-0.0933	0.1205	0.4495
Diameter	-0.0110	0.2276	0.9620
Occlusion Antagonist	-0.0074	0.1222	0.9526

Discussion

In this study, implant survival percentage of twenty-seven four-millimeter implants was 96.3%, considering that one implant failed after loading. Aside from these events, no other adverse effects or failures were observed during the investigation, confirming the potential benefits of extra-short 4-mm implants supporting unsplinted metal-ceramic screw-retained restorations. The present implant survival rate is higher than that of a retrospective study on 4-mm implants supporting fixed dental prostheses (FDPs) in severely resorbed posterior mandibles, in which a 92.3% survival rate after 24 months of loading was reported [10]; slightly higher than that found in a study on 5-mm implants placed in the posterior maxilla restored with single-tooth restorations, in which a 95.1% success rate was reported [14]; and higher than the results of another study on 6-8.5-mm implants placed in the maxilla, which reported a 94.6% survival rate after 2 years of loading [15].

Disproportionate prosthetic restorations (unfavorable CI ratio) could lead to lack of good biomechanical behavior with potential impact on MBL. According to some studies, the CI ratio should be the most approximate to the natural crown-to-root ratio [16,17]. However, there is no consensus about the appropriate CI ratio for extra-short implants and, in this study, the multivariate analysis showed a negative association between the CI ratio and MBL on the mesial site of implants. In other words, the results showed that the higher the CI ratio, the lower the mesial MBL (coefficient: -0.33), as demonstrated in Table 4. Other studies assessed the influence of the CI ratio on MBL and found no correlation between them [18,19]. On the other hand, no other study in the literature showed the negative association between these variables observed herein. Our results are therefore in contrast to other previous studies [19,20].

Although these data were not included in the statistical analysis, in this study it was observed that the position of the extra-short implant, whether between teeth/implants or in the most distal position, does not influence the rate of MBL, which in turn corroborates with another recent study [21].

Another controversial result obtained in this study was that the functional loading time also presented a negative association with MBL on the mesial and distal sites in the multivariate analysis: the longer the functional time of the implant, the lower the MBL [22]. However, the functional loading time was shown to have a low impact on the MBL, as demonstrated by the coefficient values (mesial coefficient: -0.03; distal coefficient: -0.016). These negative relationships obtained for the CI ratio and functional time with MBL may be due to the short-term analysis and the smaller sample size. Larger number of cases and long-term clinical studies are needed to confirm the results obtained herein, since a small sample size can increase the chance of false premises being assumed to be true. The retrospective design of this study also leads to the influence of confounding factors, showing less validity than prospective studies such as randomized clinical trials.

An interesting finding in this study, which corroborates with other results in the literature, is the positive association between distal bleeding on probing and MBL on the distal site in the multivariate analysis (Table 5). The distal sites of implants that had bleeding on probing presented greater MBL (coefficient: 0.16) when compared with implants without bleeding. As already shown in the literature, bleeding on probing can be a good predictor or parameter to evaluate the chance of losing attachment and MBL [23,24].

Additionally, although more implants were placed in female patients (20 implants), those inserted in male patients (6 implants) presented an average value of MBL higher than that obtained for the implants inserted in female patients (male: 0.428 × female: 0.221), as shown in the descriptive statistics in Table 1. This finding may also be due to the smaller sample of implants placed in male patients: one of these implants presented an outlier, raising the average of MBL within the group. The other variables studied, such as age, type of arch, implant diameter and occlusion antagonist, were not significantly associated with MBL on the mesial or distal sites.

Among the limitations of the present report are the small sample size and the short time of follow-up for the clinical cases. As a result, prospective long-term follow-up studies on digital workflow methodologies for extra-short implants would be recommended to confirm the clinical potential and relevance of the present technique.

In conclusion, the present success rate suggests that the use of 4-mm extra-short implants can successfully support unsplinted screw-retained fixed prostheses in the posterior jaw, regardless of the type of antagonist tooth, considering a satisfactory occlusion.

Acknowledgments

This study did not receive funding, grants, or assistance for the submission of this article.

Author Contributions

OHPB conceived and designed the work, planned and executed implant placement, and prepared the manuscript. FMS acquired data and performed the prosthetic restoration of the implants. IC organized and analyzed the data and prepared the manuscript. ARGC conceived and designed the work, substantially revised the overall workflow and prepared the manuscript. All authors read and approved the final manuscript.

Conflicts of interest

The authors declare no competing interests.

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