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ORIGINAL ARTICLE

A 5-year longitudinal cohort study on crown to implant ratio effect on marginal bone level in single implants

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Abstract

Background: A 5-year longitudinal cohort study was carried out to evaluate the influence of anatomical crown to implant ratio (CIR) on peri-implant marginal bone level (MBL) in single implants.

Materials and Methods: The longest possible implants, according to the availability of pristine bone, were inserted, one per patient, among periodontally healthy teeth in consecutively recruited subjects. CIR and MBL changes were measured on standardized radiographs. The relationship between MBL and multiple predictors was investigated. A statistical analysis suitable for mixed type distributions was conducted: for the discrete component a logistic regression model was used and for the continuous component the impact of the variables on MBL was examined by using robust nonparametric comparison tests.

Results: Seventy-eight dental implants were inserted in 34 mandibles and 44 maxillae, with one stage procedure in 40 cases and two stage in 38 cases. Thirty-five implants were <10 mm, while 43 were ≥ 10 mm long; 28 implants had a CIR ≤1 and 50 had a CIR >1. No drop-outs or implant loss were observed. Bone loss occurred only in a few cases, measuring less than 0.5 mm and being significantly more pronounced for implant length ≥10 mm, for lower CIR values and for the two stage procedure.

Conclusion: Higher CIR values were not related to increased peri-implant bone loss; a <10 mm long implant insertion may be safely considered for reduced bone heights.

KEYWORDS
crown to implant ratio, peri-implant marginal bone level, peri-implant marginal bone loss, single implant

1 | INTRODUCTION

The current literature reports long-term success for dental implants that allows complex prosthetic rehabilitations of partially and fully edentulous patients with a high level of predictability. Nonetheless, dental implants are not immune to technical failures, such as material breakdown, and biologic complications, such as marginal peri-implant bone loss.[1]

Progressive peri-implant marginal bone loss can compromise a successful implant restoration up to its complete failure. Putative initiating factors for bone loss may include: a variety of local factors, smoking and peri-implantitis; although the academic controversy relating this latest factor to marginal peri-implant bone loss is still unresolved.[2]

Peri-implant marginal bone loss values ≤1.5 mm, during the first year from implant placement, and of 0.2 mm per year, later on, were approved, by many Authors, as successful implant criteria,[3,4]; very recently, an alveolar bone loss ≥2 mm during and after the first year has been defined as pathologic.[5]

Among bone loss causes, as a local factor, an increased crown-to-implant ratio (CIR) has been proposed and investigated in the literature with conflicting results.[6] CIR is considered the equivalent of the natural teeth crown-to-root ratio (CRR) that is referred to as an anatomical CRR, the ratio between the height of the crown and the length of the root, being the cemento-enamel junction the fixed separation point, and a clinical CRR, which is the relationship between the portion of the tooth located above the marginal alveolar crest and that inside the alveolar bone as calculated from a radiograph.[6]

Although Grossmann and Sadan concluded that no definitive recommendations could be established for an optimal CRR, ideally, tooth CRR should be 1:2, when the tooth has a completely healthy periodontium; in such a condition the tooth rotation center is located in the center of the root, two-thirds apical to the marginal bone crest.[7]

However, this condition is rarely found in clinical practice, mainly due to the recurrent reduction in periodontal support, secondary to periodontitis, with subsequent increase in CRR values. Since augmented CRR values induce relocation of the tooth center of rotation toward the root apex, Dykema et al.[8] and Shillingburg et al.[9] reported that a CRR of 1:1.5 is desirable, in order to reduce to a minimum the horizontal components of occlusal forces and related harmful effects on bone loss. In addition, a minimum acceptable CRR, in the case of a healthy periodontium and controlled occlusion, is a 1:1 ratio, while a CRR greater than 1:1 might be adequate, when the opposing occlusion is composed of tissue-supported prosthesis, thanks to the reduced occlusal load.[7–9]

Similarly to CRR, the CIR is also defined either as anatomical CIR or as clinical CIR, having respectively the implant shoulder level or the marginal bone level, evaluated on radiographs, as the separating point. A CIR ranging from 1:2 to 1:1 was proposed to avoid marginal bone loss.[6,10–16]

Factors influencing anatomical CIR are either the crown or the implant length, and when considering the clinical CIR, the marginal bone level plays a role. A consensus conference on crown height guidelines for fixed implant prosthesis stated that a desirable distance between marginal bone levels to opposing dentition should range from 8 to 12 mm, considering 2 mm for occlusal porcelain, an abutment ≥5-mm high and 3 mm occupied by soft tissues (including biologic width). However, it was also highlighted that an increased height of the prosthesis, and a subsequent increased CIR value, may negatively affect the distribution of occlusal forces, causing both technically and biologically negative effects, mainly material component fracture and peri-implant marginal bone loss, respectively.[17,18]

Indeed, it is likely that higher CIR displays a form of non-axial force, in which the occlusal load acts outside the dental implants center of gravity, generates lateral forces on the implant and on peri-implant bone with its related moment of the force. In this biomechanical perspective, in the case of higher CIR, the crown acts as a lever arm, which is the perpendicular distance between the line of action of the lateral force and the dental implant center of gravity, and is directly related to the crown height. It causes localized stress accumulation on the implant and transfers stress to the peri-implant crestal bone, potentially causing technical and biologic complications.[6,10–15]

Moreover, besides an augmented crown height, a reduction in implant fixture length, such as in short implants with a length < 10 mm, as defined by Monje, may also increase both anatomical and clinical CIR.[19]

The use of short dental implants permits an appropriate tridimensional implant insertion even in atrophic alveolar ridges, overcoming the need for bone grafting procedures prior to implant placement, and thus reducing prosthetic rehabilitation time, risk of complications and expenditure. For these reasons, short implants are becoming more and more common in dental practice. Finally, a progressive loss of marginal bone may influence the clinical CIR.

The primary aim of the present study was to compare the marginal bone loss between implants with a CIR ≤1 and a CIR >1 in single-tooth implants among periodontally healthy teeth.

Secondary aims were to evaluate marginal bone level changes in relation to: implant length and diameter, smoking habit, surgical technique (one or two stage), time (time from loading to radiological survey), and position of the implant in the arch (maxilla or mandible).

2 | MATERIAL AND METHODS

2.1 | Study design

The present study was a clinical prospective non-randomized controlled study.

Patients with single tooth edentulism were consecutively recruited, from the outpatient population of a general dental clinic, and measured, from October 2012 to December 2017, and gathered data were analyzed. The study passed the local Ethical Committee and fulfilled the requirements of the Declaration of Helsinki of the World Medical Association.

Patients were consecutively recruited and checked on the yearly basis with the first radiographic evaluation (base line) on the day of the final prosthetic restoration.

2.1.1 | Inclusion criteria

- Age: between ≥ 18 years old and ≤ 80 years old.
- Single-tooth edentulism with adjacent periodontally healthy teeth, to be replaced by an implant with a single crown restoration.
- At least six-months healing after extraction and complete osseous recovery of the socket before implant insertion.
- No signs of active periodontal disease.
- An effective standard of oral hygiene with a full-mouth plaque score (FMPS) ≤25%[20] and a full-mouth bleeding score (FMBS) ≤25%.[21]

2.1.2 | Exclusion criteria

- Pre-implant/peri-implant osseous graft or pre-implant/peri-implant bone regeneration in the investigated area.
- Immediate post-extractive and/or immediately loaded implant.
- Previous history of oncological therapy consisting of irradiation and/or major osseous resection in the investigated area.
- Bisphosphonate therapy with any route of drug administration.
- Systemic or local factors possibly interfering with implant osseointegration.

2.2 | Surgery

One implant per patient, with adjacent periodontally healthy teeth, was inserted. Implant insertion was performed after a mid-crestal incision and flap elevation, in an outpatient environment under local anesthesia (2% mepivacaine with epinephrine, 20 + 12.5 mg/mL) upon

Chlorhexidine 0.2% mouth rinse just before surgery, and under an antibiotic prophylaxis (2 g of Amoxicillin, or 600 mg of Clindamycin when allergic to penicillin, 1 hour before surgery).

The longest possible implant was inserted according to the availability of pristine bone.

The implant shoulder was located at the crestal bone level. Depending on the implant stability, which was measured by the peak Insertion Torque Value (ITV) evaluated through the electronic control of the surgical unit (W&H Italia srl, Cusago, BG, Italy), the one stage procedure was applied when an ITV ≥ 30 Ncm was found. Such a value was previously considered by some authors safe enough to allow a higher risk procedure such as immediate loading of the implant.[27] A two stage procedure was employed when an ITV < 30 Ncm was encountered.

An anti-inflammatory drug (Ibuprofen 600 mg/day) if needed, was prescribed together with a chlorhexidine mouth rinse bid for 15 days.

Implants were loaded at least 3 months after insertion with a single crown restoration.

Supportive periodontal therapy, with a personalized oral hygiene recall, scaling, tooth polishing and oral hygiene instruction reinforcement was performed, in order to maintain a FMPS ≤ 25%[20] and a FMBS ≤ 25%.[21]

2.3 | Radiographic examination

Bi-dimensional periapical radiographs (70 KVp, 7 mA), registered and standardized with a long cone technique and a bite block, were taken on the day of the final restoration and at the annual controls.

The implant dimension was the standard for calibration and a software package (Osiris medical imaging software 4.19, University Hospital of Geneva, Geneva, Switzerland) was used to collect measurements registered to the nearest 1/10 mm, after identification of the marginal bone level and of the implant reference points performed by a single operator not involved in the study.

2.4 | Group assignment

After restoration, patients were assigned to CIR ≤1 and CIR >1 groups, based on radiographic measurements.

2.5 | Variables

2.5.1 | Descriptive variables

- Occlusal opposing configuration (NT, natural tooth; I, implant; FPC, fixed prosthetic crown; P, pontic; RPD, removable partial denture; FD, full denture)
- Opposing texture (NT, natural tooth; C, ceramic; R, resin; M, metal)

2.5.2 | Predictors

- CIR.
- Implant length.
- Implant diameter.
- Smoker/Non smoker.
- Surgical Technique (one or two stage).
- Time: from loading to radiological survey.
- Position in the Arch: maxilla or mandible.

2.5.3 | Confounders

- Age.
- Gender.

2.5.4 | Measures on standardized radiographs

- Crown to Implant Ratio (CIR), as an anatomical measurement, that is the ratio between the crown height, measured as the interval, in mm, lengthwise to the implant axis, between the implant/crown abutment connection and the most incisal or occlusal point of the crown and the implant length, known measurement.
- Peri-implant marginal bone level (MBL): the interval, in mm, between the implant/crown-abutment connection and the most apical mesial (MMBL) and distal (DMBL) marginal bone level, measured at different times. Measurements were averaged as a mean of the two values (MMBL and DMBL) for the statistical computations.

2.5.5 | Outcome variables

- Change at marginal bone level (ΔMBL): this variable was calculated by subtracting the MMBL and the DMBL registered at different time points respectively from their baseline value and then averaged. calculating the ΔmMBL, for each implant at each time point. A negative value representing a bone loss.
- Implant survival: an implant was considered to have survived as already described in previous. papers[22,23] and in addition when functionally loaded and lost at the removing time.
- Implant crown survival: an implant crown was considered to have survived unless fractured in the restorative material or upon fracture or loosening of the abutment/retaining screw or not in place because of implant loss or implant fracture.

2.6 | Data management and statistics

For each patient, one or more measures for bone loss were obtained over a span period of 5 years. The mean bone loss was averaged over the years, to obtain a single mean value for each patient. As a result, the mean bone level has a mixed type distribution with a discrete and a continuous component. The discrete part is a binary random variable assuming a zero value for those patients not experiencing any bone loss and a value of one otherwise. The continuous element measures the mean amount of bone loss for those patients suffering bone losses, within the time span period of the study (5 years). For this reason, a two-part analysis was conducted. Firstly, the variables, which have some impact on the bone loss event (the discrete component) were analyzed using a logistic regression model. Variable selection was performed using stepwise logistic regression with both forward selection and backward elimination. No significant correlation was detected between numerical variables in the sample at hand.[24] Secondly, conditionally on the presence of bone loss, the impact of the same explanatory variables on the amount of bone loss was examined. In this step, to compare the different groups, Yuen's two-sample trimmed mean test was used, as implemented in the R package WRS2.[25] This test is one of the most robust methods to apply when variances are heterogeneous, and it allows us to deal with outliers and non-gaussianity. The *P*-values for the tests were computed by using the bootstrap with 1999 Monte Carlo runs. Power analysis and sample size calculation were conducted using the approach proposed in Luh and Guo[24] for trimmed *t*-test with unequal variances. The code was implemented in R language (version 3.5.2). When a test spotted a significant statistical difference at the level size of 5%, the effect size was measured by using a robust, heteroscedastic generalization of Cohen's *d* approach, as proposed by Wilcox and Tian, which also prevents the issue of unequal sample sizes.[26] Values of this measure were about 0.10, 0.30, and 0.50 and correspond, respectively, to small, medium, and large effect sizes.

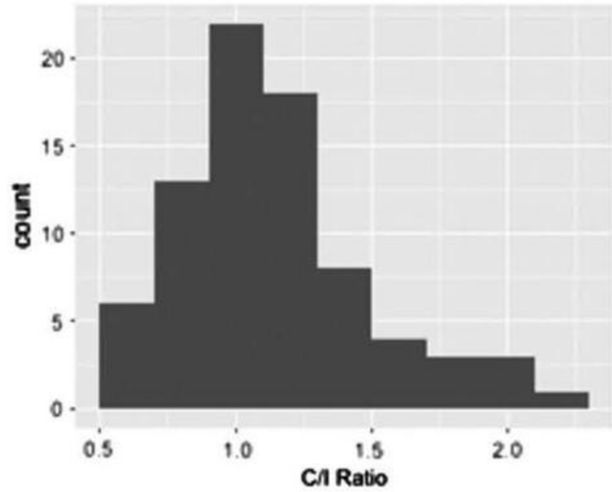

FIGURE 1 Histogram showing dental implants CIR distribution

2.7 | Compliance with the appropriate guidelines/checklist

The STROBE checklist was undertaken.

3 | RESULTS

A total of 78 titanium dental implants, one per patient, were inserted in 78 consecutively recruited patients, 44 females and 34 males, between 30 and 76 years of age (with a mean age of 49.8), of whom 28 were smokers and 50 nonsmokers.

Thirty-four implants were positioned in the mandible (1 in an incisor, 1 in a cuspid, 5 in bicuspids, 27 in the molar area) and 44 in the superior maxilla (3 in incisors, 19 in bicuspids, 22 in the molar area).

All 78 dental implants supported metal ceramic crowns, opposing 68 natural teeth, 6 metal-ceramic fixed dental prosthetic crowns and 4 metal-ceramic pontics.

Depending on the vertical bone dimension available in each single case, 35 dental implants <10 mm long (from 6 to 9 mm) and 43 implants ≥10 mm (from 10 to 15 mm) were inserted; of these, when restored, 28 implants resulted to have a CIR ≤1, while 50 had a CIR >1. The mean CIR value was 1.15 and the median CIR value was 1.08 (CIR minimum value = 0.58; CIR maximum value = 2.25) (Figure 1).

All the 35 implants <10 mm long had a CI ratio > 1; moreover, 15 implants among the longer ones showed a CIR > 1, while the remaining 28 had a CIR ≤1 (Table 1).

The one stage procedure was applied in 40 cases whereas the two stage was applied in 38 cases.[28]

No dropouts, or implant loss or implant crown loss occurred in the observation period.

FMPS and FMBS scores and Periodontal Pocket Dept values remained stable over the time.

ΔMBL was measured and related to the above-mentioned predictors. Peri-implant bone loss, indicated by negative ΔMBL values, was registered only in a few cases[36] and when occurring it was shown to be minimal. Figure 2 describes the distribution of stable sites and the amount of bone loss in losing sites.

Variations in MBL over the years have shown no statistically significant differences when evaluated in relation to: implant position in the arch (maxilla or mandible), implant diameter, time from loading to radiological survey and patient age, and when comparing males vs females and smokers vs nonsmokers, either considering all the sites or restricting the analysis only to the sites effectively losing bone.

Statistically significant differences were found, on the other hand, when evaluating mean ΔMBL in relation to: implant length, CIR values, and surgical technique.

Data resulting from a subset of the sample obtained by restricting the comparative analysis only to sites effectively losing marginal bone showed that, when comparing the MBL differences between implants <10 mm long and implants ≥10 mm, a statistically significant difference appeared indicating a minor bone loss in the shorter implants group (Table 2).

The same happens when considering CIR values >1 or ≤ 1, showing a statistically significant minor bone loss in the group CIR >1 (Table 3). All the trimmed *t*-tests, with a nominal level of 5%, show a power of about 80% for the given sample sizes.

When considering the effect of the surgical technique, the data indicated that, among cases losing marginal bone level, 21 were treated by the one stage procedure and 15 by the two stage.

In particular, the one stage procedure was applied to 11 implants ≥10 mm of length, 10 implants shorter than 10 mm, 7 implants with a CIR ≤ 1 and 14 with a CIR > 1; in the remaining cases, the two stage technique was performed (Table 4 and Table 5).

When comparing only the sites receiving the two stage technique, among sites losing bone, the trimmed mean ΔMBL was significantly statistically different and more pronounced in the group with CIR ≤1 vs that one with CIR > 1 (trimmed mean difference: −0.621; $P = 0.025$, [CI95%:−1.152; −0.090]; Yuen's effect 0.650) and in the group with

TABLE 1 Dental implants frequency distribution for length and CIR

	Implant length < 10 mm	Implant length ≥ 10 mm
CIR ≤ 1	0	28
CIR > 1	35	15

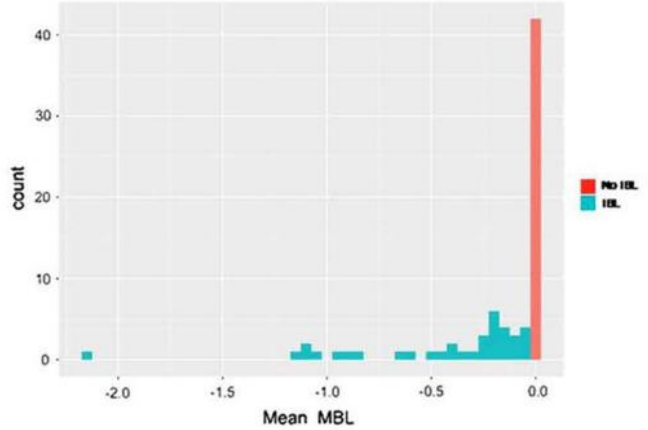

FIGURE 2 Mean MBL distribution. The red bar shows no bone loss. Green bars indicate the amount of bone loss in single cases

TABLE 2 Mean MBL variations related to implant length

	Mean MBL (±SD)	Median MBL (±MAD)
Implant length < 10 mm	−0.262 (±0.24)	−0.20 (±0.22)
Implant length ≥ 10 mm	−0.566 (±0.53)	−0.27 (±0.26)

implant length ≥ 10 mm vs the group with implant length < 10 mm (trimmed mean difference: 0.606; $P = 0.012$, [CI95%: 0.197; 1.015]; Yuen's effect 0.846) (Figures 3 and 4).

4 | DISCUSSION

The present longitudinal study has measured, radiographically, the marginal bone level in single-tooth implants with adjacent periodontally healthy teeth over 5 years. In addition, it has evaluated the related influence of several predictors on bone level such as: CIR, implant length and diameter, smoking habit, surgical technique (one or two stage), time (time from loading to radiological survey), position of the implant in the arch (maxilla or mandible) and confounders such as: age and gender.

The mean MBL appeared to be very stable over time with only a few single ΔMBL negative values, measuring less than 0.5 mm. Indeed, in a recent study, Galindo-Moreno et al. had already reported that the bone loss around a single implant among teeth was minimal over 36 months and hypothesized that the bone level was maintained by the periodontal ligament of the adjacent teeth.[29] Consistent with this finding Choquet et al. also emphasized that the level of the gingival papilla around a single-tooth implant was strongly influenced by the marginal osseous level of the nearby teeth.[30] Moreover, as reported by Tarnow et al. the gingival papilla formation, which is related to the peri-implant bone level, is much more difficult to obtain and preserve around multiple implants when compared to a single implant among teeth.[31] Therefore, the overall negligible bone loss

TABLE 3 Mean MBL variations related to implant CIR

	Mean MBL (±SD)	Median MBL (±MAD)
Implant CIR ≤ 1	−0.653 (±0.58)	−0.45 (±0.52)
Implant CIR > 1	−0.287 (±0.26)	−0.20 (±0.22)

TABLE 4 Implant length frequency distribution between the one and two stage technique in sites losing bone

	One stage technique	Two stage technique
Implant length < 10 mm	10	5
Implant length ≥ 10 mm	11	10

around a single implant registered in the present study might well be explained by insertion among periodontally healthy teeth.

The minimal MBL changes, currently registered in a few cases, are neither related to the predictors: smoking habit, position in the dental arch and time nor to the confounders: age and gender.

Nor was any relationship to implant diameter found; this last finding is in contrast to that recorded by Bayraktar et al., who demonstrated that implant diameter influenced the peri-implant bone loss more than implant length.[32]

When considering the effect of the two stage vs the one stage technique on ΔMBL values, statistically significant higher peri-implant bone loss levels were found in the one stage technique cases with implant length ≥ 10 mm and CIR ≤1. Previously published studies have shown no significant difference in ΔMBL values between one and two stage procedures either during the first 2 years from implant placement[33–35] or during 5 years of function.[27,36]

Interestingly, in the present study, when evaluating ΔMBL in relation to implant length, it was found that the bone loss observed in the shorter implants group (<10 mm long) was statistically significantly lower when compared to the group of longer implants (≥10 mm long) but only for the restricted group of sites losing marginal bone. Similar findings were published by Rokni et al.[37] The present results differ from the observation of Monje et al. who reported, for short implants (<10 mm), bone loss values equal to those recovered around longer implants (≥10 mm).[19]

In the current study, apart from the effect of implant length on the ΔMBL, CIR influence was also analyzed. Many studies have been conducted in the attempt to elucidate CIR effect on peri-implant marginal bone loss which report conflicting results. Tawil et al.[18] found no association between CIR and bone loss, moreover Birdi et al.[38] and Okada et al.[39] reported similar ΔMBL values for both groups of implants having CIR ≤1 and CIR >1. Malchiodi et al.[40] found, however, a direct relationship between higher CIR values and increased bone loss levels, conversely, Garaicoa-Pazmino et al.[6] showed that higher CIR values were associated with less peri-implant radiographical bone loss. As already reported by many authors, also in the present study evaluating single edentulism, the anatomical CIR has been considered, rather than the clinical CIR, which is more explanatory in bone atrophies.[10,16,41–44]

As expected, all the shorter implants, <10 mm long, showed a CIR > 1, together with 15 of the 43 implants ≥10 mm long. The present results demonstrate that a CI ratio > 1 was associated with lower

TABLE 5 CIR frequency distribution between the one and two stage technique in sites losing bone

	One stage technique	Two stage technique
Implant CIR ≤ 1	7	8
Implant CIR > 1	14	7

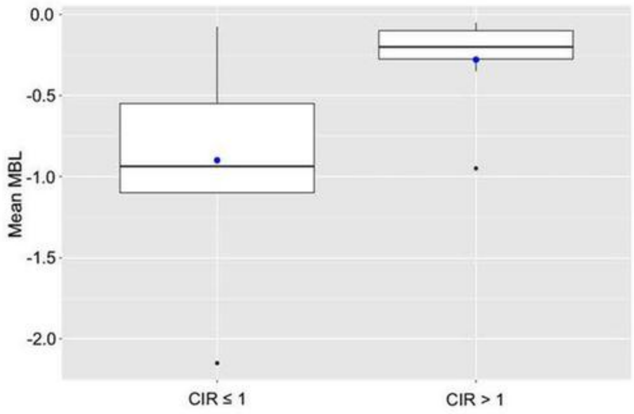

FIGURE 3 Mean MBL variations registered in two stage technique cases in relation to implant CIR. The blue point represents the mean

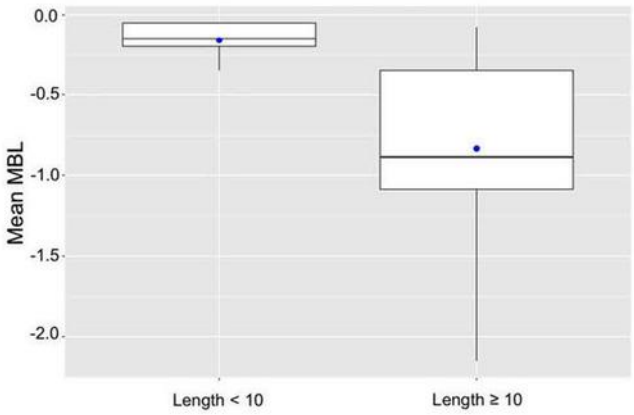

FIGURE 4 Mean MBL registered in two stage technique cases in implants of ≥10 mm long and < 10 mm long. The blue point represents the mean

levels of peri-implant bone loss, similar to that which has already been reported by Garaicoa-Pazmino et al., Blanes et al., and Lee, et al.[6,10,16]

Our findings appear to indicate that bone loss is neither related to implant length nor to anatomical CI ratio and that, conversely from previous hypotheses, higher CI ratio values (CIR > 1) may not be considered as a risk factor for an increased peri-implant bone loss over time, especially when compared to CIR < 1.

In this perspective, the insertion of a shorter implant may be considered in cases of reduced availability of vertical bone, thus avoiding osseous regenerative or reconstructive procedures, and reducing intervention phases, time, side effects, and expenditure. This would represent, from a clinical standpoint, a safe, and reliable treatment option for single-tooth implant rehabilitation among periodontally healthy teeth.

Further surveys with a larger group of patients followed for a longer period of time are nevertheless required to confirm the findings of the present study.

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CONFLICT OF INTEREST

All the authors, Luca Ramaglia, Federica Di Spirito, Massimiliano Sirignano, Michele La Rocca, Umberto Esposito and Ludovico Sbordone, declare that no conflict of interest, current and within the past 5 years, exists in relation to any financial organization regarding the material discussed in the manuscript.

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