# Retrospective Study of Short and Extra-Short Implants Placed in Posterior Regions: Influence of Crown-to-Implant Ratio on Marginal Bone Loss

Eduardo Anitua, MD, DDS, PhD;*,† Laura Piñas, Degree of Dentistry;* Gorka Orive, PhD†

## ABSTRACT

*Aim:* The aim of this study is to evaluate the influence of crown-to-implant (CI) ratio as well as other surgical, prosthetic and biomechanical variables on marginal bone loss (MBL) and on the survival rates of implant-supported prostheses in short implants (≤8.5 mm in length) placed in posterior areas of maxilla and mandible.

*Material & Methods:* This was a retrospective study based on clinical charts and follow-up recordings from a single private practice over a period of 10 years. Patients rehabilitated in the posterior region of the jaws by means of prostheses supported by implants of ≤8.5 mm length were included. Patients-related, surgery-related. and implant-related variables, as well as other prosthetic and biomechanical variables. were registered. The data were split into two groups according to the value of CI ratio (CI < 2 and CI ≥ 2). MBL was measured from radiographs using an image analysis software. Implant and prosthesis survival rates were recorded.

*Results:* One hundred twenty-eight short implants placed in 63 patients were evaluated. The mean follow-up period was 21.88 months (standard deviation (SD): 22.9, range 7–113 months). Eighty-six implants (67.2%) had a CI ratio of <2, whereas it was ≥2 in 42 implants (32.8%). The mean value of CI ratio was 1.82 (SD: 0.42; range 1.04–3.31). The average MBL after 1 year of follow-up was 0.35 (SD: 0.50), and it was 0.45 (SD: 0.46) mm for subsequent evaluations. Survival rates of implants and prosthesis were 100%. The presence of a cantilever had a negative influence on the first year MBL ($p < .05$).

*Conclusions:* The CI ratio had not a significant influence on MBL in Biotechnology Institute (BTI; Vitoria, Spain) short implants humidified with PRGF-Endoret and placed in posterior areas. The only variable that showed a significant negative influence on first year postloading MBL was the use of cantilever for rehabilitations.

KEY WORDS: extra-short implants, implant survival, marginal bone loss, retrospective, short implants

## INTRODUCTION

In the pioneering era of oral implantology, it was thought that the rationale for using implant-supported restorations and determining the optimal prosthetic crown/implant ratio had to be based in the hypothesis of considering the implant as a tooth root. However, as the field advanced, it was observed that these initial guidelines should not be axiomatic paradigms.[1,2] For example, in the case of teeth, the periodontal ligament essentially attaches the tooth to the surrounding alveolar bone, whereas in the case of dental implants, a stable and long-term connection depends mainly on implant osseointegration, which is an intimate contact between alveolar bone and implant surface, without interposition of fibrous tissue around the implants. In addition, until recently, clinicians used to place the longest possible implants in any given site with the aim of increasing the surface available for osseointegration and, at the same time, maintaining a crown/implant ratio that mimics as much as possible the natural tooth/root ratio.

In patients with reduced alveolar bone height, the insertion of standard length implants is often

*Private practice, Implantology and Oral Rehabilitation, Vitoria, Spain; †Biotechnology Institute (BTI), Vitoria, Spain

Reprint requests: Dr. Eduardo Anitua, Biotechnology Institute, Instituto Eduardo Anitua, c/Jose Maria Cajigal 19, 10007 Vitoria, Spain; e-mail: eduardoanitua@eduardoanitua.com



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challenging and may require additional invasive bone augmentation procedures.[3,4] The latter is often associated with increased patients' morbidity, higher cost, and duration. The introduction of short and extra-short implants[5–8] has represented a very appealing therapeutic alternative, particularly in the case of the atrophic posterior regions of mandible and maxilla, where apart from difficult access, limited visibility, reduced space, and poor bone quality, there is the risk of involving the inferior alveolar nerve or penetrating the maxillary sinus during implant placement.

The predictability of short implants was initially controversial. In fact, although the earliest articles showed slightly lower survival rates for short implants than those for standard length implants,[9,10] the latest studies and systematic reviews suggest similar survival rates.[11–13] Esposito and colleagues in a Cochrane systematic review on maxillary sinus augmentation procedures concluded that short implants may also provide additional advantages being as effective but causing fewer complications than longer implants placed using more complex techniques.[14] In another review on horizontal and vertical bone augmentation techniques,[4] it was concluded that short implants appeared to be a better alternative than vertical bone grafting.

This evidence has been reinforced by several biomechanical studies suggesting that maximum bone stress is independent of implant length[15] and even that implant width is more important than the additional length for optimizing loading stress distribution.[16] Although these in vitro or in silico biomechanical studies are limited by not providing a real clinical evidence on patients, they help to understand the biomechanical forces involved under an established and accepted three-dimensional mesh, and thus predict what can happen in the clinical practice. In addition, eliminating or minimizing the lateral force on the prosthesis and force distribution by splinting multiple implants may play a significant role in reducing stress on implants and especially on shorter ones.[15]

The increased use of short implants has generated disproportionately large prosthetic restorations compared with the implant length on which they are standing. Although the use of short implants is already quite widespread and accepted by clinicians, there is still a tendency to think that disproportionate prosthetic restorations could induce poor biomechanical behavior with a potential impact on marginal bone loss (MBL), leading to reduced survival rate of implants. After applying an occlusal force, the crown of the implant will act as lever arm, causing crestal bone stress, and eventually leading to crestal bone loss.[17] Studies evaluating this topic are heterogeneous in terms of the implants evaluated and the anatomical locations studied.[1,18–24] In general, although no sound association between MBL and the crown-to-implant (CI) ratio is reported, there is not a general consensus about the appropriate CI ratios for short implants. In addition, in the case of short implants, apart from the CI ratio, other variables may influence the MBL and the survival rate including the surgical variables, the types of prosthesis, the type of adjacent structures and the different distances to them, the type of occlusal antagonist structure, the prosthetic rehabilitation type, the use of cantilevers, or the angulation of the implant.

To shed some light on this topic, we decided to evaluate the influence of CI ratio as well as other surgical, prosthetic, and biomechanical variables on MBL and on the survival rates of implant-supported prostheses in short implants (≤8.5 mm in length) placed in posterior areas of maxilla and mandible.

## MATERIAL AND METHODS

This article was written following the STROBE (Strengthening the Reporting of Observational studies in Epidemiology) guidelines[25] and included all patients treated at the Clínica Dental Eduardo Anitua at Vitoria, Spain, between 2001 and 2009, who fulfilled the following criteria:

- both genders;
- one or more short implants (≤8.5 mm in length range between 5.5 and 8.5 mm) placed in the posterior areas of maxilla or mandible;
- implants that were loaded for at least 6 months; and
- with a CI ratio of ≥1.

A retrospective cohort study design was used. One hundred twenty-eight short BTI acid-etched surface implants (Biotechnology Institute [BTI], Vitoria, Spain) consecutively placed in maxilla and mandible of 63 patients were included and evaluated.

### Implant Placement-Surgical Protocol

In all patients, the same surgical protocol and treatment plan was followed. Before surgery, patients underwent a routine dental scaling to start the implant treatment with an adequate gingival status. A panoramic X-ray was taken prior to the intervention to assess bone quality and quantity and to measure the ridge height and width of the supporting bone. In all cases, a computed axial tomography scan was also made to allow the physician to make a detailed case study using specialized software for implant surgery planning (BTI Scan®, BTI). The prosthetic rehabilitations were made by three prosthodontists with over 10 years of experience.

During the days prior to the intervention, all patients received adequate prophylaxis and oral hygiene instructions. One hour before the intervention, patients received 1 g of amoxicillin and 1 g of acetaminophen as prophylactic medication. Antibiotic administration continued during 5 to 7 days after surgery. Soon before surgery, all patients rinsed for 1 minute with chlorhexidine digluconate 0.20%. Lips and perioral area were also cleaned with chlorhexidine. An infiltrative anesthesia was induced, and incisions were made to elevate a full-thickness flap. Implant sites were prepared using a low-speed drilling procedure (50 rpm) without irrigation.[26] Before installation, implants were carefully embedded in liquid Plasma Rich in Growth Factors (PRGF-Endoret®, BTI) with the aim of bioactivating the implant surface.[27]

PRGF-Endoret was prepared in 9 mL citrated tubes (BTI S.L.) from patient's blood by centrifugation at 580 *g* for 8 minutes at room temperature. The milliliter fraction located just above the sedimented red cells, but not including the buffy coat, was collected.[27] In general, healing was allowed for a minimum of 3 months, after which the surgical abutments were connected. Shortly thereafter, the suprastructure was placed.

A percentage of 59.4 of the implants were loaded between 4 and 6 months after insertion with an average of 5.4 months (standard deviation [SD] = 2.97). An 18% of the implants were loaded between 0 and 3 months while 29 implants (22.6%) were loaded >6 months after insertion. Prior to the final prosthesis placement, implants were loaded with a provisional screwed prosthesis to promote a progressive loading. The structure of the provisional prosthesis was made of titanium and composite resin. After 6 to 9 months, the final prosthesis was placed, also with a metal reinforced titanium structure. Occlusion was always checked, and the majority of implants were splinted either to short or long implants (91.4%).

After the intervention, patients were advised to take in case of pain, acetaminophen (1 g/8 h) or ibuprofen (600 mg/8 h). Patients were also instructed on how to maintain proper oral hygiene around implants. Finally, a panoramic radiograph was taken just after the intervention to verify the adequate placement of the implants.

## Postsurgical Clinical Assessments

After the surgical phase patients were scheduled for periodic evaluations at 2 to 3 days after intervention, at 1 month, at 3 months, at 6 months, at 1 year and, subsequently, once a year. At each follow-up visit, the status of the implant was assessed by evaluating the following parameters: peri-implant soft tissue health (plaque index, bleeding index, and presence of inflammation), prosthesis mobility, pain, and marginal bone resorption. Any kind of complication was also recorded. Panoramic radiographs were carried out yearly to assess the peri-implant bone levels in the follow-up period.

The following implant success criteria were adopted: the implant was stable and supported the prosthesis, there was absence of pain, peri-implant tissues infection or any other implant-related pathosis, absence of a radiolucent line around the implant, and none of the following events occurred: implant loss, fracture of the implants or of any component that makes support of the prosthesis impossible, and MBL greater than 1.5 mm in the first year of function and 0.2 mm per year thereafter. Implant loss could be due to biological (failure to achieve osseointegration or loss of acquired osseointegration) or biomechanical causes.

For MBL assessment, peri-implant bone levels were measured on the panoramic radiograph made just after the surgery (baseline) and subsequent radiographs. The MBL measurements were grouped in (1) first year postloading and (2) at least 3 years postloading.

All panoramic radiographs were performed using a positioning pin (with patient's chin resting on a standard device) and with the Frankfurt plane parallel to the ground. Measurements on the panoramic radiographs were performed by a computer software (Sidexis XG, Sirona Dental Systems, Bensheim, Germany), which conducts a calibration of the X-ray by a known length (implant length). Once the radiograph was calibrated to a 1:1 measure, eliminating the possible presence of magnification, measurements were made mesially and distally to the implants, calculating the distance between the uppermost point of the implant platform and the most coronal contact between the bone and the implant.

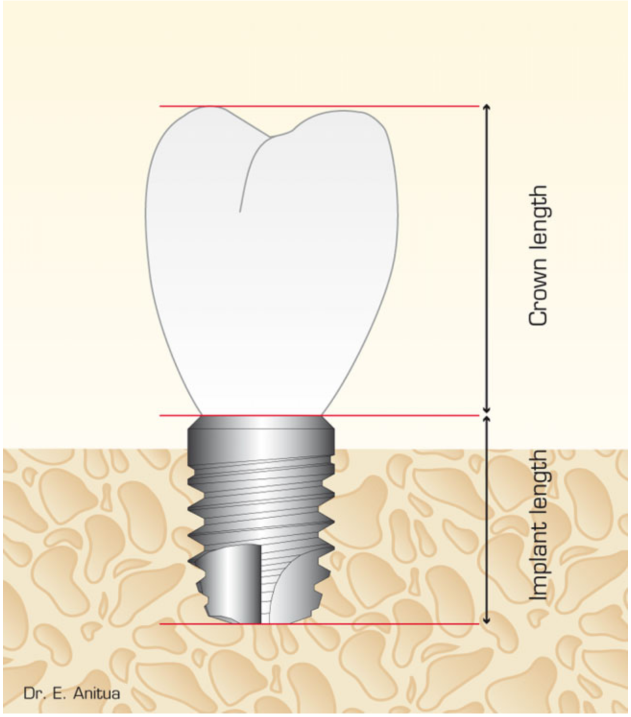


**Figure 1** Diagram representing the measurements of the implant and crown to the posterior calculation of the CI ratio: The crown was measured from the highest cuspid of molars and premolars occlusal side, to the top of the implant platform, along a perpendicular line. The implant was measured at the center, from the platform to the end of the apex.

The bone level recorded just after the surgical insertion of the implant was the basal value to compare with subsequent measurements over time.

Patient-related, surgery-related, and implant-related variables, as well as prosthetic variables, were registered from patient's clinical records.

The CI ratio was determined by two measurements: the crown was measured from the highest cuspid of molars and premolars occlusal side, to the top of the implant platform, along a perpendicular line. The implant was then measured at the center, from the platform to the end of the apex (Figure 1).

## Statistical Analysis

Data collection and analysis was performed by two independent examiners (other than restorative dentists). Descriptive statistics were performed when necessary considering both the implant and the patient as the unit of analysis. Absolute and relative frequency distributions were calculated for qualitative variables and mean values and standard deviations for quantitative variables. Implant and prostheses survival rates were calculated using a Kaplan–Meier analysis. The influence of CI ratio as well as other surgical, prosthetic, and biomechanical variables on the MBL was analyzed using a univariate and multivariate linear regression model. SPSS v15.0 for Windows statistical software package (SPSS Inc., Chicago, IL, USA) was used for statistical analysis.

# RESULTS

In this study, a total of one hundred twenty-eight short implants were placed in 63 patients. The diameter of short implants ranged between 3.00 and 6.00 mm, and lengths between 5.5 and 8.5 mm. The frequency distribution of the lengths and diameters of the short implants is shown in Table 1. Fifty of the 63 patients were females (79.4%), and the mean age at insertion time was 58.21 years (SD = 13.2, range from 18 to 86 years). Three patients were smokers (4.8%), and none of them referred alcohol habits. One of the patients was diabetic (1.6%), seven patients had previous periodontal disease (11.1%), one patient had previous radiation (1.6%), four patients had parafunction-bruxism

**TABLE 1 Diameters and Lengths of the Implants**

| | | Diameter (mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 3.00 | 3.50 | 3.75 | 4.00 | 4.50 | 5.00 | 5.50 | 6.00 | Total |
| Length (mm) | 5.5 | 0 | 0 | 0 | 0 | 0 | 8 | 1 | 0 | 9 |
| | 6.5 | 0 | 0 | 3 | 1 | 10 | 10 | 3 | 0 | 27 |
| | 7.0 | 0 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 5 |
| | 7.5 | 1 | 0 | 6 | 2 | 7 | 19 | 5 | 2 | 42 |
| | 8.0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| | 8.5 | 0 | 2 | 5 | 5 | 13 | 12 | 7 | 0 | 44 |
| Total | | 1 | 2 | 17 | 10 | 31 | 49 | 16 | 2 | 128 |

**TABLE 2 Description of the Most Important Surgical, Biomechanical, and Prosthetic Variables Registered for Each Implant**

| Implants | | No. of Implants | % |
|---|---|---|---|
| Anatomical location | Maxilla | 36 | 28.1 |
| | Mandible | 92 | 71.9 |
| Surgical phases | One | 45 | 35.2 |
| | Two | 83 | 64.8 |
| Immediate loading | No | 113 | 88.3 |
| | Yes | 15 | 11.7 |
| Bone graft | Yes | 47 | 36.7 |
| | No | 81 | 63.3 |
| Prosthesis type | Single crown | 3 | 2.3 |
| | Bridge | 117 | 91.4 |
| | Complete | 8 | 6.3 |
| Fixation type | Screwed | 105 | 82.0 |
| | Cemented | 23 | 18.0 |
| Antagonist type | None | 10 | 7.8 |
| | Natural tooth | 23 | 18.0 |
| | Unitary prosthesis | 5 | 3.9 |
| | Bridge prosthesis | 52 | 40.6 |
| | Complete prosthesis | 38 | 29.7 |
| Cantilever | Yes | 12 | 9.4 |
| | No | 116 | 90.6 |
| Inclination | Yes | 24 | 18.8 |
| | No | 104 | 81.2 |
| | | Mean | SD |
| Crown length (mm) | | 13.4 | 2.5 |
| Ratio (I/C) | | 1.8 | 0.4 |
| Crown width (mm) | | 8.7 | 2.4 |

(6.3%), and none reported previous maxillary pathology. Table 2 shows the descriptive statistics of the most important implant-related variables.

The mean follow-up time of implants since insertion was 34.6 months (SD = 23.7; range 20 to 124 months), while the mean follow-up time since loading was 28.9 months (SD = 22.9; range 14 to 114 months). Table 3 shows the life table analysis for the implants.

The anatomical location of the one hundred twenty-eight implants is shown in Figure 2. Ninety-two implants (71.9%) were placed in the posterior areas of the mandible, whereas 36 were placed in the posterior maxilla (28.1%). Twenty-nine of the implants were placed using special surgical techniques (two implants after maxillary sinus elevation, vertical bone augmentation in 25 implants or split-crest expansion for two

**TABLE 3 Life Table Analysis**

| Interval, Years | Implants Censored | Failed Implants | Lost to Follow-Up | Interval Survival | Cumulative Survival |
|---|---|---|---|---|---|
| 0–1 year | 128 | 0 | 0 | 100% | 100% |
| 1–2 years | 128 | 0 | 32 | 100% | 100% |
| 2–3 years | 96 | 0 | 73 | 100% | 100% |
| 3–4 years | 23 | 0 | 12 | 100% | 100% |
| 4–5 years | 11 | 0 | 0 | 100% | 100% |
| >5 years | 11 | 0 | | 100% | 100% |

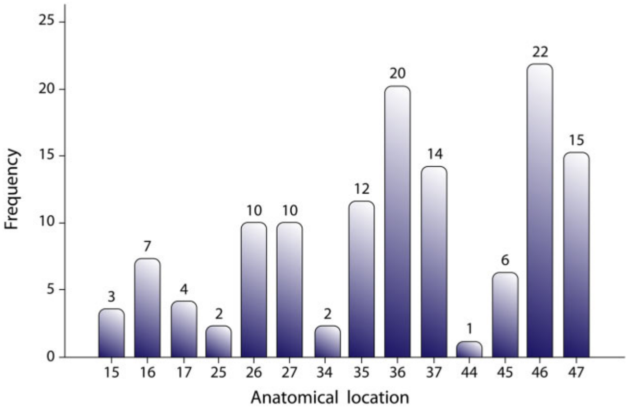


**Figure 2** Anatomical locations frequency distribution of the one hundred twenty-eight short implants included in the study.

implants) (22.7%), and for 47 implants (36.7%) particulate bone graft was used (autologous or xenogeneic biomaterial: Bio-Oss®, Geistlich Biomaterials, Baden-Baden, Germany). In 43 cases, autologous bone was used, whereas in four cases, a xenograft was employed. Only 15 implants were submitted to immediate loading protocol (11.7%). Eighty-three implants (64.8%) followed two surgical phases, and 45 implants (35.2%) followed a single surgical phase.

Regarding the type of prosthesis, 56 patients (88.9%) were rehabilitated using bridges with splinted implants, whereas four patients were rehabilitated using screwed complete overdentures (6.3%), and the three remaining patients had cemented single crowns (4.8%). The descriptive statistics of implant-based prostheses type is also described in Table 2.

The mean length of the crown was 13.41 mm (SD = 2.46; range between 7.75 and 21.65 mm). The calculated CI ratio ranged between 1.04 and 3.31, showing a mean CI ratio of 1.82 (SD = 0.42). The CI ratio of 86 implants (67.2%) was <2, whereas it was ≥2 in 42 implants (32.8%). The mean mesio-distal width of the crown was 8.65 mm (SD = 2.42; range 3.71 to 18.39 mm).

In the opposing jaw (occlusal antagonist), an implant-supported restoration was the most frequent structure (95 implants, 74.2%), followed by natural tooth (23 cases, 18.0%) or none of them (10 cases, 7.8%). A cantilever was placed in 12 implants (9.4%, four in mesial and eight in distal position), and 24 of the implants were placed inclined (18.8%, mean 14.36 degrees).

Regarding the MBL, after the first year postloading, the mean MBL was 0.35 mm (SD = 0.5, $n = 128$), after 2 years it was 0.38 mm (SD = 0.5, $n = 96$), and after at least 3 years of function, it was 0.45 mm (SD = 0.5, $n = 23$). There was no statistically significant difference between the MBL measurements at different follow-up times ($p > .05$), indicating that bone level around implants under functional loading was stable over time.

The overall survival rates of short implants and prosthesis were 100% for the implant and patient-based analysis, respectively, at the end of the follow-up time (Table 3).

Analyzing the influence of the MBL during first year postloading, after making the different simple linear regression models, the only two variables that reached statistical significance were the type of jaw (maxilla/mandible) and the use of cantilevers. After performing the multiple linear regression model including both variables as well as the possible interaction between them, the only variable that remained significant in the model was the use of cantilevers for prosthetic rehabilitations.

Conversely, none of the studied variables showed statistically significant influence on MBL during subsequent evaluations (from 2 years postloading).

No significant influence was found between the CI ratio and MBL, even considering separately CI < 2 and CI ≥ 2. The use of a cantilever was found to have a negative influence on MBL during the first year postloading ($p < .05$), showing a mean MBL value of 0.74 mm (SD = 0.85) in the 12 implants where cantilevers were used versus 0.31 mm (SD = 0.46) in the 116 ones that were not rehabilitated using cantilevers (Figure 3). However, this difference was not observed later than 3 years of loading, when the MBL mean values

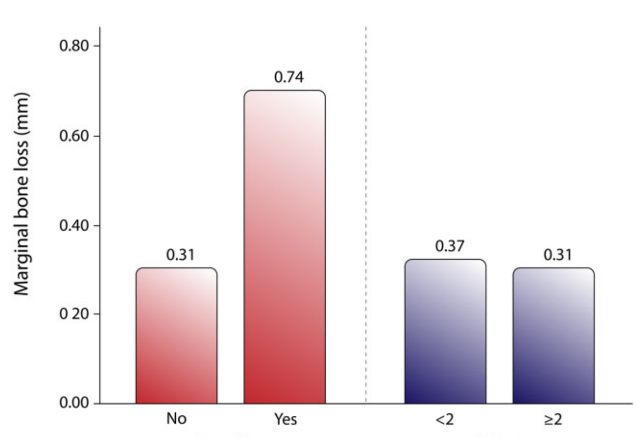


**Figure 3** Mean first year postloading marginal bone loss depending on the use of cantilevers and the CI ratio.

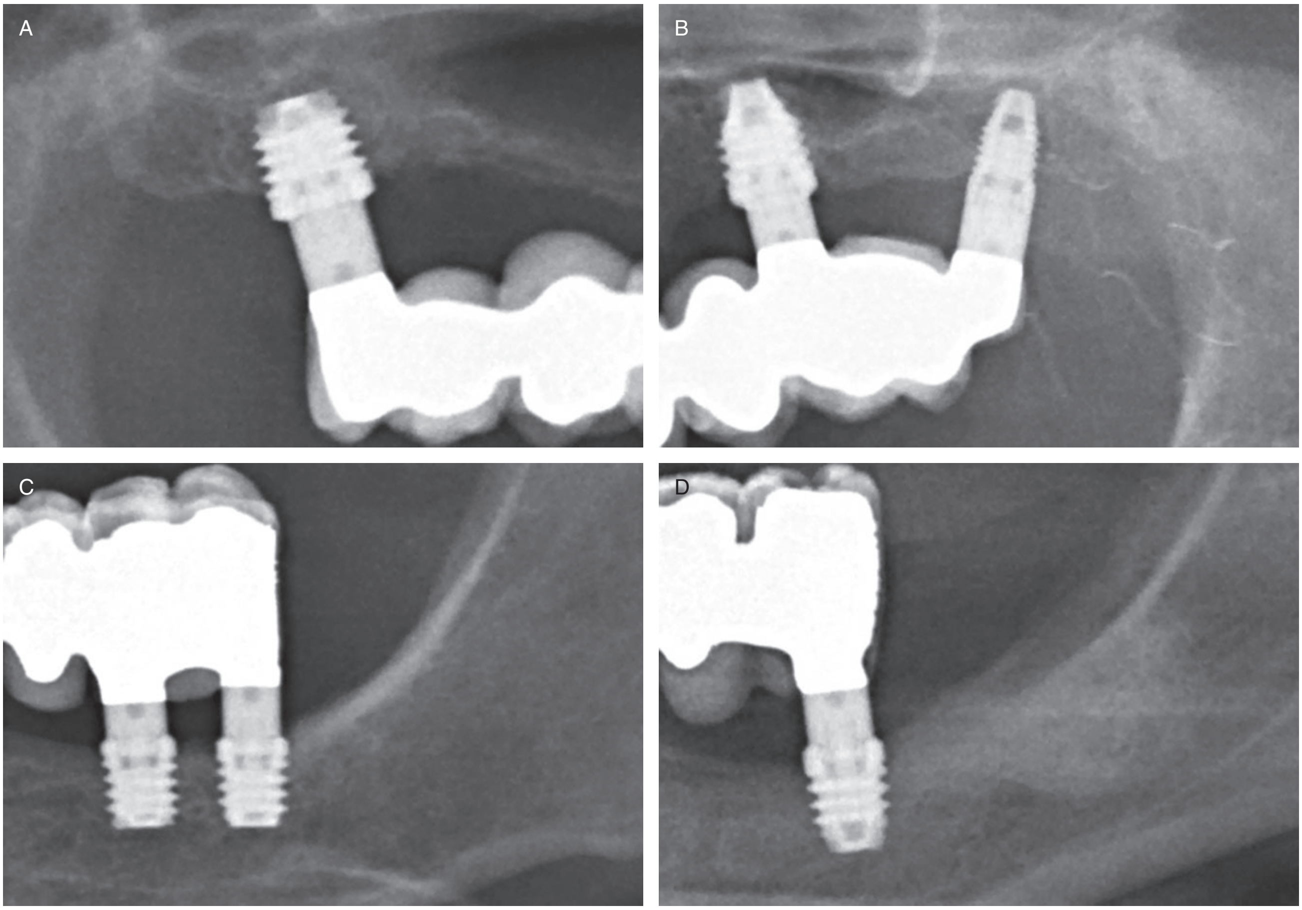


**Figure 4** Radiographic images of four cases (A–D) included in the study.

were 0.50 mm (SD = 0.57) using cantilevers and 0.44 mm (SD = 0.46) with no cantilevers.

None of the other registered variables, including patient-related, biomechanical, or prosthetic variables, showed any influence on the MBL either during the first year postloading or later. Figure 4 shows the radiographic images of four cases included in the study.

## DISCUSSION

The prosthetic rehabilitations in which short implants are involved often lead to imbalances between the lengths of the crowns and the implants. It has been suggested that disproportionate prosthetic restorations could induce poor biomechanical behavior with a potential impact on MBL and reduced implant survival rate.[17] In this study, no associations between CI ratio of implant-supported prostheses in short implants in posterior regions and MBL were found. This lack of association was observed at any observation time.

It has been reported that the effect of implant diameter on stress distribution in bone is more significant than the effect of the implant's length or its geometry. In addition, the maximum stress is located around the neck of the implant, and the majority of the stress is distributed in the bone adjacent to initial implant threads.[16] In this study, we found that the use of cantilevers, which represents a challenging biomechanical situation, is related with an increased MBL during the first year postloading, a result that is not in agreement with those reported by Blanes and colleagues[17] However, in the study of Blanes and colleagues, cantilevers were not taken into account when evaluating the MBL.

Several recent studies have evaluated the potential influence of CI ratio on different variables including MBL, implant survival, or the risk of developing complications. The heterogeneity of the different studies makes it difficult to reach a conclusion, but none of them reported any association between the CI ratio and MBL. In one study,[23] an increased CI ratio was associated with a significant increase in prosthetic complications on single-tooth locking-taper implants. This result was not observed in other studies like the one of

Schneider and colleagues on unitary implants in the posterior jaws.[24]

Previous studies in which short implants were used have evaluated the influence of CI ratio on MBL.[18,19,22] In general, most of these studies concluded that no relation may be established between an unfavorable CI ratio and MBL, independently of the type of prosthetic rehabilitation.[19,22] These results are similar to the ones reported in the present study. In particular, Tawil and colleagues evaluated the influence of some prosthetic parameters on the implant survival and on the occurrence of biologic or biomechanical complication rates of short implants (<10 mm). Two hundred sixty-two short machined surface implants were evaluated. No relevant effect on peri-implant bone loss was observed as related to CI ratio or occlusal antagonist. In that study, neither cantilever length nor bruxism had a significant effect on MBL.

In another study, Birdi and colleagues[22] evaluated the influence of CI ratios of 309 single-tooth restorations supported by short implants (length of 5.7 or 6.0 mm) on first bone-to-implant contact levels. No significant relationship was found between the two variables.

Rokni and colleagues[18] conducted a study in which implant length ("short" vs "long"), surface area, and CI ratio and their relationship to MBL was assessed in one hundred ninety-nine sintered porous-surface implants placed in 74 partially edentulous patients. Results showed that long implants and/or splitting could result in greater crestal bone loss as compared with short and standalone implants.

One important issue to bear in mind when using short implants is the aesthetic results of the treatment, even more when a high CI ratio is present and normal anatomic relations can be greatly altered. Regarding this, short implants are usually used to restore posterior regions of maxilla or mandible, in most cases as posterior pillars of bridges located at the molar level, so the large crowns do not have a high aesthetic impact on these areas, where aesthetics is not always demanded.

In our study, all restorations were performed in posterior regions of molars and premolars (Figure 2). Another group of our implants presented complete hybrid dentures, where the aesthetic impact is also not important because pink gum is used to distribute the prosthetic space that would correspond only to the teeth.

When interpreting the results of the present study, it is important to remind that several limitations should be considered. One important issue that should be kept in mind is that results come from a retrospective study. This type of study has less validity than randomized prospective clinical trials, due to issues of selection bias and confounding factors. Additionally, retrospective studies rely on the completeness of data entered in the patient's chart, which may implicate the risk of missing data because of misplaced, misfiled, or missing information in the chart. However, we do not have reasons to believe that any of these records were selectively missing due to the presence or absence of any key variable.

In summary, our results suggest that there is no association between the CI ratio of short implants and MBL in the posterior regions. The only variable that negatively influenced MBL was the use of cantilever for the prosthetic rehabilitations.

When placing short implants in the posterior regions, it is necessary to carry out an adequate planning of the case according to the available bone ridge height and choosing properly the implant length and diameter. Successful clinical results can be expected using short implants independent of the CI ratios. Instead, the use of cantilevers in these situations should be managed carefully. These suprastructures could compromise the biomechanical stability of the implants and increase the associated MBL as it has been observed in this study.

## CONCLUSIONS

In this study, no significant relations between CI ratio of BTI short implants humidified with PRGF-Endoret and placed in posterior areas and MBL were found. The only prosthetic-biomechanical variable that showed a significant negative influence on MBL was the use of cantilever for the prosthetic rehabilitations. Such findings should be confirmed by further prospective comparative long-term studies.

## CONFLICT OF INTEREST AND SOURCES OF FUNDING STATEMENT

This study was financially supported by Biotechnology Institute (BTI), the manufacturer of the implant system used in this study. Orive G and Begoña L are researchers at BTI. Anitua E is the scientific director of BTI.

## REFERENCES

1. Schulte J, Flores AM, Weed M. Crown-to-implant ratios of single tooth implant-supported restorations. J Prosthet Dent 2007; 98:1–5.

2. Misch C. Contemporary implant dentistry. 3rd ed. Amsterdam, The Netherlands: Elsevier, 2008.
3. Tonetti MS, Hammerle CH. Advances in bone augmentation to enable dental implant placement: consensus report of the Sixth European Workshop on Periodontology. J Clin Periodontol 2008; 35:168–172.
4. Esposito M, Grusovin MG, Felice P, Karatzopoulos G, Worthington HV, Coulthard P. Interventions for replacing missing teeth: horizontal and vertical bone augmentation techniques for dental implant treatment. Cochrane Database Syst Rev 2009 Oct 7;(4):CD003607. doi: 10.1002/14651858.CD003607
5. ten Bruggenkate CM, Asikainen P, Foitzik C, Krekeler G, Sutter F. Short (6-mm) nonsubmerged dental implants: results of a multicenter clinical trial of 1 to 7 years. Int J Oral Maxillofac Implants 1998; 13:791–798.
6. Nedir R, Bischof M, Briaux JM, Beyer S, Szmukler-Moncler S, Bernard JP. A 7-year life table analysis from a prospective study on ITI implants with special emphasis on the use of short implants. Results from a private practice. Clin Oral Implants Res 2004; 15:150–157.
7. Anitua E, Orive G, Aguirre JJ, Andia I. Five-year clinical evaluation of short dental implants placed in posterior areas: a retrospective study. J Periodontol 2008; 79:42–48.
8. Van Assche N, Michels S, Quirynen M, Naert I. Extra short dental implants supporting an overdenture in the edentulous maxilla: a proof of concept. Clin Oral Implants Res 2012; 23:567–576.
9. Chan MF, Narhi TO, de Baat C, Kalk W. Treatment of the atrophic edentulous maxilla with implant-supported overdentures: a review of the literature. Int J Prosthodont 1998; 11:7–15.
10. Sennerby L, Roos J. Surgical determinants of clinical success of osseointegrated oral implants: a review of the literature. Int J Prosthodont 1998; 11:408–420.
11. Kotsovilis S, Fourmousis I, Karoussis IK, Bamia C. A systematic review and meta-analysis on the effect of implant length on the survival of rough-surface dental implants. J Periodontol 2009; 80:1700–1718.
12. Romeo E, Bivio A, Mosca D, Scanferla M, Ghisolfi M, Storelli S. The use of short dental implants in clinical practice: literature review. Minerva Stomatol 2010; 59:23–31.
13. Telleman G, Raghoebar GM, Vissink A, den Hartog L, Huddleston Slater JJ, Meijer HJ. A systematic review of the prognosis of short (<10 mm) dental implants placed in the partially edentulous patient. J Clin Periodontol 2011; 38:667–676.
14. Esposito M, Grusovin MG, Rees J, et al. Interventions for replacing missing teeth: augmentation procedures of the maxillary sinus. Cochrane Database Syst Rev 2010 Mar 17;(3):CD008397. doi: 10.1002/14651858.CD008397
15. Pierrisnard L, Renouard F, Renault P, Barquins M. Influence of implant length and bicortical anchorage on implant stress distribution. Clin Implant Dent Relat Res 2003; 5:254–262.
16. Anitua E, Tapia R, Luzuriaga F, Orive G. Influence of implant length, diameter, and geometry on stress distribution: a finite element analysis. Int J Periodontics Restorative Dent 2010; 30:89–95.
17. 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; 18:707–714.
18. Rokni S, Todescan R, Watson P, Pharoah M, Adegbembo AO, Deporter D. An assessment of crown-to-root ratios with short sintered porous-surfaced implants supporting prostheses in partially edentulous patients. Int J Oral Maxillofac Implants 2005; 20:69–76.
19. Tawil G, Aboujaoude N, Younan R. Influence of prosthetic parameters on the survival and complication rates of short implants. Int J Oral Maxillofac Implants 2006; 21:275–282.
20. Blanes RJ, Bernard JP, Blanes ZM, Belser UC. A 10-year prospective study of ITI dental implants placed in the posterior region. I: clinical and radiographic results. Clin Oral Implants Res 2007; 18:699–706.
21. Gomez-Polo M, Bartens F, Sala L, Tamini F, Celemin A, Del Rio J. The correlation between crown-implant ratios and marginal bone resorption: a preliminary clinical study. Int J Prosthodont 2010; 23:33–37.
22. Birdi H, Schulte J, Kovacs A, Weed M, Chuang SK. Crown-to-implant ratios of short-length implants. J Oral Implantol 2010; 36:425–433.
23. Urdaneta RA, Rodriguez S, McNeil DC, Weed M, Chuang SK. The effect of increased crown-to-implant ratio on single-tooth locking-taper implants. Int J Oral Maxillofac Implants 2010; 25:729–743.
24. Schneider D, Witt L, Hammerle CH. Influence of the crown-to-implant length ratio on the clinical performance of implants supporting single crown restorations: a cross-sectional retrospective 5-year investigation. Clin Oral Implants Res 2012; 23:169–174.
25. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet 2007; 370:1453–1457.
26. Anitua E, Carda C, Andia I. A novel drilling procedure and subsequent bone autograft preparation: a technical note. Int J Oral Maxillofac Implants 2007; 22:138–145.
27. Anitua E, Sanchez M, Orive G, Andia I. The potential impact of the preparation rich in growth factors (PRGF) in different medical fields. Biomaterials 2007; 28:4551–4560.