The Correlation Between Crown-Implant Ratios and Marginal Bone Resorption: A Preliminary Clinical Study

Miguel Gómez-Polo, DDS, DrOdont[a]/Fabricio Bartens, DDS[a]/Leticia Sala, DDS[a]/
Faleh Tamini, DDS, Dr Odont[b]/Alicia Celemín, DDS, Dr Odont[c]/Jaime del Rio, MD, Dr Med, DDS[c]

Purpose: The crown-implant ratio is defined as the physical relationship between each individual restoration's parts located both inside and outside the bone. This relationship represents the physical concept of a type I lever, which may be of biomechanical importance in implant treatment outcomes. **Materials and Methods:** Specific patient data related to fixed implant prostheses were retrieved and studied in an effort to clinically and radiographically correlate crown-implant ratios. **Results:** Recorded marginal bone resorption around implants (2.11 ± 1.30 mm) at the end of a defined observation period did not correlate with the measured crown-implant ratio, which yielded values between 0.43 and 1.5 mm ($P > .05$). **Conclusion:** The mechanical determinants of implant success or failure are still not defined. It has been postulated that an increase in both crown-tooth, and comparably crown-implant, ratios would lead to a resultant increase in the magnitude of nonaxial forces transmitted to the tooth or implant. This could then lead to an increased vulnerability of either tooth or implant abutments to supporting bone loss. However, additional factors appear to impact long-term bone maintenance behavior around either type of abutment. Within the limited scope of this study, crown-implant ratios were not associated with recorded peri-implant bone loss. *Int J Prosthodont 2010;23:33–37.*

The sequelae of tooth loss are often associated with compromised masticatory function and unpredictable alveolar ridge resorption, which may in turn complicate prosthodontic treatment outcomes. Bone resorption presents two serious challenges: absence of a sufficient amount of bone for implant placement and a resultant alteration in the vertical dimension of occlusion with esthetic implications. Both considerations may require the use of shorter implants or longer crowns, leading to a crown-implant ratio much greater than the crown-root ratios associated with naturally healthy teeth.

In tooth-supported fixed prostheses, traditionally accepted criteria support the notion of a predictably favorable prognosis for adequate crown-root ratios. However, when fixed prostheses are restored with implant abutments, such ratio considerations cannot be applied arbitrarily.

From a simple theoretic point of view, the crown-root relationship is the relationship between the length of the anatomical crown of the tooth (from the cementoenamel junction [CEJ] to the most coronal point) and the length of the anatomical root (from the CEJ to the radicular apex). However, from a clinical point of view, the crown-root relationship is defined as the physical relationship between the portion of the tooth situated within the alveolar bone compared to the portion outside of the alveolar bone, as seen radiographically.[1] The crown-root proportion represents the biomechanical concept in type I leverage, whose fulcrum, or center of rotation, is situated at the center of the root that is involved in the alveolar process. This relationship can increase with time, primarily as a result of the loss of supporting alveolar bone. Subsequently, the

[a]Lecturer, Department of Bucofacial Prosthesis, Faculty of Dentistry, University Complutense, Madrid, Spain.
[b]Professor, Department of Bucofacial Prosthesis, Faculty of Odontology, McGill University, Montreal, Canada.
[c]Professor, Department of Bucofacial Prosthesis, Faculty of Odontology, University Complutense, Madrid, Spain.

Correspondence to: Dr Alicia Celemín. Department of Bucofacial Prosthesis, Pza. Ramón y Cajal s/n, 28040 Madrid, Spain. Fax: 0034-91-3942029. Email: acelemin@odon.ucm.es

Table 1 Crown-Implant Ratios in the Context of Implant Length

Length (mm)	Distribution	Mean crown-implant ratio
6.0–8.0	12%	0.99
8.1–10.0	42%	0.87
10.1–12.0	25%	0.81
12.1–15.0	21%	0.70

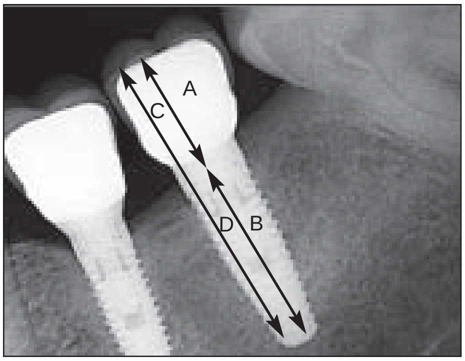


Fig 1 Parallel technique radiography (A and B: radiographic crown-implant relationship, C and D: integrated crown-implant relationship).

crown portion will increase (force point) and the radicular portion will decrease (resistance point). The center of rotation will then move towards the apex, causing the tooth to become more vulnerable to harmful lateral forces.[2,3] This premise underscores the popular conviction regarding the role of biomechanical stresses in peri-implant bone loss. On the other hand, an equally popular theoretic etiology for such bone loss borrows heavily from the etiology of periodontal disease. However, the resultant quantitative changes in bone support may also be initiated by a compromised interfacial osteogenesis during the postsurgical healing phase. As a result, diverse occlusal forces and microbiologically related events can then combine to compromise an implant's support.

Short implants with altered microscopic and macroscopic features have been introduced to expand the scope for implant placement whererever reductions in morphologic bone height are encountered. This strategy leads to the creation of what might be considered unfavorable crown-implant ratios.[4] Consequently, a surgical alternative to placing shorter implants is to restore the resorbed bone height via a variety of interventions. To date, height regeneration treatments appear to offer variable outcome predictability.[5]

Radiographic analyses are employed to measure crown-root ratios. Several studies confirm that periapical radiographs are very accurate in the detection of bone defects, irrespective of their location.[6,7] They therefore remain the most acceptable method for the measurement of crown-root ratios.

The same methodology can be applied to implants, thereby defining the resultant ratio as the physical relationship between the portion of the restoration situated inside the bone (in an ideal case this would be the entire length of the implant) compared with the portion outside. However, once bone resorption occurs, this terminology is no longer valid since the length of the implant does not correspond to the part situated inside the bone.

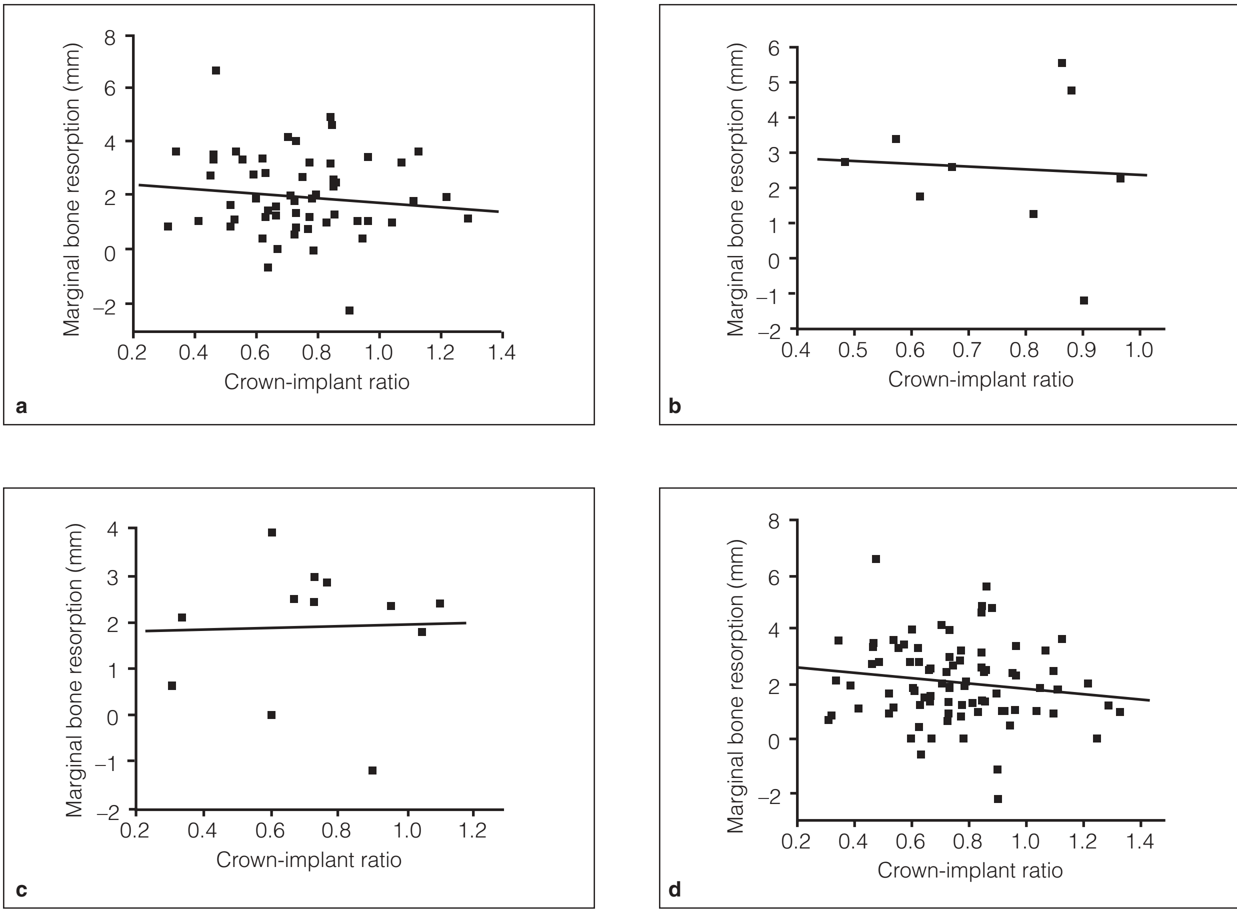
The objective of this preliminary study was to assess retrospectively whether diverse crown-implant ratios might affect the time-dependent behavior of peri-implant bone levels.

Materials and Methods

A group of 90 healthy patients whose partial edentulism was managed with implant prosthesis replacement were selected from the University Clinic of the Department for Implant Prostheses, University Complutense, Madrid, Spain. The selection process was developed using patients treated from 1998 to 2003. Inclusion criteria comprised the following: patients treated with implants 4- ± 0.2-mm wide and 8- to 15-mm long, placed in native bone, and restored with single and multiunit fixed prostheses. The exclusion criteria included patients who had difficulty keeping their appointments, those with severe peri-implant resorption (more than 1.0 mm) prior to initiating prosthetic replacement, patients with poor oral hygiene, severe or brittle systemic diseases, and smokers.

Sixty-nine patients with 85 implants satisfied the inclusion and exclusion criteria and were included in the study. Ten implants were restored with single crowns, 63 with two-unit fixed partial dentures (FPDs), and 12 with three- to four-unit FPDs. The implants were located in the following regions: maxillary incisor (5%), maxillary canine (6%), maxillary premolar (20%), maxillary molar (17%), mandibular premolar (20%), and mandibular molar (32%). The lengths of the implants were 6.0 to 8.0 mm (12%), 8.1 to 10.0 mm (42%), 10.1 to 12.0 mm (25%), and 12.1 to 15.0 mm (21%) (Table 1). The average crown-implant ratio at the begining of the study was 0.82 ± 0.21, and the values ranged between 0.43 and 1.5.

Radiologic and clinical measurements of the crown and implant length, as well as the peri-implant bone resorption, were performed at the time of permanent



Figs 2a to 2d Correlation between marginal bone resorption and crown-implant ratio in **(a)** splinted-crown implant restorations, **(b)** single-crown implant restorations, **(c)** three- to four-unit FPDs, and **(d)** all implants included in the study.

fixation (cementation) of the prosthesis and after a 5-year follow-up period.

Every implant length was registered prior to surgical intervention, with each one placed level with the surrounding alveolar bone. Following prosthetic tooth replacement, an axially oriented periodontal probe was placed to measure the occlusal height of the crown by recording the distance from the most coronal point to the implant-abutment junction. Three separate measurements were taken and the mean value recorded.

Periapical radiographs were taken of all implants collected for this study, employing the technique of parallelism (Fig 1) with a Hawe Super-Bite (Hawe Neos Dental), designed for repeatable placement of films parallel to the long axis of the implant and perpendicular to the central ray, as described by Chaytor et al.[8] The length of both crowns and implants was measured from the radiographs using a digital calliper. The crown measurement was reflected as the distance of the axial axis between its most apical and crowned points by obtaining three measurements and calculating the mean The length of the implant was obtained as the distance between the most apical points to the implant shoulder. Bone resorption was measured from the implant shoulder to the bone-implant interface. Distal and mesial measurements were taken and the mean value recorded for each implant.

Results

At the study's conclusion, the implant-supported prostheses had been worn for 5.7 years ± 8 months. All implants were immobile and none were associated with reported spontaneous or percussion-induced pain. The average marginal bone resorption was 2.12 ± 1.30 mm, with values ranging between 0.0 and 6.61 mm. The correlation analyses revealed that within the limits of this study, there was no correlation between the crown-implant ratio and marginal bone resorption, regardless of the type of fixed prosthetic replacement used ($P > .05$) (Figs 2a to 2d).

Discussion

Numerous studies have described both the measuring techniques and estimated crown-root ratios for natural teeth. Data are available for individual teeth (eg, 1.78 for the mandibular central incisor and 2.23 for the mandibular canine) and ratios are cited as being greater in men than women and greater in the mandible as opposed to the maxilla.[9] Moreover, the employed terminology or descriptors are not specific and range from adequate to inadequate or satisfactory to unsatisfactory. Adequate relationships between a supporting tooth abutment for a fixed prosthesis and its crown are defined as having a 1:2 ratio, although it has been suggested that this is very hard to find.[10] A 1:1.5 relationship may be considered desirable, while a lower ratio may be acceptable for periodontally sound teeth with favorable occlusal conditions.

Penny and Kraal[11] concluded that a 1:2 abutment-crown relationship is too conservative and that it can limit treatment. Shillinburg[12] suggested that a 1:1.5 relationship is more accurate and a 1:1 relationship is the absolute minimum accepted under favorable conditions. He also reflected on the existing difference as depending on the antagonistic arch, and suggested that an abutment for a removable tissue-supported prosthesis could quite possibly incorporate supporting teeth with a ratio of less than 1:1.

These articulated concepts may serve as a starting point for certain treatment decisions involving implant abutments. However, it must be recalled that while implants also function as analogs for tooth roots, their biomechanical behavior may be quite different. Comparing a presumed optimal crown-root ratio supported by a specifically evolved type of attachment (the periodontal ligament) with another (a man-made one) that derives its support from an induced healing response yielding an ankylotic-like response appears to be a moot point.

Nonetheless, an increased crown-implant ratio leads to an increase in the lever arm, with a possible increase in the transmission of overload forces of the nonaxial kind. Mechanical forces on bone can indeed induce cellular changes and result in bone remodeling. But overloading the bone can also increase the risk of local microdamage. If this zone is not remodeled fast enough to keep up with this damage, it is postulated that microfractures could appear, with an increase in bone loss and a risk of potential implant failure, hence the suggestion that unfavorable crown-implant ratios should be considered a biomechanical risk factor.[13]

Monitoring peri-implant crestal bone levels following occlusal loading associated with prosthesis placement has long been a topic for discussion. This has encouraged the development of criteria that may impact treatment outcomes.[14,15] It appears that small changes in the height of the bone crest do not influence the success of implants in the long term.

Albrektsson et al[15] first described vertical peri-implant bone loss as one of the criteria for analyzing the success of implants. A maximum of 1.5 mm during the first year of loading[14] and 0.2 mm thereafter was proposed. Ever since, numerous hypotheses have tried to explain the reason for this initial bone loss. The radiographic observation that the remodeled crest is found at the level of the first thread after placing the implant under strain suggests that actual implant placement produces a concentration of tensions at the most coronal part of the implant. Other authors have suggested that remodeling is produced as a result of the inflammatory infiltrate that appears at the interface between the implant and abutment, combined with the attempt of the peri-implant soft tissues to establish a biologic seal that protects the interface between the bone and implant in the oral cavity.

The data collected during this preliminary study suggest that the radiographically analyzed sites that did not match the proposed success criteria did not correspond with the localizations in which the crown-implant relationship was less favorable. This observation could mean that although the distribution of forces is better when the length of the implant is greater with respect to the crown, other factors may influence the observed changes. It is tempting to suggest that the quality of occlusion may play an important and fundamental role in the correct distribution of the forces.

It is clear that the limit between the mechanical conditions that could lead to the failure of an implant, as opposed to those it is capable of adapting to, are still not defined.[16] Numerous publications seem to suggest that as peri-implant bone resorption occurs and indeed progresses, a resultant increase in the forces on the cortical bone can bring about the failure of the implant. However, this need not necessarily be the routine case when dealing with an osseointegrated attachment mechanism. This preliminary assessment, coupled with other observations that underscore the fundamental difference in the nature of the tooth and implant attachment mechanism, demands far more rigorous analysis of what contributes to implant failure.

Conclusion

A preliminary question regarding the possible relationship between crown-implant ratios and progressive peri-implant bone loss was posed. Within the scope of this study, it appears that crown-implant ratios between 0.43 and 1.5 were not associated with peri-implant bone loss.

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Literature Abstract

Prosthetic complications in mandibular metal-resin implant-fixed complete dental prostheses: A 5- to 9-year analysis

The aim of this retrospective clinical study was to investigate the complications encountered in patients restored with a maxillary conventional complete denture and a mandibular metal-resin implant-fixed complete denture prosthesis, and the relationship these complications had with recall period, age, and sex. The records of 46 patients (mean age: 59 years) presenting with 233 implants were reviewed. Forty-three patients had five mandibular implants, while 3 had six mandibular implants. All implants were placed in the anterior mandible between the mental foramina. Implant diameters ranged from 3.25 mm to 4.5 mm, and implant lengths varied from 8 mm to 18 mm. Mandibular frameworks were constructed of various seminoble and noble alloys. Acrylic resin denture teeth were then veneered to the framework with heat-processed acrylic resin. All patients received a new maxillary conventional complete denture on the day the mandibular prostheses were inserted. Cantilever lengths were designed to accommodate a minimum of first molar occlusion. Retaining screws were tightened to 20 Ncm. Patients were first recalled after 24 hours, then at 3, 6, 9, and 12 months and annually thereafter. Fifteen types of complications were studied over three recall periods (≤ 2 years, 2 to 5 years, and > 5 years). The percentage of patients exhibiting each complication and corresponding 95% confidence intervals were tabulated. Logistic regression analysis was used to determine the effect of time period, age, and sex on the following complication groups: tooth fracture, maxillary denture relines, screw complications, and tooth replacement. The average follow-up was 7.9 years (range: 5 to 9.7 years). There was one implant failure at the 6-year recall. There was 100% continuous prosthesis success. Nine (15.2%) patients experienced fractured mandibular teeth at the ≤ 2-year recall. In the 2- to 5-year recall period, 15 (32.6%) patients required hard relines for the maxillary complete denture. At the > 5-year recall, the most common complication was mandibular tooth replacement, with 22 (47.8%) patients experiencing this complication. The probability of tooth fracture did not increase significantly for recall period, age, or sex. The odds of a complete denture reline were 3.71 and 8.49 for the 2- to 5-year and > 5-year recall periods, respectively. Patients were 1.06 times more likely to require a reline for every year of age increase. Patients had an odds of 52.5 and 7.7 for posterior teeth replacement and screw complication, respectively, at the > 5-year recall compared to ≤ 2-year recall period. The authors rightly acknowledge that the lack of standardization of the dental materials used and other variables are important weaknesses in this study. However, this investigation provides clinicians information on the most commonly expected complications, and their chances of occurring over a particular time period, such that patients can be adequately informed.

Purcell BA, McGlumphy EA, Holloway JA, Beck FM. *Int J Oral Maxillofac Implants* 2008;23:847–857. **References:** 54. **Reprints:** Dr Bradley A. Purcell, 55 Caren Avenue, Suite 270, Worthington, OH 43085. Email: bpurcell@worthingtondental.com—*Elvin W.J. Leong, Singapore*