Review

Influence of Crown/Implant Ratio on Marginal Bone Loss: A Systematic Review

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Background: With the increased use of short dental implants (<10 mm), a high crown/implant (C/I) ratio has become a common finding. However, the effect of the C/I ratio on the marginal bone loss (MBL) has not yet been examined extensively. Hence, the aim of the present systematic review is to explore the influence of the C/I ratio on the success rate and MBL of dental implants.

Methods: Three electronic databases (PubMed, Ovid MEDLINE, and Cochrane Central) and a manual search for human trials with a minimal follow-up of 6 months are used for the present study. A statistical analysis of the influence of the C/I ratio was performed on the peri-implant MBL while considering follow-up period, type of implants, implant connection, and technical and biologic complications.

Results: One hundred ninety-six potential articles were identified on the selected databases. Only 57 articles were selected for full-text evaluation. According to the inclusion criteria, a total of 13 articles were included in this systematic review. A significant negative association between the C/I ratio and the MBL was found ($P = 0.012$). However, no statistically significant difference was found ($P > 0.15$) for potential effects regarding the observation period, the type of implant connection, or between both methods of evaluating the C/I ratio.

Conclusions: Within the limitations of the present study, the C/I ratio of implant-supported restorations has an effect on peri-implant marginal bone level. Within the range of 0.6/1 to 2.36/1, the higher the C/I ratio, the less the peri-implant MBL. *J Periodontol 2014;85:1214-1221.*

KEY WORDS

Dental implant-abutment design; design implantation; dental implants; dental prosthesis, implant-supported.

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Tooth loss is often associated with compromised esthetics, function, and subsequent alveolar bone resorption that ultimately may compromise the final rehabilitation procedure.[1,2] Bone resorption presents several challenges, including the prevention of appropriate implant position or even the absence of sufficient bone for implant placement.[3] Various procedures are available currently to overcome these limitations. The use of short dental implants (<10 mm) represents a reliable alternative option.[4] The benefits of using a shorter implant include no need for advanced bone grafting and, consequently, lower risk of complications and expenses, which greatly increases a patient's acceptance.[5] As proof of their effectiveness, short implants have shown survival rates similar to standard (≥10 mm) implants,[6,7] regardless of their length and width.[8] However, a recent meta-analysis demonstrated that, even with a similar long-term survival rate, shorter implants failed 2.5 years earlier than the standard ones.[7]

Nevertheless, the use of short dental implants is not exempt from clinically challenging situations. An increased crown/implant (C/I) ratio is usually found when <10-mm implants are placed compared to the normal crown/root (C/R) ratio associated with healthy dentition. Theoretically, the C/R ratio is the relationship between the length

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of the crown and the length of the root, taking the cemento-enamel junction as the fixed point separating both. Conversely, the clinical C/R ratio is the physical relationship between the portion of the tooth located above the alveolar bone compared to the portion embedded into the alveolar bone, as seen radiographically.[9]

Accordingly, the C/I ratio can be defined anatomically, which takes the implant shoulder as the boundary between the crown and the implant, and clinically, which takes the bone level as the boundary separating crown and implant (Fig. 1). Over the years, several publications reported the C/I ratios of their implant-supported prosthesis.[10-12] However, although some authors reported the anatomic C/I ratio,[13,14] others showed the clinical C/I ratio.[15,16] Although the clinical C/I ratio seems to describe a more realistic biomechanical scenario,[17] the anatomic C/I ratio is most commonly found in the literature.

The importance of the C/I ratio relies on the theory that unfavorable occlusal forces, including non-axial and overload, represent one possible explanation for biologic and technical complications.[17,18] Higher C/I ratios display a form of non-axial force in which the crown acts as a lever arm that creates a bending moment, transferring stress to the peri-implant crestal bone.[19] Technical complications[20] and/or crestal bone loss[21] may result from this occlusal stress. As a result, C/I ratios from 0.5 to 1 were proposed to avoid crestal bone loss.[22]

Literature exploring the influence of the C/I ratio on the success rate and implant marginal bone loss (MBL) is heterogeneous, with a limited number of studies reporting great variability regarding their findings. Although some studies failed to show a correlation between the C/I ratio and MBL,[10,13,17] others reported higher amounts of MBL with increased C/I ratios.[12] Surprisingly, some studies even reported an inverse relationship between the C/I ratio and MBL, finding better results with higher ratios.[15,16] In addition, there is limited literature reporting the incidence of biologic and/or technical complications associated with this topic.

Hence, the aim of the present review is to explore the influence of the C/I ratio on the success and MBL of dental implants.

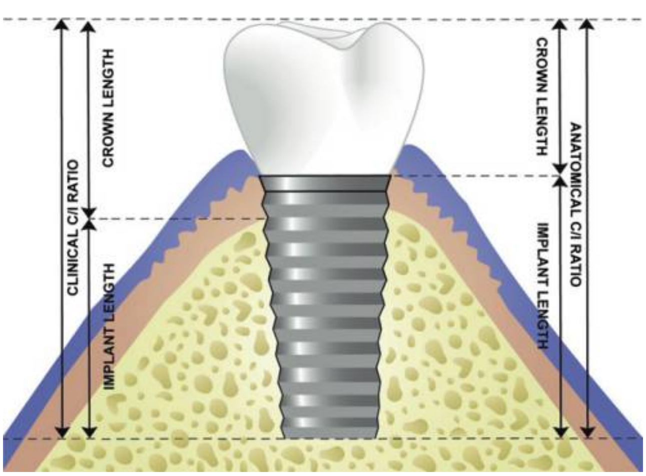

Figure 1.
Representation of the anatomic and clinical C/I ratio.

MATERIALS AND METHODS

Three electronic databases, including PubMed, Ovid (MEDLINE), and Cochrane Central, were used to find relevant studies. Articles restricted to the English language were considered without any time limitation. The search was conducted from February 2013 through March 2013 by two examiners (FS and CG-P). The search terms used included the following: ("Jaw, edentulous"[mh] OR "Alveolar process"[mh] OR "Dental implants, single-tooth"[mh] OR "Dental implantation"[mh] OR "Dental implants"[mh] OR "Dental prosthesis design"[mh] OR "Crown-to-implant ratio"[tiab]) AND ("short"[tiab] OR "restoration"[tiab] OR "bone loss"[tiab]), where mh and tiab represented MeSH term and title or abstract, respectively.

Furthermore, references in the included papers were identified and reviewed by their titles and abstracts. A supplementary manual search in dental journals up to February 2013 was performed, including the following: 1) *Journal of Clinical Periodontology*; 2) *Journal of Oral and Maxillofacial Surgery*; 3) *Journal of Periodontology*; 4) *The International Journal of Periodontics & Restorative Dentistry*; 5) *International Journal of Prosthodontics*; 6) *European Journal of Oral Implantology*; 7) *Journal of Oral and Maxillofacial Implants*; 8) *Journal of Oral Implantology*; 9) *Implant Dentistry*; 10) *Clinical Implant Dentistry and Related Research*; 11) *Clinical Oral Implants Research*; 12) *Journal of Prosthetic Dentistry*; 13) *International Journal of Oral and Maxillofacial Surgery*; and 14) *Journal of Dental Research*.

For this systematic review, only articles fulfilling the following selection criteria were considered: human clinical trials, either prospective or retrospective, that reported the mean C/I ratio and MBL with at least 6-month follow-up. In addition, these papers had to include how the C/I ratio was measured. Conversely, animal studies, finite element analysis, case reports/series, review articles, or clinical trials with less than five participants and insufficient follow-up time were excluded.

The relationship between the C/I ratio and the MBL was evaluated while considering the observation period, the type of implant connection, and between both types of measurement for the C/I ratio for any additional effects. No additional interpretation for timing of restoration was made because of the fact that, after analyzing current evidence, different protocols for time of restoration delivery have shown no effect on MBL.[23]

Publication bias was assessed qualitatively by judging the selection and comparability of the study groups and the ascertainment of the exposure or outcome of interest for the included studies.[24] Qualitative analysis pertained to the criteria for determining the quality of the research. For the statistical analysis, it was assumed that heterogeneity was present in the studies' datasets.

The potential relationship between the C/I ratio and MBL was determined using multivariate random-effects metaregression,[25] in which the covariates include the C/I ratio, the observation period, the type of connection, and the type of measure (anatomic/clinical). A P value of 0.05 was set as the significance threshold. The Newcastle–Ottawa scale (NOS) was used to assess the quality of such studies for a proper understanding of nonrandomized studies.[26]

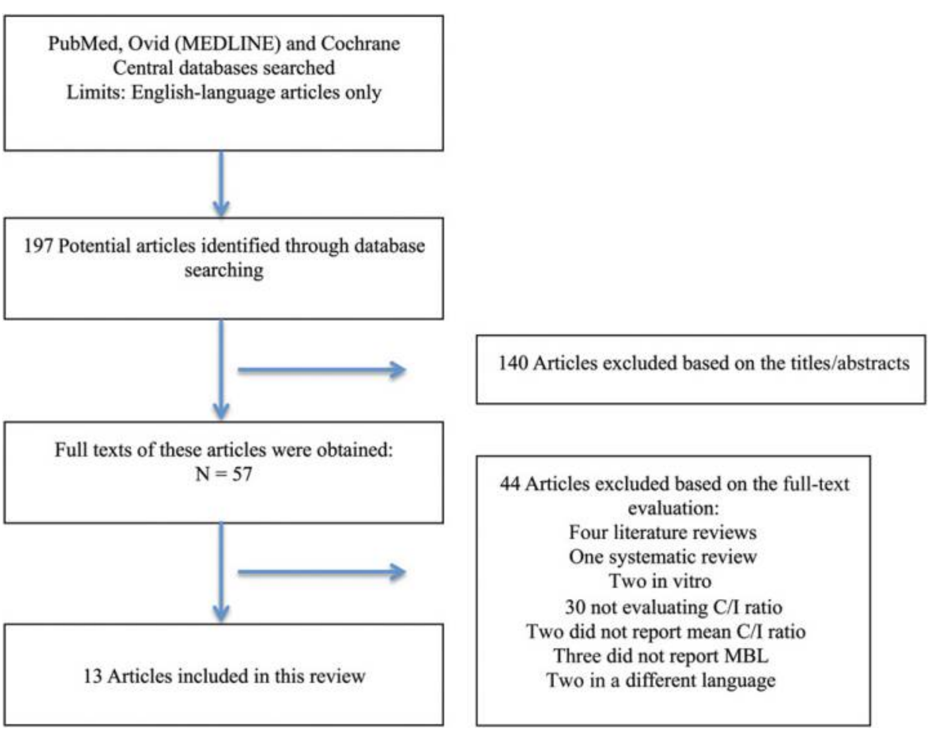

Figure 2.
Flowchart of the screening process.

RESULTS

During the screening process, 197 potential articles were identified, and 140 were excluded based on their titles and abstracts as represented in the flowchart (Fig. 2). A full-text version of the 57 remaining articles was obtained for evaluation. Forty-four of the articles were excluded from the present study by not accomplishing the inclusion criteria as depicted in Figure 2. Only 13 articles were included in this systematic review.[10-13,15,16,27-33]

The multivariate random-effects metaregression yielded a significant association between the C/I ratio and the MBL ($z = -2.52$, $P = 0.012$, 95% confidence interval = –2.09 to 0.26 as represented in Fig. 3).

Table 1 summarizes the characteristics of the included articles. The results from the present study fail to show any statistically significant difference ($P > 0.15$) favoring any potential effect regarding the observation period, the type of the implant connection, or the types of measurement for the C/I ratio (clinical or anatomic).

All the articles included in the present systematic review are prospective or retrospective human clinical trials with the clear aim of studying survival of dental implants and assessing the influence of the C/I ratio on it. Because no randomized clinical trial was included, the NOS was used to assess the quality of all the included studies for a proper understanding of nonrandomized studies.[26] This was performed by a single, masked examiner (AM). The mean ± SD NOS for the studies included in the present systematic review is 6.78 ± 2.01, displaying what the authors of this study determined an acceptable level of evidence of C/I influence on implant survival in the included studies.

DISCUSSION

Centripetal and centrifugal bone loss after tooth extraction is often associated with inadequate bone quantity for proper three-dimensional implant placement.[1] To overcome the bone resorption problem, bone augmentation procedures are often recommended to create a better environment for implant osseointegration. Nonetheless, this might lead to intraoperative and postoperative complications (i.e., excessive bleeding

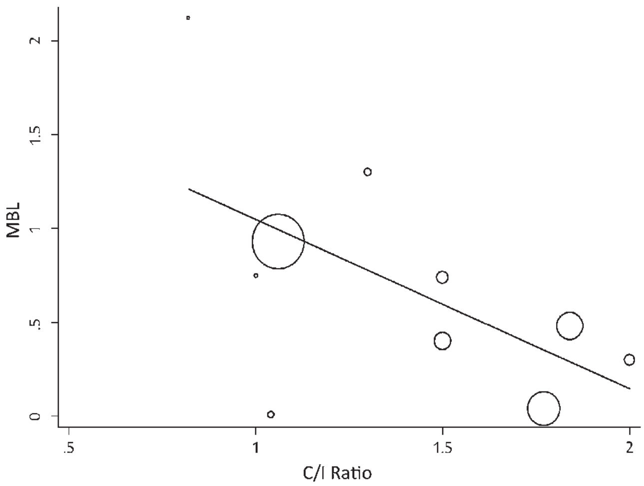

Figure 3.
Association between the C/I ratio and MBL according to the random-effects metaregression expressed in proportion and millimeters, respectively. The area of each circle is inversely proportional to the variance of the MBL estimate.

or morbidity of the donor site). Furthermore, it is important to bear in mind that cost and time would increase, thus decreasing the patient's overall satisfaction and acceptance of treatment. Therefore, the use of narrower and shorter implants was thought to minimize drawbacks.[6,7,34,35] Consequently, when <10-mm implants are placed in partially dentate patients, a high C/I ratio might be displayed. In this situation, short implants are often under bending moments because of a large C/I ratio. It could thus be hypothesized that an increase in MBL is caused by an increased C/I ratio.

Blanes[17] demonstrated in a previous systematic review that an increased C/I ratio did not have repercussions on MBL. However, because of the dearth of available data when performed, conclusive results could not be drawn. Conversely, the present findings confirm that a high C/I ratio does not contribute to more peri-implant MBL.

The loss of supporting bone around dental implants in function is reported as one of the major complications for implant failure.[36,37] Biologic and mechanical complications are capable of inducing disturbances of the supporting tissues around implants, including peri-implantitis and perimucositis.[38] Although potential host risk factors were identified and strongly associated with peri-implant diseases,[39] the assessment of the biomechanical properties of implant-supported restorations remains a challenge.

Rieger et al.[19] demonstrated that high levels of stress during bending moments are located around the neck and apex of the implant. In addition, the authors observed a distribution of these bending forces along the axis of the implant fixture. These outcomes may suggest that higher C/I ratios may create more stress around the implant shoulders and induce bone loss that could endanger the long-term success rates.[19] Nevertheless, previous animal studies failed to demonstrate that stress concentrations around implants could lead to bone resorption.[40,41] Despite such concerns, implants with an increased C/I ratio can still achieve a long-term survival rate as long as the occlusion and parafunctional habits are controlled.[13]

It has been suggested that occlusal overload should be considered as a possible risk factor for peri-implant tissue breakdown and a primary cause for early implant failure.[42] In a systematic review, Chambrone et al.[43] were not able to determine whether an excessive occlusal load has a negative effect on osseointegration. One possible explanation is the lack of information regarding prosthetic factors. As observed in the present study, only some of the included studies mention in detail the implant systems used, opposing arch, and type of restoration, factors which may facilitate a more accurate analysis. Furthermore, splinting implants aims to reduce the amount of force applied over a single implant to avoid excessive occlusal forces, but no clear distinction among the included studies was found to establish a difference between groups and their influence on the MBL.

The present results report an inverse correlation between the C/I ratios and the MBL ($P = 0.012$). In concordance with a previous systematic review,[17] the clinical application of these findings suggests that shorter implants (<10 mm) supporting larger implant-supported restorations may have less MBL compared to standard implants (≥10 mm). Despite the current biomechanical considerations, every clinical scenario should be analyzed properly. Moreover, a correlation of the present study was found with previous results that showed that MBL around short dental implants (<10 mm) is similar when compared to standard longer implants.[44] Hence, together with this fact, it is understandable to think that MBL is independent of implant length. However, it is important to bear in mind that, because MBL is the major predictor for implant success, length will play a crucial role in failure timing. This assumption is in accordance with Monje et al.[7] who found that short implants, as defined for implants <10 mm, fail 2.5 years before standard implants (≥10 mm). Furthermore, the present findings demonstrate that short dental implants with a high C/I ratio could be considered as a possible treatment option without major concern for the MBL. Controversially, Bayraktar et al.[45] in a finite element analysis reported that the

Table 1.

Characteristic of the Included Articles

							Implant Factors				Prosthetic Factors					
Reference	Type of Study	Sample Size (patient)	Sample Size (implants)	Follow-Up (months)	Survival Rate (%)	MBL (mm)	Implant Length (mm)	Type of C/I Ratio	C/I Ratio (Mean)	Screwed or Cemented	Internal or External Hexagon	Splinted or Non-Splinted	Restoration Type	Antagonist	Location	Implant Surface
Krennmair et al., 2002[11]	RET	112	146	35.8	97.30	1.3 ± 0.8	<10 and ≥10	N/A	1.30/1	SCR and CEM	INT	Non-Spl	S	N/A	Ant/Post, Max/Mand	TPS
Rokni et al., 2005[27]	PROS	74	199	46	N/A	0.4 ± 0.4	<10 and ≥10	Anatomic	1.5 /1	SCR	N/A	Spl and Non-Spl	FP	N/A	Max/Mand	SP
Tawil et al., 2006[13]	PROS	109	262	53	N/A	0.74 ± 0.65	<10	Anatomic	2.36/1	SCR and CEM	EXT	N/A	FP, S	I, T, FP	Max/Mand	M
Blanes et al., 2007[15]	PROS	83	192	120	94.10	0.04 ± 0.2	<10 and ≥10	Clinical	1.77/1	SCR	INT	Spl and Non-Spl	FP, S	N/A	Post	TPS
Birdi et al., 2010[10]	RET	194	309	20.9	100	0.3 ± 0.8	<10	Anatomic	2.0/1	CEM	INT	Non-Spl	S	N/A	Post, Max/Mand	N/A
Gomez-Polo et al., 2010[28]	RET	69	85	68.4	100	2.12 ± 1.30	<10 and ≥10	Anatomic	0.82/1	CEM	INT	Spl and Non-Spl	FP, S	N/A	Ant/Post	N/A
Rossi et al., 2010[29]	PROS	35	40	24	95.00	0.75 ± 0.71	<10	Anatomic	1.0/1	N/A	N/A	N/A	S	N/A	Post, Max/Mand	SLA
Urdaneta et al., 2010[30]	RET	81	326	70.7	98.10	0.33 ± N/A	<10 and ≥10	Anatomic	1.6/1	N/A	INT	Non-Spl	S	I, T, FP, RP, None	Ant/Post, Max/Mand	N/A
Danza et al., 2011[31]	RET	23	206	23	97.1	1.2	<10 and ≥10	N/A	0.6/1	CEM	N/A	Spl	FP	I, T, FP, RP	Ant/Post, Max/Mand	N/A
Deporter et al., 2012[32]	PROS	24	48	120	95.50	1.2 ± N/A	<10	N/A	1.4/1	SCR	INT	Spl and Non-Spl	S	I, T	Post, Mand	TBS
Lee et al., 2012[16]	RET	175	259	68.4	N/A	0.93 ± 0.15	N/A	Clinical	1.06/1	N/A	EXT	Spl and Non-Spl	FP, S	N/A	Post, Max/Mand	PT, RBM, SAE

Table 1. (continued)

Characteristic of the Included Articles

Reference	Type of Study	Sample Size (patient)	Sample Size (implants)	Follow-Up (months)	Survival Rate (%)	MBL (mm)	Implant Factors				Prosthetic Factors					
							Implant Length (mm)	Type of C/I Ratio	C/I Ratio (Mean)	Screwed or Cemented	Internal or External Hexagon	Splinted or Non-Splinted	Restoration Type	Antagonist	Location	Implant Surface
Schneider et al., 2012[33]	RET	70	100	74.4	95.80	0.008 ± 0.74	<10 and ≥10	Anatomic	1.04 / 1	SCR and CEM	EXT	Non-Spl	S	I, T, FP, RP	Post	PETO
Malchiodi et al., 2014[12]	PROS	136	259	36	98.80	0.48 ± 0.29	<10 and ≥10	Anatomic	1.84/1	N/A	N/A	Spl and Non-Spl	FP, S	N/A	Post, Max/Mand	M

RET = retrospective; PROS = prospective; N/A = not available; MBL: marginal bone loss; C/I = crown to implant; SCR = screwed restorations; CEM = cemented restorations; INT = internal hexagon; EXT = external hexagon; Non-Spl = non-splinted restorations; Spl = splinted restorations; S = single crown; FP = fixed prosthesis; I = implant; T = teeth; RP = removable prosthesis; Ant = anterior; Post = posterior; Max = maxilla; Mand = mandible; TPS = titanium plasma sprayed; ; SP = sintered porous; M = machined surface; SLA = sandblasting and acid etched; TBS = titanium bead sintering; PT = pure titanium; RBM = resorbable blasting media; SAE = smooth acid-etched; PETO = phosphate-enriched titanium oxide.

implant length had less influence on the MBL than the implant diameter and targeted the crown height as the main factor affecting the surrounding hard tissues. Moreover, if accepting that MBL is the main predictor in implant long-term success, a recent meta-analysis showed the null hypothesis that implant diameter matters for short-implant success rate.[8] Consequently, both short and standard implants must be meticulously maintained to minimize MBL and increase the long-term survival rate.[7]

Conversely, several publications described that increased C/I ratios may not be considered a risk factor for implant failure. Tawil et al.[13] failed to establish a correlation between MBL and numerous variables, including C/I ratio, the presence of cantilever, and the occlusal table and pattern. Similarly, Birdi et al.[10] in a retrospective cohort study evaluating 309 implants found no association between the C/I ratio and MBL. More recently, Okada et al.[46] showed that implants with high C/I ratios had an increased bone remodeling activity, but MBL did not differ from implants with similar and lower C/I ratios. In addition, the authors suggested that proper plaque control might provide an additional effect for implant stability.

Numerous publications mentioned the C/I ratios of their implant-supported prosthesis.[10-12] However, the measurement of the C/I ratio has been approached from different perspectives because of the absence of a consensus definition of C/I ratio.[17] Commonly, some authors reported the anatomic C/I ratio,[13,14,29] whereas others showed the clinical C/I ratio,[15,16] which it has been described to represent a more realistic scenario.[17] The results from the present study do not support any potential effect for either type of measurement of the C/I ratio.

CONCLUSIONS

Conflicting and limited information on the C/I ratio was found in the literature. When analyzing the results from the present study, caution should be taken when extrapolating the conclusions to clinical scenarios. Most of the included articles lacked information to determine the reliability of the restored implants. Although throughout the years multiple studies evaluated the mechanical consideration of implant therapy, this study fails to demonstrate that high C/I ratios may play a role in promoting MBL. Nonetheless, biomechanics and occlusal considerations have been demonstrated to be of paramount importance. Within the limitations of the present study, it can be concluded that a high C/I ratio of implant-supported restorations may provide a protective effect on peri-implant marginal bone level.

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