CLINICAL ORAL IMPLANTS RESEARCH

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A systematic review on marginal bone loss around short dental implants (<10 mm) for implant-supported fixed prostheses

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Abstract

Purpose: This systematic review aimed to evaluate the effect of implant length on peri-implant marginal bone loss (MBL) and its associated influencing factors.

Material and methods: An electronic search of the PubMed and MEDLINE databases for relevant studies published in English from November 2006 to July 2012 was performed by one examiner (AM). Selected studies were randomized clinical trials, human experimental clinical trials or prospective studies (e.g., cohort as well as case series) with a clear aim of investigating marginal bone loss of short dental implants (<10 mm) supporting fixed prostheses. A random-effect meta-regression model was used to determine the relationship between the effect size mean MBL and the covariate "implant length." Additionally, a subgroup analysis, by means of a random-effect one-way ANOVA model, comparing mean MBL values at different levels of each factor ("type of connection" and "type of prostheses") was also performed.

Results: The meta-regression of mean MBL on the moderator "implant length" was found to be insignificant ($P = 0.633$). Therefore, it could not be concluded that implant length had an effect on peri-implant MBL. In addition, standardized differences in mean MBL on the subgroups short (<10 mm) and standard (≥10 mm) implants, as determined by the meta-analysis (random-effect model), were found to be statistically insignificant ($P = 0.222$).

Conclusions: Within limitations of the present systematic review, it could be concluded that short dental implants (<10 mm) had similar peri-implant MBL as standard implants (≥10 mm) for implant-supported fixed prostheses.

Short dental implants have slowly gained popularity among clinicians because of their ability to provide a successful restoration while avoiding vital structures and the morbidity of advanced bone grafting techniques. There is still no consensus regarding the length to be considered short or standard implant. Some uses 7 mm as the cut-off length (Hagi et al. 2004), and others use 8 mm (Renouard & Nisand 2006) or 10 mm (Monje et al. 2013a). Several meta-analyses have also determined the factors that influence the long-term success of short dental implants (Romeo et al. 2006; Pommer et al. 2011; Sun et al. 2011; Telleman et al. 2011b; Annibali et al. 2012; Monje et al. 2013a, 2013). For instance, short dental implants were less predictable if they were of machined surfaces or if they were placed in areas of poorer bone quality, for example the maxilla (Sun et al. 2011). Despite these limitations, short dental implants, regardless of their diameters (Monje et al. 2013b), have been shown to enjoy similar long-term survival rates as standard (≥10 mm) implants (Pommer et al. 2011; Sun et al. 2011; Telleman et al. 2011b; Monje et al. 2013a). However, if failures do occur, short implants generally fail 2.5 years earlier compared to standard implants (Monje et al. 2013a). It seems plausible that marginal bone loss (MBL) affects long-term survival of short implants as they present with less bone contact surface to maintain osseointegration. As such, MBL around short implants is more crucial than standard implants (≥10 mm).

Factors such as implant–abutment connection (Penarrocha-Diago et al. 2012), implant

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neck design (Penarrocha-Diago et al. 2012), surgical trauma (Qian et al. 2012), prosthetic considerations (Cardaropoli et al. 2006), implant design (Canullo et al. 2010), and patient's habits (Galindo-Moreno et al. 2005) have been shown to affect MBL. Moreover, it is hypothesized that poor crown-to-implant (C/I) ratio results in occlusal overloading of implants leading to MBL and the eventual loss of osseointegration (Isidor 1996). The importance of the C/I ratio relies on the theory that unfavorable occlusal forces, including nonaxial and overload, represent one possible explanation for biological and technical complications (Isidor 2006; Blanes 2009). As the matter of fact, higher C/I ratios display a form of nonaxial force where the crown acts as a lever arm that creates a bending moment, transferring stress to the peri-implant crestal bone (Rieger et al. 1990). Therefore, this systematic review aimed to investigate the influence of implant length on MBL and the factors that might influence the outcome obtained in rough surface dental implants.

Material and methods

Screening process

An electronic search of the PubMed and MEDLINE databases for relevant studies published in English from November 2006 to July 2012 was performed by one examiner (AM). The key words used in the search included a combination of "dental implants," "endosseous implants," "oral implants," "short implants," and "short length." A manual search of implant-related journals, including *Clinical Implant Dentistry and Related Research, Journal of Oral and Maxillofacial Implants, Clinical Oral Implants Research, Implant Dentistry, European Journal of Oral Implantology (2008–2012), Journal of Oral Implantology, International Journal of Oral and Maxillofacial Surgery, Journal of Oral and Maxillofacial Surgery, Journal of Dental Research, International Journal of Prosthodontics, Journal of Prosthetic Dentistry, Journal of Clinical Periodontology, Journal of Periodontology, and The International Journal of Periodontics and Restorative Dentistry*, from November 2006 to July 2012, was also performed.

Included studies were randomized clinical trials, human clinical trials, or prospective trials with a clear aim of investigating marginal bone loss around short dental (<10 mm) implants supporting fixed prostheses. Studies had to have a minimum sample size of 10 healthy patients with 10 short implants that were in function for at least 1 year. In addition, short and standard implants were only considered if they were placed in pristine residual ridges that did not receive any bone augmentation procedures such as sinus floor augmentation, onlay bone grafting, or guided bone regeneration. The Newcastle–Ottawa scale (NOS) was used to assess the quality of such studies for a proper understanding of nonrandomized studies (Stang 2010). Animal studies and retrospective human trials with insufficient information were not considered to avoid any risk of bias. Furthermore, studies involving smooth surface implants or immediate implant placement and/or loading and implants with platform switching were excluded too. Studies using short and standard implants to support the same prostheses were also excluded.

Several factors, such as implant length, implant system, total number of implants placed, location, type of prosthesis, follow-up periods after loading, type of implant–abutment connection, and MBL, were extracted from the selected studies and analyzed.

Statistic analysis

To carry out the present systematic review, the Metafor package for R Software (URL http://www.jstatsoft.org/v36/i03/ (Borenstein, et al. 2009) and the URL http://www.r-project.org/ for the statistic software R) and Microsoft Excel 2003 (Microsoft Excel, Redmond, WA, USA) were used for calculations. Furthermore, the software MiKTEX (http://www.miktex.org/) was used for performing the graphics: forest plots (Figs. 2, 3, and 6) and dispersion diagrams (Figs 4 and 5) have been constructed to display the results. In the analyses, random-effects models were used, and the variance τ^2 of the true effects across studies by the method of moments was estimated.

The systematic review aimed to combine included studies taking MBL as effect size. The mean MBL of the 5 selected studies and 95% confidence interval (CI) was provided. Moreover, a meta-regression was carried out to figure out the relation between the effect size "mean MBL" and the covariate "implant length." The same analysis was performed for the covariate "follow-up after loading." Additionally, a subgroup analysis, by means of a random-effect one-way ANOVA model, to compare mean MBL values at different levels of each factor ("type of connection" and "type of prostheses") was also performed. Furthermore, to ascertain the results obtained, another meta-analysis was carried out to compare mean MBL of studies comparing/reporting MBL of short (<10 mm) and standard implants (≥10 mm) by two different groups (Romeo et al. 2006; Gulje et al. 2012).

Results

Study selection

An initial screening yielded a total of 785 articles, of which 63 potentially relevant articles were selected after an evaluation of their titles and abstracts. Full texts of these articles were obtained with only five articles fulfilling the inclusion criteria and subsequently analyzed in this meta-analysis (Fig. 1). Details of all included studies were summarized in Table 1. Of them, three studies were comparative studies assessing MBL of short and standard implants (Romeo et al. 2006; Esposito et al. 2011; Gulje et al. 2012). Standard implants reported in the article by Esposito et al. 2011;. were placed in augmented bone and thus excluded for the standard implants group. Additionally, one article compared short implants with either platform-switched or platform-matched abutment connection (Telleman et al. 2011a). Therefore, only data from the platform-matched group was extracted for this systematic review as it was shown that platform switching might significantly affect MBL (Atieh et al. 2010). Another article reporting on MBL around short (6-mm-long) implants was also included (Rossi et al. 2010).

Study quality

All the articles included in the present systematic review were prospective human clinical trials evaluating short dental implants. Three of the included studies were randomized clinical trials (Esposito et al. 2011a; Gulje et al. 2012; Telleman et al. 2011a). The Newcastle–Ottawa scale (NOS) was used to assess the quality of nonrandomized trials (Romeo et al. 2006; Rossi et al. 2010). According to this, both did not show to be "high quality" studies (six stars) failing both in the "outcome" section, but still acceptable due to their prospective nature to be included in the present study.

Implant selection

A total of 382 short dental implants of less than 10 mm were analyzed, of which 59 were 5.0 mm (15.45%), 142 were 6.0-mm implants (37.95%), 111 were 8.0 mm (29.06%), and 70 were 8.5 mm (18.32%). For the standard implants group (≥10 mm), an overall of 258 implants were included, where 104 were 11.0 mm implants (38.9%) and 154 were

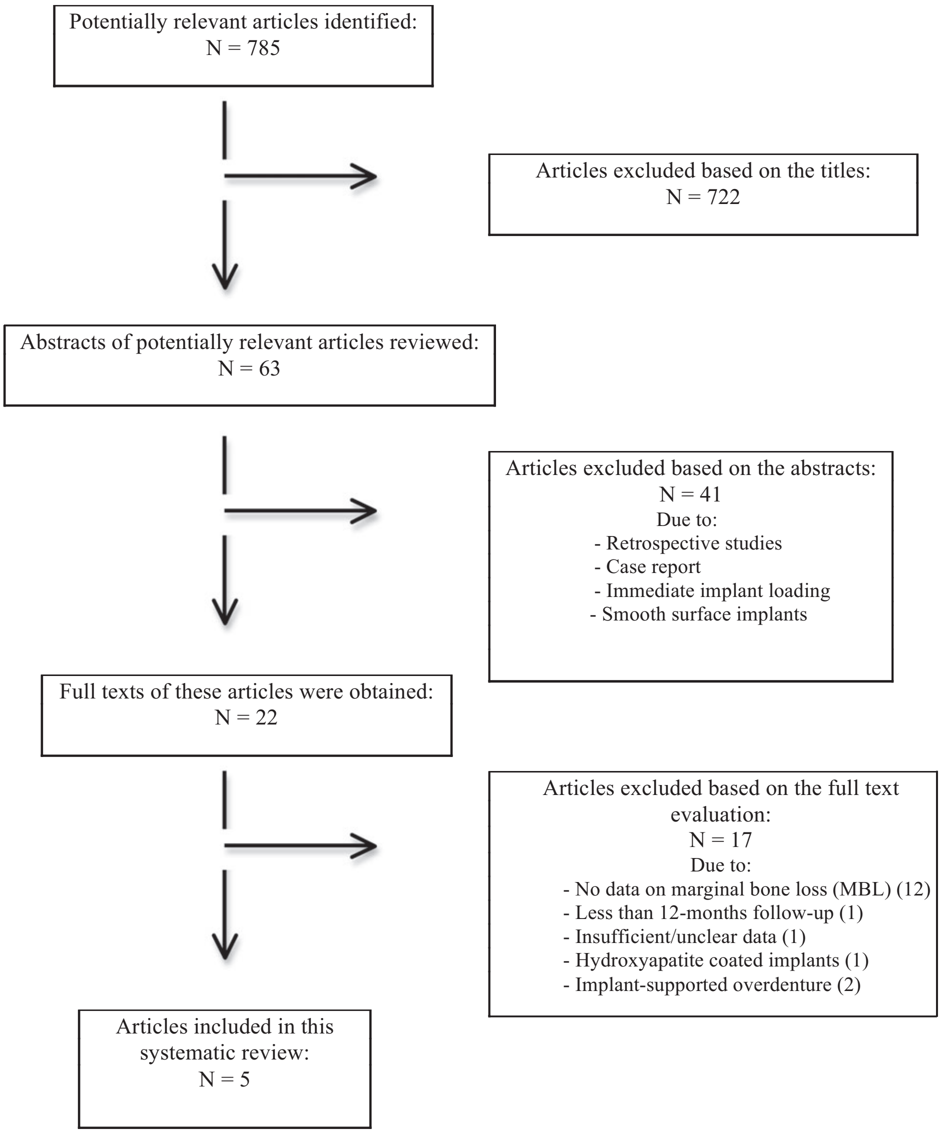

Fig. 1. Flow chart of the screening process.

10.0-mm implants (61.1%). Implant diameters ranged between 3.75 mm and 6 mm.

Type of prosthesis

All the studies included reported on MBL around short and standard implants supporting fixed prostheses. Two studies (Rossi et al. 2010; Esposito et al. 2011; Telleman et al. 2011a) reported on MBL supporting single crowns (SC), two others (Esposito et al. 2011; Gulje et al. 2012) studied MBL around implant-supported fixed partial dentures (FPDs). High heterogeneity ($P < 0.0001$) was found out within subgroups "SC" and "FPD." The random-effects one-way ANOVA model to compare mean MBL, on the two subgroups, found no statistically significant differences ($P = 0.602$) between "SC" and "FPD" (Fig. 2). Therefore, the overlying prosthesis had no effect on the MBL around short implants.

Type of connection

Three studies (Esposito et al. 2011; Gulje et al. 2012; Telleman et al. 2011a) included implants with internal connection while the two studies (Romeo et al. 2006; Rossi et al. 2010) included implants with external connection. The random-effects one-way ANOVA model used in the comparison of the mean MBL effect size between the two levels (internal and external) of the factor "type of connection" showed statistically significant differences ($P = 0.038$), favoring the internal connection. Therefore, MBL around short implants with external connection was greater than that around short implants with internal connection (Fig. 3).

Follow-up after loading

One of the limitations of this systematic review was the scarcity of long-term follow-up prospective studies available in the literature. All the articles included, except one (Romeo et al. 2006), were short term (12–24 months). As expected, the meta-regression evaluating the relationship of mean MBL on follow-up period after loading yielded statistical significance ($P = 0.0003$), and thus, the linear regression over the follow-up has an influence upon mean MBL. Henceforth, the greater the follow-up period after loading, the more MBL was expected (Fig. 4). However, it is important to mention that one of the greatest limitations of the present study was the heterogeneity of the studies ranging from 12 to 168 months.

Location

None of the included studies examined MBL around short implants based on their location, for example maxilla or mandible. Therefore, MBL could not be analyzed by location.

Relationship between implant length and mean MBL

The random-effect model, which served to examine the regression of mean MBL and "implant length," showed a nonsignificant regression slope ($P = 0.633$) as depicted in Fig. 5. Therefore, MBL around implants does not seem to be influenced by implant length. In addition, the meta-analysis (random-effect model) performed to compare standardized differences in mean MBL on the subgroups short (<10 mm) and standard (≥10 mm) implants becomes statistically nonsignificant ($P = 0.222$) (Fig. 6).

Discussion

Compared to teeth, dental implants lack periodontal ligament and therefore are less able to withstand traumatic occlusal forces. Thus, they are more vulnerable to nonaxial forces, for example moment, torsional, and shear forces exerted to the surrounding bone around implants (Kim et al. 2005). As a result, dental implants should be placed in alignment to vectors of loading (Clelland et al. 1993). It is speculated that reduced implant length might complicate the biomechanical effects of loads transferred to the surrounding bone (Hasan et al. 2010). To address this issue, wider implants are developed in an attempt to reduce prosthetic and implant complications and also to improve the long-term implant survival rates. Furthermore, it is noteworthy to mention that short implants are placed in

***Table 1.* Descriptive information of the studies included in the systematic review**

Author (Year)	Study design	Number of patients	Number of implants	Follow-up after loading (months)	Implant system	Implant length (mm)	Implant width (mm)	Location	Type of prosthesis	Type of connection	Mean MBL (mm)
Esposito et al. (2011)	RCT	30	59	12	EZ Plus	5	6	UM/LM	FPD	Internal	0.97 ± 0.56
Telleman et al. (2011a)	RCT	47	70	12	NanoTite XP Certain	8.5	4.1–5	UM/LM	SC	Internal	0.74 ± 0.61
Gulje et al. (2012)	RCT	49	104	12	OsseoSpeed	6	4	UM/LM	FPD	Internal	0.2 ± 0.22
		46	100	12	OsseoSpeed	11	4	UM/LM	FPD	Internal	0.41 ± 0.46
Romeo et al. (2006)	Prospective	57	111	168	TPS/SLA	8	3.75–4.1	UM/LM	FPD/SC/FCD	External	1.6 ± 1.5
		71	154	168	SLA/SLA	10	3.75–4.1	UM/LM	FPD/SC/FCD	External	1.7 ± 1.4
Rossi et al. (2010)	Prospective	35	38	24	SLActive	6	4.1–4.8	UM/LM	SC	External	0.75 ± 0.71

UM, upper maxilla; LM, lower maxilla; FPD, fixed partial denture; SC, single crown; FCD, fixed complete denture; RCT, randomized controlled trial.

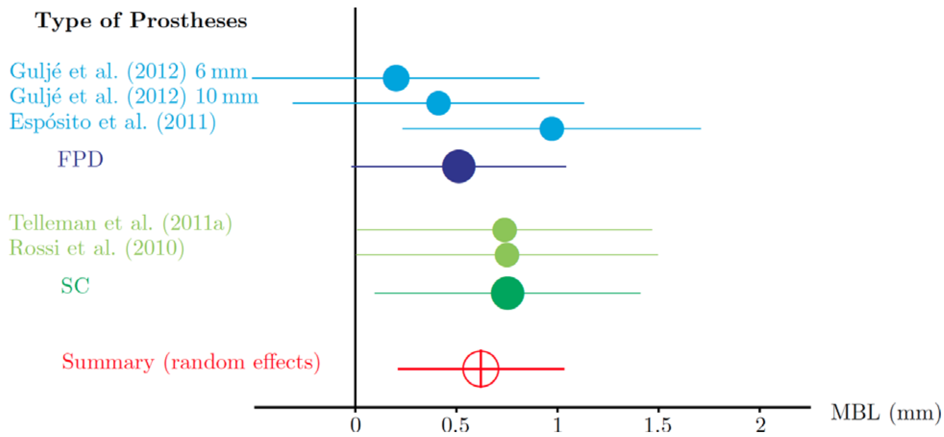

Fig. 2. Random-effects one-way ANOVA model to compare mean MBL (mm) and 95% confidence interval on the two subgroups [fixed partial denture (FPD) and single crown (SC)] of studies determined by the type of prosthesis.

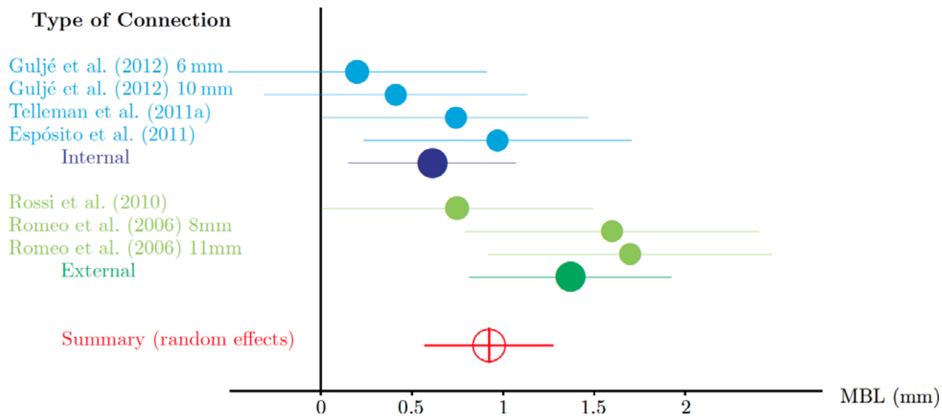

Fig. 3. Random-effects one-way ANOVA model to compare mean MBL (mm) and 95% confidence interval on the two subgroups (internal and external) of studies determined by the type of connections.

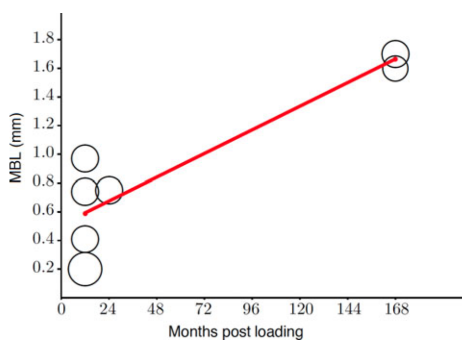

Fig. 4. Regression of mean MBL (mm) on follow-up period after loading (months) (random-effects model).

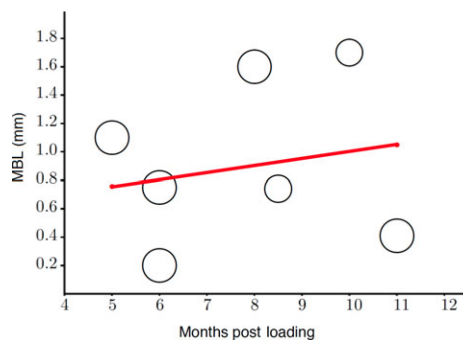

Fig. 5. Regression of mean MBL (mm) on implant length (mm) (random-effects model).

resorbed regions to avoid further grafting/surgical procedures, and thus, the clinical crown height may be greater than the implant length. This poor C/I ratio will lead to excessive occlusal loading and with a nonaxial loading acting as a lever arm, a bending moment is created that may bring on technical and biological complications (Isidor 2006; Blanes 2009). Interestingly, the C/I ratio of implant-supported prostheses does not seem to influence the MBL (Blanes 2009). Aside from this controversial fact, the clinician is interested in the long-term success of implant therapy and the predictability of using short dental implants as an alternative to regeneration approaches for placing longer implants.

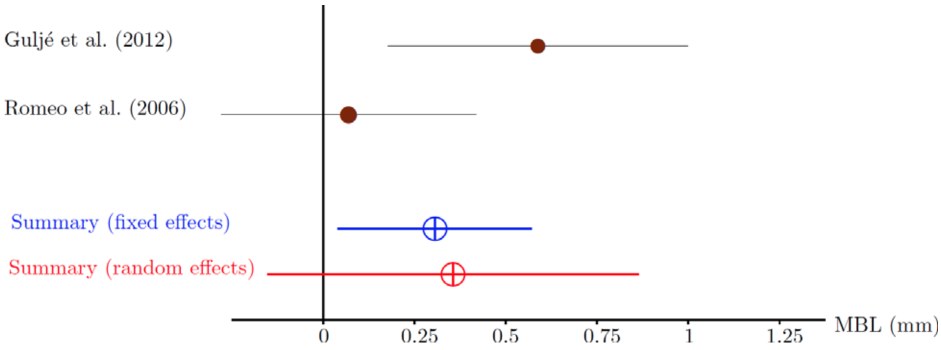

Fig. 6. Standardized mean difference MBL (mm) and 95% confidence interval.

There is still no consensus regarding the ideal MBL expectable around an implant once that it is under function and about the progression of the MBL. This systematic review showed that MBL around short implants is not influenced by implant length. It also revealed that MBL around short implants did not exceed the first criteria established for standard implants (Albrektsson et al. 1986). However, MBL around short dental implant may jeopardize implant stability and lead to implant failure. Consequently, short implants must be meticulously maintained to minimize MBL and increase the long-term survival rate. Indeed, Laurell and Lundgren have demonstrated that some trademarks show lesser level of MBL in long-term studies (5 years) than others (Laurell & Lundgren 2011). Hence, our findings also point out the need of the revision of the existent success criteria to propose a new one depending on implant features (i.e., type of connection).

It has been shown that rough surface short implants is a predictable approach to overcome the limitations caused by vertical bone resorption (Pommer et al. 2011; Telleman et al. 2011b; Monje et al. 2013a). However, all these meta-analyses have pointed out the same limitation: the lack of long-term prospective studies. Indeed, the present systematic review only considered one long-term study (Romeo et al. 2006), and thus, a clear conclusion on the long-term survival rate of short implants cannot be drawn. Assuming that excessive MBL will trigger implant mobility, results of this review may explain the results obtained in the meta-analysis performed by Monje et al. 2013a; where it was reported that, if failure occurs, short implants generally fail 2.5 years before standard implants. Accordingly, Lum 1991;. demonstrated in a finite element analysis model that horizontal and vertical occlusal forces placed on implant are distributed mainly to the crestal bone, rather than along the entire implant surface. Therefore, the maximum stresses and strains in nonaxial and axial loadings appeared mainly at the upper edge of the cortical bone, and they do not have a significant impact by implant length. On the other hand, some studies found that by increasing the lever arm, bending moments are exerted on the implants, thus resulting in MBL (Qian et al. 2009; Chou et al. 2010). In this sense, short implants are often under bending moments because of large C/I ratio. It could thus be hypothesized that increase in MBL is caused by disproportionate C/I ratio. Nonetheless, and in concordance to our findings, Blanes demonstrated in a systematic review that a large C/I ratio did not have repercussions upon MBL (Blanes 2009). In addition, it has been shown that splinting short implants provide more strain distribution during functional loading, helping to reduce the lever (Chou et al. 2010; Yilmaz et al. 2011). Nevertheless, the present systematic review failed to show that FPD has less MBL than SC ($P = 0.602$).

Irrespective of implant length, peri-implant MBL currently constitutes a clinical challenge in implant dentistry, and it is a controversial issue. Several variables such as surgical trauma (Qian et al. 2012), prosthetic considerations (Cardaropoli et al. 2006), implant and implant neck design (Canullo et al. 2010; Penarrocha-Diago et al. 2012), or patient's habits (Galindo-Moreno et al. 2005) have a significant effect on MBL. Short implants are not exempt to consideration, and based on the findings of the present study, all these parameters must be thoroughly assessed when shorter implants are used to rehabilitate edentulous spaces. In this sense, many studies have shown the potential mechanical advantages of the internal connections over the external connection (Norton 1999)(Maeda et al. 2006). Internal connection implants reduce bending forces and consequently minimize MBL caused by overloading. This systematic review too found that internal connection short implants have less MBL (Pessoa et al. 2010). Hence, assuming that short implants are more prone to fail before standard implants due to their shorter length, the type of connection, such as internal connection, may improve the long-term success rate.

Despite the high quality of studies selected to perform this systematic review, there is potential risk of bias because of the heterogeneity and the small number of well-designed studies available in the literature related to MBL around short implants. Therefore, precautions should be exercised when interpreting the results of this review.

Conclusions

Within the limitations of the present systematic review, it can be concluded that short dental implants (<10 mm) have similar MBL when compared to standard implants (≥10 mm) for implant-supported fixed prostheses. Nonetheless, due to their shorter lengths, having adequate bone around these implants is crucial for their long-term success. Therefore, utilizing implant–abutment internal connection may minimize MBL thus increasing implant survival rate.

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Disclosure

The authors do not have any financial interests, either directly or indirectly, in the products or information listed in the paper.

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