

Short implants versus longer implants with maxillary sinus lift. A systematic review and meta-analysis

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Abstract: This study compared the survival rate of dental implants, amount of marginal bone loss, and rates of complications (biological and prosthetic) between short implants and long implants placed after maxillary sinus augmentation. This systematic review has been registered at PROSPERO under the number (CRD42017073929). Two reviewers searched the PubMed/MEDLINE, Embase, LILACS, and Cochrane Library databases. Eligibility criteria included randomized controlled trials, comparisons between short implants and long implants placed after maxillary sinus augmentation in the same study, and follow-up for >6 months. The Cochrane Collaboration's tool for assessing the risk of bias in randomized trials was used to assess the quality and risk of bias of the included studies. The search identified 1366 references. After applying the inclusion criteria, 11 trials including 420 patients who received 911 dental implants were considered eligible. No significant difference was observed in the survival rate [$p = 0.86$; risk ratio (RR): 1.08; 95% confidence interval (CI): 0.46–2.52] or in the amount of marginal bone loss ($p = 0.08$; RR: -0.05; 95%CI: -0.10 to 0.01). However, higher rates of biological complications for long implants associated with maxillary sinus augmentation were observed ($p < 0.00001$; RR: 0.21; 95%CI: 0.10–0.41), whereas a higher prosthetic complication rate for short implants was noted ($p = 0.010$; RR: 3.15; 95%CI: 1.32–7.51). Short implant placement is an effective alternative because of fewer biological complications and similar survival and marginal bone loss than long implant placement with maxillary sinus augmentation. However, the risk of mechanical complications associated with the prostheses fitted on short implants should be considered.

Keywords: Dental Implants; Sinus Floor Augmentation; Prosthesis Failures; Meta-Analysis.

Introduction

Dental implants are considered an option for oral rehabilitation, particularly in the posterior maxillary region.¹ However, it is not possible to place dental implants with an adequate length in some clinical situations, primarily due to the lack of sufficient bone.² One option to overcome this limitation is using short implants.³ Another option is augmentation of the bone height through techniques such as maxillary sinus augmentation with or without bone grafting, which enables long implant placement.⁴



Short implant placement has been considered as a less invasive alternative, and it is associated with greater simplicity, a shorter surgical duration, and lower morbidity rates and costs.^{5,6} Furthermore, the clinical outcomes of short implants are reportedly similar to those of long implants in the posterior maxillary region.^{7,8} However, the bone-to-implant contact area with short implants may be small, impairing the primary stability and osseointegration process⁹ and eventually leading to implant failure.¹ In addition, the discrepancy in the crown-to-implant ratio (C/I ratio) may increase the risk of marginal bone loss and other complications such as screw loosening, prefabricated abutment fracture, retention loss, and crown debonding.^{10,11} Maxillary sinus augmentation, which is performed using the lateral window technique or Summers technique, has shown favorable outcomes regarding implant survival.^{6,12} However, these are complex surgical procedures because they can result in postoperative complications that increase the morbidity rate and increase the patient's reluctance to undergo the procedure.^{13,14} The cost and duration of treatment are greater than that in conventional implant placement without bone grafting.¹⁵

Different reviews have reported the use of short implants with available alternative treatments.^{1,15,16,17} However, more randomized controlled trials (RCTs) have reported comparisons between short implants and long implants placed after maxillary sinus augmentation.^{8,18,19,20,21,22,23} Thus, the choice of technique (short or long implants with maxillary sinus augmentation) should be based on recently published literature, including the relative risks of each technique.

The present systematic review aimed to compare short implants and long implants (length > 8.5 mm) placed after maxillary sinus augmentation for survival rates, amount of marginal bone loss, and biological and prosthetic complications. The null hypotheses were as follows. First, there is no difference in the survival rate between short implants and long implants placed after maxillary sinus augmentation. Second, the implant length does not influence the amount of marginal bone loss. Third, the implant length does not change the occurrence of biological and/or prosthetic complications.

Methodology

This systematic review was registered in the PROSPERO database (CRD42017073929) and structured according to the PRISMA checklist.²⁴ The protocol was established according to models proposed in the relevant literature.^{16,25}

Eligibility criteria

Studies meeting the following criteria were included: a. RCTs; b. comparisons between short implants without maxillary sinus augmentation and long implants with maxillary sinus augmentation in the same study; and c. follow-up for > 6 months. No restrictions on language or date of publication for searching in the electronic databases were made. Studies meeting at least one of the following criteria were excluded: a. animal studies; b. *in vitro* studies; c. case series or case reports; d. retrospective studies; e. patients or data repeated in other articles included; f. computer simulations; g. studies that presented only short implants without a comparison group; h. studies that considered short implants longer than 8.5 mm; and i. studies with short implants associated with maxillary sinus augmentation technique.

Search

The following question was elaborated for the PICO process (population, intervention, comparison, outcomes): Do short posterior maxillary implants exhibit the same clinical predictability as long implants placed after maxillary sinus augmentation? The population (P) was patients rehabilitated with dental implants in the posterior maxilla; the intervention (I) was short implant (≤ 8.5 mm) placement; the comparison (C) was long implant (> 8.5 mm) placement after maxillary sinus augmentation; and the outcomes (O) were the survival rate of implants, amount of marginal bone loss, and biological and prosthetic complication rates.

Two researchers independently searched the PubMed/Medline, Embase, LILACS, and Cochrane Library databases for articles published up to January 2018 according to the eligibility criteria. Studies comparing the survival rate of short implants (≤ 8.5 mm) placed in the posterior maxilla with that

of long implants (> 8.5 mm) placed after maxillary sinus augmentation were selected. The search terms included (short implant and maxilla) OR (short implant and sinus lift) OR (short implant and sinus elevation) OR (short implant and maxilla and augmentation) OR (short implant and sinus floor augmentation) OR (short implant and maxilla and dental implant) OR (short implant and sinus lift and dental implant) OR (short implant and sinus elevation and dental implant) OR (short implant and maxilla and augmentation and dental implant) OR (short implant and maxilla and dental implant) OR (short implant and sinus floor augmentation and dental implant).

No filters and limits were used in the database searches. A manual search of electronically available publications up to January 2018, including studies available ahead of print, was conducted by two reviewers for specific journals: *Clinical Implant Dentistry and Related Research*, *Clinical Oral Implants Research*, *International Journal of Oral and Maxillofacial Implants*, *International Journal of Oral and Maxillofacial Surgery*, *Journal of Clinical Periodontology*, *Journal of Dentistry*, *Journal of Oral and Maxillofacial Surgery*, *Journal of Oral Implantology*, *Journal of Oral Rehabilitation*, and *Journal of Periodontology*. A third researcher analyzed the possible differences in the selection of the investigators. Any disagreements were resolved by discussion and consensus of all authors. The Cohen's kappa coefficient was calculated to measure the inter-reader agreement in the study selection process.

Risk of bias

One author evaluated the risk of bias in the included studies using the Cochrane Collaboration's tool for assessing the risk of bias in randomized trials. The assessment criteria were separately prepared for different domains: random sequence generation, allocation concealment, blinding (patients and/or outcome assessment), incomplete outcome data, and other bias. For each domain, the risk of bias was graded as high, low, or unclear based on criteria described in the Cochrane Handbook for Systematic Reviews of Interventions version 5.1.0. A second author was responsible for checking the risk of bias, and a consensus was obtained with another author in case of discrepancies.

Data extraction

One researcher extracted the data from articles (quantitative or qualitative), and another checked these data. The following data were recorded: author/year, number of patients, mean age, length of short and long implants and number of implants, diameter (mm) of implants, implant system, insertion bone graft/system, technique performed, follow-up (months), amount of marginal bone loss, complications (biological and prosthetic), and survival rates of implants (short and long implants).

Summary measures

The meta-analysis was based on the Mantel-Haenszel (MH) and Inverse Variance (IV) weighting methods. The outcome measures evaluated by risk ratio (RR) included the survival rates of implants and biological and prosthetic complications. The amount of marginal bone loss was evaluated by mean difference (MD) and the corresponding 95% confidence interval (CI). The RR and MD values were considered significant when the P-value was < 0.05. Reviewer Manager 5 software (the Cochrane Collaboration) was used for meta-analysis. The I² statistic was used to analyze the percentage of variations due to heterogeneity. I² values > 75% (range: 0–100) indicated high heterogeneity. Because the meta-analysis showed significant heterogeneity (p < 0.10), a random-effects model was adopted, whereas the fixed-effect model was used when heterogeneity was not statistically significant.^{26,27,28}

Results

The database search yielded 1366 references, including 421 from PubMed/MEDLINE, 414 from Embase, 453 from LILACS, and 78 from Cochrane Library. Following the selection of studies according to the inclusion and exclusion criteria and the removal of duplicate articles, full versions of 26 articles were selected for reading (Figure 1). After reading, 11 studies^{8,18,19,20,21,22,23,29,30,31,32} met the inclusion criteria and were selected for the final analysis. Thus, 15 studies were excluded^{4,5,6,7,33,34,35,36,37,38,39,40,41,42,43}; the reasons for exclusion are specified in Table 1.

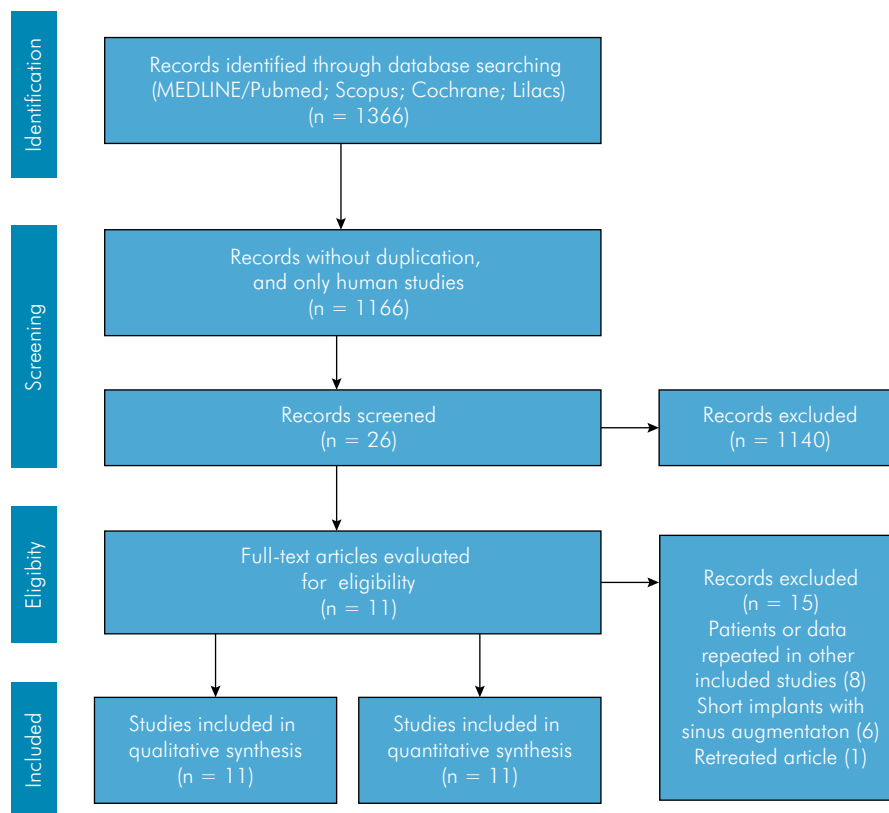


Figure 1. Flow diagram of the literature search and results

Table 1. Reasons for the exclusion of 15 articles.

Reason for Exclusion	References
Patients or data repeated in other included articles	5, 6, 33, 34, 35, 36, 37, 38
Short implants with sinus augmentation	4, 7, 39, 40, 41, 42
Retread	43

The inter-investigator agreement (Kappa) was calculated by evaluating the selected titles and abstracts. The values derived for the articles selected from PubMed/MEDLINE (kappa = 0.96), Embase (kappa = 0.95), LILACS (kappa = 0.93), and Cochrane Library (kappa = 1.00) suggested a high level of agreement between investigators.

A total of 420 patients with a mean age of 52.20 years received 911 implants, including 437 short implants and 474 long implants placed after maxillary sinus augmentation; the implants were performed using the following techniques: osteotome sinus floor elevation,¹⁸ crestal sinus lift,²¹ and lateral sinus lift.^{8,19,20,22,23,29,30,31,32} The lateral

sinus augmentation procedure was performed with bone grafting in all studies,^{8,19,20,22,23,29,30,31,32} with xenografts being most commonly used. One study used an autograft (iliac crest donor site),²³ and another did not use any graft materials.¹⁸ The commercially available implant systems included those produced by BTI Biotechnology Institute (Vitoria, Alava, Spain), Zimmer Biomet (Palm Beach Gardens, FL, USA), Institut Straumann AG (Basel, Switzerland), Dentsply Implants (Molndal, Sweden), MegaGen (Gyeongbuk, South Korea), Global D (Lyon, France), and Southern Implants (Irene, South Africa).

The length of short implants ranged from 4 mm to 8.5 mm, while that of conventional, long implants ranged from 10 mm to 15 mm. The diameter of all implants ranged from 3.75 mm to 7.0 mm. In addition, five studies reported the use of internal connections,^{8,19,20,22,29} four used external connections,^{21,23,31,32} and two did not report the type of connection.^{18,30} The follow-up period of included studies varied from 9 to 36 months (Table 2).

Table 2. Characteristics of studies included (n= 11).

Author/Year	Patients (N)	Mean age (years)	Length short implants and longer implants		Diameter (ø mm)	Implant system	Insertion bone graft/system	Techniques performed	Follow-up (Months)	Mean (SD)		Complications: N°		Implant survival rate	
			N° of implants	N° of implants						MBL (mm)	Distal	Biological	Prosthetic	Short Implants	Longer Implants
Toschieri et al. 2017 ²⁰	49	S: 52.21 L: 51.05	≤ 8.5 mm	≥ 10 mm	S/L: 3.75/4.0/ 4.5 mm	BTI Biotechnology Institute	Bio-Oss small granules Geistlich Pharma AG, Wolhusen, Switzerland	Lateral window	36	Mesail/Distal S: 0.91 (±1.22) / 0.94 (±1.43) Mesail/Distal L: 1.15 (±0.68) / 1.06 (±0.70)	S: 0 L: 0	S: 0 L: 0	100%	100%	
Gastaldi et al. 2017 ²¹	20	S: 53.4 L: 58.6	5.0/6.0 mm	10 mm	S/L: 5.0/6.0 mm	External Hex XFO55/6xx (Zimmer Biomet)	Granular anorganic bovine bone (Endobon, Zimmer Biomet)	Crestal sinus lift	36	S: 0.89 (±0.25) L: 1.08 (±0.29)	S: 0 L: 1	S: 2 L: 0	100%	100%	
Zhang et al. 2017 ¹⁸	41	S: 37.5 L: 35.5	6 mm	10 mm	S/L: 4.1/4.8 mm	Straumann implants (Standard Plus)	No grafting materials	Osteotome sinus floor elevation	9	NR	S: 0 L: 1	S: 0 L: 0	100%	100%	
Pohl et al. 2017 ¹⁹	94	S/L: 50.5	6 mm	11/13/ 15 mm	S/L: 4.0 mm	OsseoSpeed 4.05 (Asira Tech)	Bio-Oss™ Granules, Geistlich, Switzerland	Lateral window	36	S: 0.44 (±0.44) L: 0.45 (±0.55)	S: 0 L: 0	S: 10 L: 3	100%	100%	
Bechara et al. 2016 ⁸	53	S: 47.5 L: 49.2	6 mm	≥ 10 mm	S/L: 4.0/4.5/5.0/ >5.0 mm	AnyRidge implants	Porcine particulate bone graft OsteoBio-GenOs, Tecross Dental	Lateral window	36	S: 0.20 mm L: 0.27 mm	S: 0 L: 19	S: 0 L: 0	100%	95.6 %	
Esposito et al. 2016 ²²	20	S: 60.75 L: 56.4	4 mm	10/11.5/13 mm	S: 4.0 L: 4.0/4.5 mm	TwinKon Universal SA2 – (Global D)	Porcine particulate bone graft Gen-Os, OsteoBioL, Tecross	Lateral window	20	S: 0.47 (±0.12) L: 0.50 (±0.13)	S: 2 L: 10	S: 1 L: 2	91.8%	87.8%	
Esposito et al. 2015 ²³	28	S: 56 L: 52	5–8.5 mm	11,5–13 mm	S: 4.0/5.0/6.0/ 7.0 mm L: 4.0/5.0 mm	ExFeel implants and/or Rescue implants (MegaGen Implant)	Granular autogenous bone (iliac crest)	Lateral window	12	S: 1.05 (±0.20) L: 1.01 (±0.16)	S: 0 L: 3	S: 0 L: 0	98.83%	97.82%	
Esposito et al. 2014 ²⁹	15	S/L: 56	5 mm	≥ 10 mm	S: 6.0 mm L: 4.0 mm	Rescue and EZ Plus (MegaGen)	Granular anorganic bovine bone (Bio-Oss; Geistlich Pharma, Wolhusen, Switzerland)	Lateral window	36	S: 1.36 (±0.53) L: 1.74 (±0.37)	S: 4 L: 1	S: 3 L: 0	91.2%	97.3%	
Guljé et al. 2014 ³⁰	40	S: 50 L: 48	6 mm	11 mm	S/L: 4.0 mm	OsseoSpeed 4.05, Dentsply Implants	Bio-Oss granules Geistlich, Wolhusen, Switzerland	Lateral window	12	S: 0.1 (±0.2) L: 0.1 (±0.3)	S: 0 L: 0	NR	100%	100%	
Pistilli et al. 2013 (A) ³¹	40	S: 61.1 L: 58.5	5 mm	≥ 10 mm	S/L: 5.0 mm	ExFeel (MegaGen)	porcine particulate bone graft OsteoBio-GenOs, Tecross Dental	Lateral window	12	S: 1.16 (±0.30) L: 1.53 (±0.59)	S: 0 L: 5	S: 1 L: 0	97.2%	100%	
Pistilli et al. 2013 (B) ³²	20	S/L: 57.6	6 mm	≥ 10 mm	S/L: 4.0 mm	Southern Implants	porcine particulate bone graft OsteoBio-GenOs, Tecross Dental	Lateral window	12	S: 1.41 (±0.31) L: 1.53 (±0.55)	S: 0 L: 4	S: 0 L: 0	100%	100%	

Risk of bias

The Cochrane Collaboration's tool for assessing risk of bias in randomized trials indicated that all studies showed a low risk of bias for random sequence generation, allocation concealment (selection bias), incomplete outcome data (attrition bias), selective reporting (reporting bias), and other sources of bias. Regarding blinding of participants and personnel, one study reported the blinding of patients without the blinding of surgeons,¹⁸ whereas two studies reported no blinding of surgeons.^{31,32} All other studies were unclear about this parameter. This may have been due to difficulty in blinding surgeons and/or patients scheduled for auxiliary surgical, particularly in split-mouth design studies.^{29,31,32} Blinding of outcome assessment was reported for almost all included studies.^{18,21,22,23,29,31,32} However, a few studies were unclear regarding this.^{8,20,30} (Figure 2).

Implant survival rate

All the studies included the cumulative implant survival rate. Among the 911 dental implants placed in the posterior maxilla,^{8,18,19,20,21,22,23,29,30,31,32} only 18 (1.97%) failed. These included nine short implants (2.05%) and nine long implants placed after maxillary sinus augmentation (1.89%). Twelve implants were lost before loading (six short implants and six long implants). After loading, six implants were lost (three short implants and three long implants).

Among the reported lost implants, eight studies used a regular diameter,^{8,18,19,20,22,23,30,32} and five studies used a wide diameter^{8,21,23,29,31} for short implants, whereas nine studies used a regular diameter^{8,18,19,20,22,23,29,30,32} and four studies used a wide diameter^{8,21,23,31} for long implants placed after sinus augmentation. The studies reported different reasons for implant failures, such as smoking habits and periodontal disease,⁸ mobility at implant-abutment connection,^{22,23} problems with the osseointegration process, and overload caused by prostheses.²³ The results of the meta-analysis verified no difference in the survival rate between short implants and long implants placed after maxillary sinus augmentation ($p = 0.86$; RR: 1.08; 95%CI: 0.46–2.52) (Figure 3).

Marginal bone loss

Ten studies reported data in terms of the amount of marginal bone loss, which was reported in millimeters. However, only eight of these studies^{19,21,22,23,29,30,31,32} were used for meta-analysis because one study reported bone loss separately (mesial and distal),²⁰ and another study reported marginal bone loss without standard deviation.⁸ The mean amount of marginal bone loss for short implants was 0.86 mm (range: 0.10–1.41 mm), whereas for long implants placed after maxillary sinus augmentation, it was 0.99 mm (range: 0.10–1.74 mm). The meta-analysis based on MD found no significant difference between short implants and long implants ($p = 0.08$; RR: -0.05; 95%CI: -0.10 to 0.01) (Figure 4).

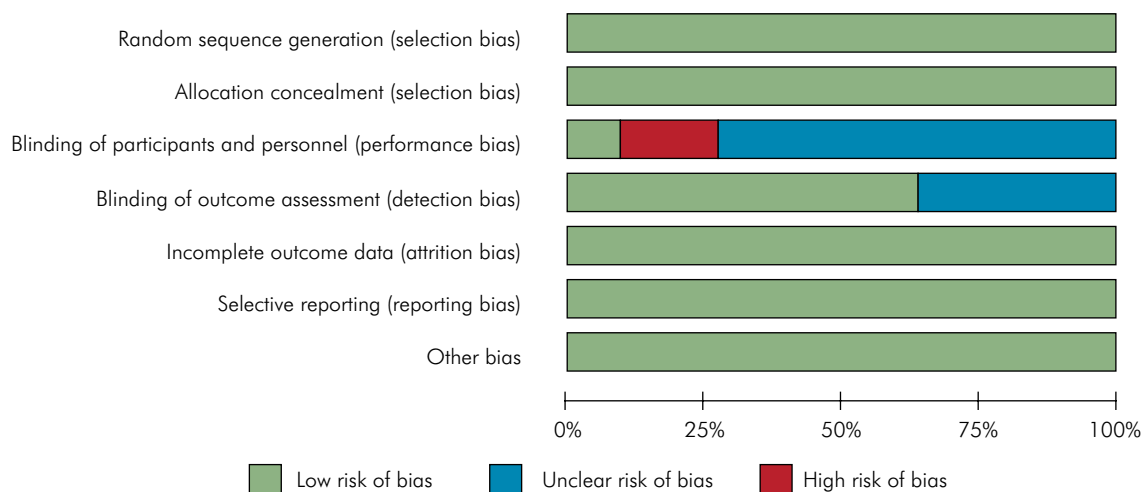


Figure 2. Included studies assessed using Cochrane Collaboration's tool for assessing risk of bias in randomized trials

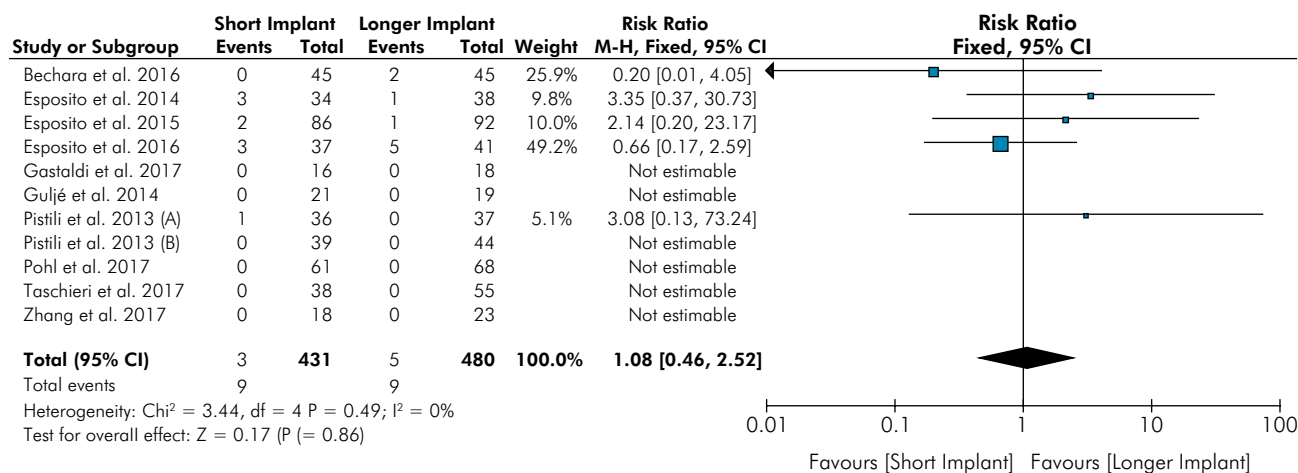


Figure 3. Forest plot for the event “implant survival”

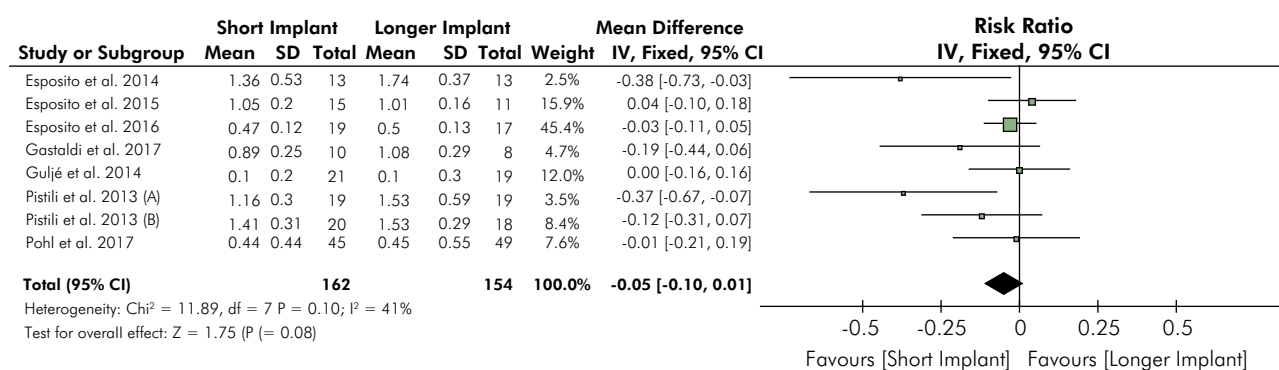


Figure 4. Forest plot for the event “marginal bone loss”

Biological complications

Biological complications were reported in eight included studies;^{8,18,21,22,23,29,31,32} however, three studies did not verify any biological complications after the follow-up period.^{19,20,30} There were immediate postoperative complications (pain and swelling after surgery, acute sinus infection) as well as late postoperative complications (chronic sinus infection, partial or total graft failure). Short implants were associated with significantly lower biological complication rates compared with long implants placed after maxillary sinus augmentation ($p < 0.00001$; RR: 0.21; 95%CI: 0.10–0.41) (Figure 5). The most common complications associated with long implants included perforated sinus membrane, palpation pain, pain and swelling after surgery, chronic sinus infection, and postoperative bleeding.^{8,21,22,23,29,32}

Prosthetic complications

Ten studies reported data for prosthetic complications;^{8,18,19,20,21,22,23,29,31,32} however, five studies did not verify the type of prosthetic complications after the follow-up period.^{8,18,20,23,32} The reported complications included fracture of the metal structures in the restoration, ceramic fractures, debonding, retention loss, abutment fracture, and fixation screw loosening.^{19,21,22,29,31} Short implants were associated with higher rates of prosthetic complications compared with long implants ($p = 0.010$; RR: 3.15; 95%p CI: 1.32–7.51) (Figure 6).

Heterogeneity

Heterogeneity was considered low for the survival rates of implants ($P = 0.49$; $I^2 = 0\%$), amount of marginal bone loss ($p = 0.10$; $I^2 = 41\%$), biological complications

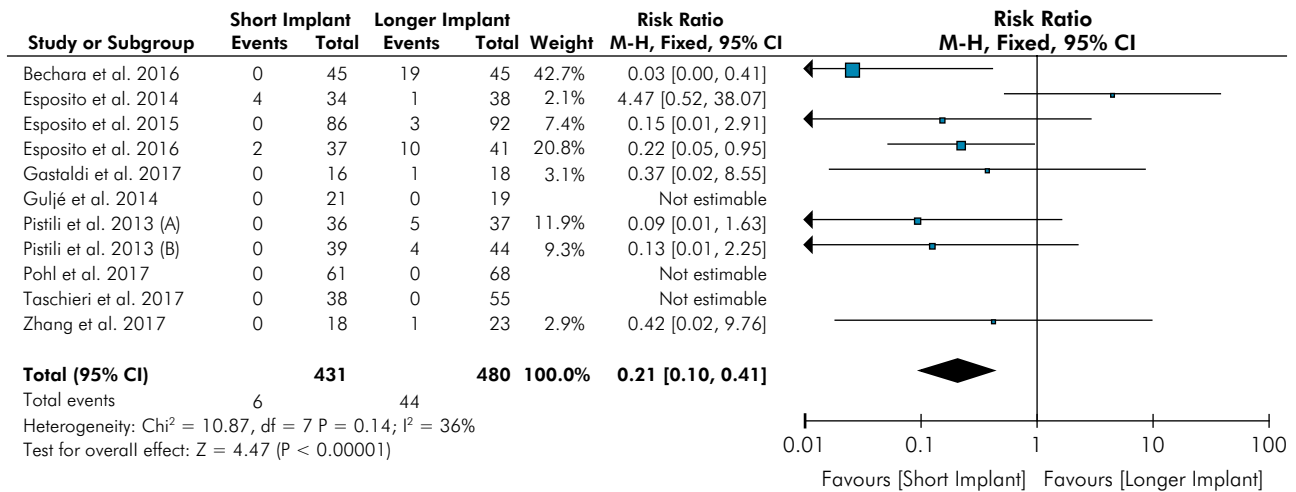


Figure 5. Forest plot for the event “biological complications”

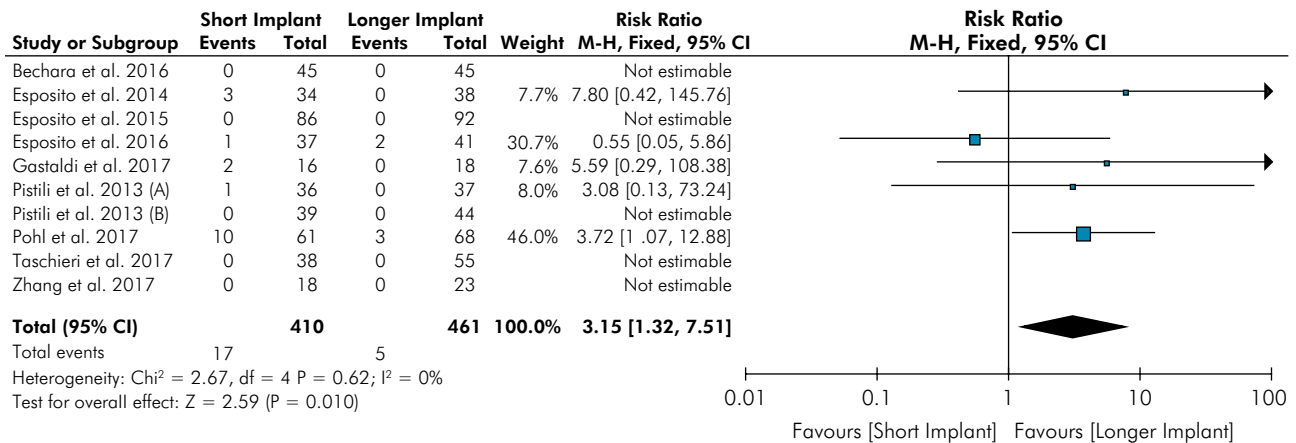


Figure 6. Forest plot for the event “prosthetic complications”

(p = 0.14; I² = 36%), and prosthetic complications (p = 0.62; I² = 0%). Furthermore, the funnel plots did not show asymmetry for all analyses, indicating the absence of publication bias (Figure 7).

Discussion

The findings of this systematic review and meta-analysis suggested that for posterior maxillary rehabilitation, short and long implant placement have similar implant survival rates. Thus, the first null hypothesis was accepted. Moreover, this finding agrees with the findings in studies reporting high

success rates for short implants used for posterior maxillary rehabilitation.^{1,8,18,44} Furthermore, different systematic reviews evaluating only short implants showed survival rates between 93.1% and 99.1%,^{45,46} which corroborate with the survival rate of 98.09% in the current review.

Among the selected studies, only five reported information pertaining to implant loss, including nine short implants and nine long implants. Accordingly, the failure rates for short and long implants were 1.90% and 1.95%, respectively. Some studies have reported mobility, chronic sinus infection, and history of periodontal disease and abscess as reasons for implant

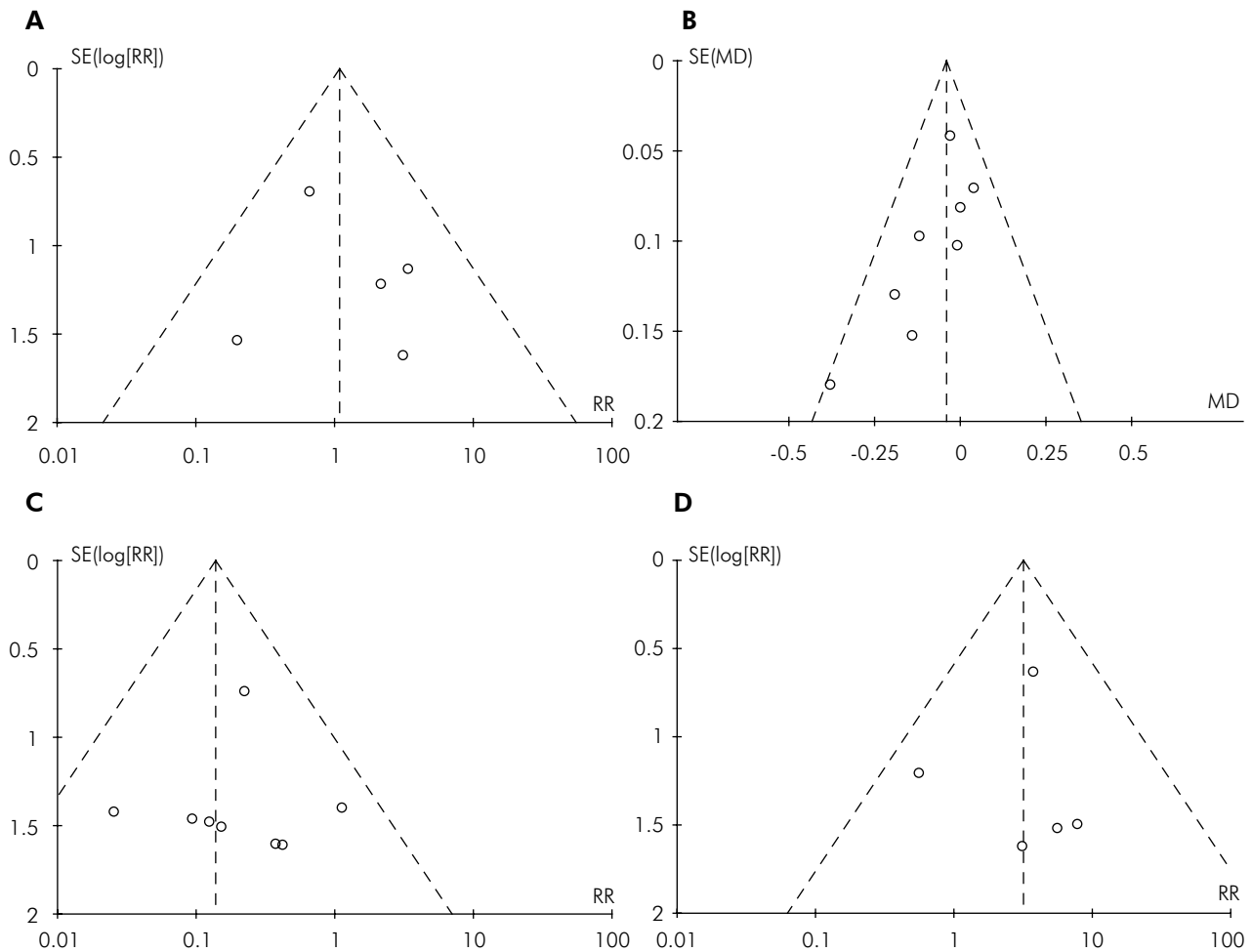


Figure 7. Funnel plot for the assessment of publication bias for A, “implant survival,” B, “marginal bone loss,” C, “biological complications,” and D, “prosthetic complications”

loss.^{8,22,23,29} However, not all studies have reported the reasons for implant loss³¹. Some risk factors may influence the survival of implants,^{47,48,49} including occlusal overload after prosthetic rehabilitation. From the biomechanical perspective, when comparing short implants with long implants, short implants may be associated with a trend for higher stresses within the implant and consequently on the cortical bone tissue.⁵⁰ However, this can be overcome by using implants with splinted crowns.^{50,51}

Another factor that may influence the increase in implant survival rate, regardless of length and diameter, is the fact that some studies report that implants with a wide diameter (≥ 5 mm) are more favorable than implants with a narrow and regular

diameter.^{52,53} No such association was found in the present systematic review and meta-analysis. Studies that used implants with a 4-mm diameter showed 100% survival rates for both types of implants.^{19,30,32} Similarly, studies that analyzed implants with a diameter of 5 mm reported survival rates of 100% for long implants placed after maxillary sinus augmentation and 97.2% for short implants.³¹ The reason for this finding may be consideration of the implant diameter as a secondary factor for the long-term survival of implants placed in the posterior maxillary region.⁵⁴

Primary stability is also essential for the success of dental implants.^{49,55} A lack of primary stability may compromise osseointegration and the longevity of osseointegrated implants.^{56,57} Analysis of the implant

stability quotient (ISQ) using devices such as the Osstell ISQ has been documented in only two studies,^{8,18} which stated high values indicating good primary stability after both short and long implant placement. Resonance frequency analysis measurements result in a mean ISQ value of 68.68 for short implants and 70.69 for long implants placed after sinus augmentation. These findings are consistent with those of a previous study reporting the achievement of good primary stability for short implants.⁵⁸ Furthermore, these values are within the limits previously established in the literature (54–74 ISQ).⁵⁹

The literature suggests that modification of the implant design and surface may accelerate the process of osseointegration and influence the success of dental implants,⁶⁰ primarily in the analysis of short implants and machined implants.^{47,49} The surface properties of the implant have been identified as an important factor for osseointegration.^{61,62} Bechara et al.⁸ performed a unique study that assessed implant surfaces reinforced with nanostructured calcium and reported a high success rate for both long implants placed after maxillary sinus augmentation (95.6%) and short implants (100%); however, the study did not perform comparisons with other surfaces. Therefore, it is difficult to conclude whether there is an actual benefit in terms of the success rate, particularly for short implants.

Marginal bone stability is another relevant factor for implant-supported rehabilitation because excess bone loss is considered as one of the secondary factors that may lead to implant loss.⁶³ However, the current analysis finds no difference in the marginal bone loss between short implants and long implants placed after maxillary sinus augmentation. Thus, the second hypothesis was also accepted. Moreover, this finding is consistent with previous data showing similarity in marginal bone loss values for short and long implants placed in the posterior jaw.¹

Although there was no difference in marginal bone loss in the present systematic review, it is important to note that several studies observed greater marginal bone loss with long implants placed after maxillary sinus augmentation.^{8,21,29,31,32} This bone loss may have occurred because long implants are supported on grafted bone, which is considered to be of poorer

quality compared with natural bone.⁶⁴ In this way, it is indicated that the use of short implant is preferable considering only the bone loss aspect. However, no difference for bone loss between implant lengths was observed in this study. In addition, prosthetic complications are statistically more common for long implants and preclude a simple explanation. It is important to emphasize that bone loss may be influenced by several factors such as the implant geometry,⁶⁵ parafunctional habits,⁶⁶ crown fixation system,⁶⁷ biological factors,⁶⁸ systemic factors,⁶³ overheating during surgical preparation,^{44,47} and the prosthesis loading condition.²⁵ However, because of lack of data in the included studies, we could not perform sub-analyses based on these variables, and this may be considered as a limitation to our study.

The third hypothesis was rejected because significant differences were found in the biological and prosthetic complication rates between short implants and long implants placed after maxillary sinus augmentation. In the quantitative analysis of biological complications, a higher rate for long implants than for short implants was seen, which is consistent with previous findings showing an increased risk of biological complications after the performance of complementary surgical procedures for bone augmentation.^{44,69}

The use of auxiliary techniques such as maxillary sinus augmentation is less accepted than conventional implant placement techniques because it results in increased morbidity, costs, and surgical duration^{35,70} along with an increase in the time required for rehabilitation.³⁵ The main complications reported in the included studies were membrane perforation, bleeding and sinusitis,^{8,18,22,29,31,32} and pain and swelling.^{8,22,23} However, these factors, even if documented as complications, cannot be considered limiting in terms of the decision to perform maxillary sinus augmentation for long implant placement, particularly if the dental surgeon has a good learning curve.

Regarding the rate of prosthetic complications, short implants are considered unfavorable compared with long implants. These results are in agreement with those reported in the literature, which indicate higher risks of prosthetic complications with the use of short implants because of an increase in the C/I

ratio, which leads to mechanical failures such as loosening, pillar bolt, and ceramic fractures.^{19,22,29,31,71,72} Verri et al.⁷³ reported that a C/I ratio of 1:1 may be considered more favorable in terms of lowering the risk of mechanical or prosthetic complications.

The results of the present review must be evaluated with care due to the limitations presented in the selected studies. One limitation of our review is the short follow-up period in some included studies and the small sample size in others. Moreover, some selected studies did not report failure rates for the different variables such as diameter, implant-abutment connection, C/I ratio, and others. Finally, in some studies, the length of the implants was selected by the surgeon according to individual

clinical circumstances. Further RCTs that include parameters that may influence the findings such as C/I ratio, splinting factor, implant geometry, and implant surface, should be conducted.

Conclusion

In conclusion, our findings suggest that short implant placement is an effective alternative to long implant placement with maxillary sinus augmentation because of fewer biological complications and similar survival and marginal bone loss. However, the risk of mechanical complications associated with the prostheses fitted on short implants should be considered.

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