BMJ Open

# Ultrashort implants versus longer implants with sinus floor elevation in severely atrophic posterior maxilla: a systematic review and meta-analysis



| | |
|---|---|
| Journal: | *BMJ Open* |
| Manuscript ID | bmjopen-2019-029826 |
| Article Type: | Research |
| Date Submitted by the Author: | 13-Feb-2019 |
| Complete List of Authors: | Yan, Qi; School & Hospital of Stomatology, Wuhan University, Department of Oral Implantology<br>Wu, Xinyu; School & Hospital of Stomatology, Wuhan University, Department of Oral Implantology<br>Su, Meiying; School & Hospital of Stomatology, Wuhan University, Department of Oral Implantology<br>Hua, Fang; School & Hospital of Stomatology, Wuhan University, Centre for Evidence-Based Stomatology; Division of Dentistry, The University of Manchester, Cochrane Oral Health<br>Shi, Bin; School & Hospital of Stomatology, Wuhan University, Department of Oral Implantology |
| Keywords: | ORAL & MAXILLOFACIAL SURGERY, SYSTEMATIC REVIEW, Ultrashort Dental Implant, Sinus Floor Elevation, Evidence-Based Dentistry, Oral Implantology |
| | |

# Ultrashort implants versus longer implants with sinus floor elevation in severely atrophic posterior maxilla: a systematic review and meta-analysis

Qi Yan [1, 2, a], Xinyu Wu [1, 2, a], Meiying Su [2], Fang Hua [3, 4, *], Bin Shi [1, 2, *]

1. Hubei-MOST KLOS & KLOBM, School & Hospital of Stomatology, Wuhan University, Wuhan, China.
2. Department of Oral Implantology, School and Hospital of Stomatology, Wuhan University, Wuhan, China.
3. Centre for Evidence-Based Stomatology, School & Hospital of Stomatology, Wuhan University, Wuhan, China
4. Division of Dentistry, School of Medical Sciences, Faculty of Biology, Medicine and Health, University of Manchester, Manchester Academic Health Science Centre, Manchester, UK

[a] Qi Yan and Xinyu Wu contributed equally to this work.

[*] **Corresponding authors:**

Fang Hua

Centre for Evidence-Based Stomatology, School & Hospital of Stomatology,

Wuhan University, 237 Luoyu Rd, Wuhan 430079, China

Tel: +86 27 87686226

Email: huafang@whu.edu.cn

Bin Shi

Department of Oral Implantology, School & Hospital of Stomatology,

Wuhan University, 237 Luoyu Rd, Wuhan 430079, China

Tel: +86 27 87686222

Email: Shibin_dentist@whu.edu.cn

## Abstract

**Objectives:** To compare the use of ultrashort implants ( ≤ 6 mm) in severely atrophic posterior maxilla versus longer implants ( ≥ 10 mm) with sinus floor elevation.

**Methods:** Electronic searches in PubMed, Embase and the Cochrane CENTRAL were conducted by two independent authors. Retrospective and prospective hand searches were also performed. The outcome measures included implant survival (primary outcome), marginal bone loss (MBL) and adverse events. Quality of evidence were assessed according to GRADE.

**Results:** A total of seven randomized controlled trials involving 310 participants were included. No significant difference in survival rate was found for one- to three-year follow-up (RR=1.01, 95% CI: 0.97, 1.04, p=0.74, $I^2$ = 0%, moderate quality evidence) or for three-year or longer follow-up (RR=1.00, 95% CI: 0.97, 1.04, p=0.79, $I^2$ = 0%, moderate quality evidence). However, ultrashort implants showed significantly less MBL in one- to three-year follow-up (MD=-0.13 mm, 95% CI: -0.21, -0.05; p=0.001, $I^2$ = 87%, low quality evidence) and in three-year or longer follow-up (MD=-0.25 mm, 95% CI: -0.40, -0.10; p=0.001, $I^2$ = 0%, moderate quality evidence). In addition, ultrashort implant resulted in fewer surgery-related adverse events.

**Conclusions:** For atrophic posterior maxilla, ultrashort implants are a promising alternative to sinus floor elevation. However, use of ultrashort implants might lead to more late adverse events. Additional high-quality studies are needed to evaluate the long-term effectiveness of ultrashort implants.

**Clinical Significance:** Ultrashort implants could be recommended in atrophic posterior maxilla as an alternative to sinus floor elevation. Attention should be paid to avoid late adverse events in clinical practice.

**Registration:** PROSPERO (CRD42018103531).

**Keywords:** ultrashort dental implant; sinus floor elevation; systematic review; oral implantology

**Word count:** 3032 (main text); 254 (abstract)

**Strengths**

- Only randomized controlled trials were sought and included.
- Participant-unit data were used for syntheses.
- Subgroup analyses by follow-up length were performed.

**Limitations**

- Serious risk of bias was found within and across studies and the quality of evidence was only low to moderate.

## 1. Introduction

Dental implants supporting prostheses are commonly considered a promising method for the rehabilitation of missing teeth.[1-3] However, dental implantation in the posterior maxilla is usually challenging due to insufficient vertical bone volume, poor bone quality, limited visibility, reduced inter-arch space, and sinus pneumatisation.[4 5] These conditions are exacerbated if patients have a history of wearing removable dentures.[6]

To achieve sufficient bone volume in the posterior maxilla, sinus floor elevation using the lateral window approach or the osteotomy technique have been introduced and widely used over the past 40 years.[7 8] Using these techniques with or without bone grafting, conventional implants can be placed in the elevated sites. The implant success rate is typically greater than 90% in long-term evaluation.[9-11] The lateral window approach is used in up to 22.1% of all dental implantation procedures.[12] However, sinus floor elevation surgery is usually associated with higher cost, more complicated surgical procedures, and a high prevalence of complications such as infection, sinus membrane perforation and graft failure.[13-15] In addition, the clinical outcome of sinus floor elevation can also be restricted by extremely insufficient residual bone height, abnormal sinus anatomy, thickening of the sinus membrane, stability of the grafted bone and the number of missing teeth.[16-19]

Short implants with improved implant design and surface properties have been successfully applied as an alternative to sinus floor elevation surgery and have shown good results in posterior maxilla. Implants $\leq$ 10 mm,[20] $\leq$ 8 mm,[21] $\leq$ 7 mm,[22] and 6-8 mm [23] have been reported to have survival rates comparable to those of longer implants. For severely atrophic maxilla in which even short implants necessitate sinus floor elevation, ultrashort implants, defined as implants $\leq$ 6 mm in length, have been introduced as another alternative.[6 24 25] Ultrashort implants require a less complicated

surgical approach and are used in cases when sinus floor elevation surgery is not applicable,[26 27] especially in cases of maxillary sinusitis, maxillary cyst, large vessels and other cases involving abnormal sinus anatomy. Studies have explored the short- and long-term survival rates of ultrashort implants.[27-31] Unfortunately, evidence supporting the use of ultrashort implants in the posterior maxilla is weak, and no guideline statement is currently recommended.

The present systematic review aimed to compare the effectiveness of ultrashort implants and longer implants ($\geq$ 10 mm) with sinus floor elevation in atrophic posterior maxilla. Outcome measures of interest included survival rate, marginal bone loss (MBL) and adverse events.

## 2. Materials and methods

### *2.1 Protocol and registration*

This systematic review and meta-analysis was reported in accordance with the PRISMA guidelines.[32] The review protocol has been registered at PROSPERO (CRD42018103531).

### *2.2 Eligible criteria*

Randomized controlled trials (RCTs) meeting the following pre-determined inclusion criteria were included:

- Partially edentulous patients in the premolar and molar regions of the maxilla, for whom the residual bone height in the atrophic posterior maxilla was sufficient for the insertion of an ultrashort implant but insufficient for the insertion of longer implants;
- One or more ultrashort implants were placed in the posterior maxilla without

sinus floor elevation in the ultrashort implant group;

- One or more longer implants were placed in the posterior maxilla after sinus floor elevation by any technique in the elevation group;
- One year or longer follow-up period; and
- The primary (survival rate) and secondary (MBL and adverse events) outcomes of interest were measured.

*2.3 Information sources and search strategies*

Two authors (QY and XW) searched PubMed, Embase, and the Cochrane CENTRAL (The Cochrane Central Registration of Controlled Trials) for RCTs, independently and in duplicate. A third author (FH) was consulted to resolve any disagreements. Main search terms included: "dental implant", "short implant", "ultrashort", "alveolar bone loss", "atrophic maxilla", "sinus lift", and "sinus floor elevation". No restriction was set regarding publication year, publication language or status. The last search was conducted on 31/05/2018. The detailed search strategies are listed in **appendix 1**. In addition, retrospective and prospective searches were conducted by checking the reference lists of key articles and studies citing these key articles, using Google Scholar.

*2.3 Study selection and data collection*

Two review authors (QY and XW) conducted the study selection independently and in duplicate. The titles and abstracts of all records were scanned. Full texts of studies were obtained in cases they appeared to meet the inclusion criteria or further information were needed to determine eligibility. Studies excluded at this or subsequent stages were recorded with the reasons for exclusion. All disagreements were resolved by discussion.

Two review authors extracted the data independently and in duplicate using

specifically designed data extraction forms. The extracted data included citation details (year of publication, country of origin, setting and source of funding), details on the participants (demographic characteristics, residual bone height and inclusion criteria), details of intervention (implant length, diameter, brand, surface structure, surgical method, follow-up time, prosthesis type), outcome assessment, sample size calculation and trial registration. Corresponding authors were conducted for missing data or information.

*2.4 Risk of bias of included studies*

Two authors (QY and XW) assessed the risk of bias of each included study independently and in duplicate using the Cochrane risk of bias assessment tool for RCTs.[33] Disagreements were resolved through discussion. A third review author (F.H.) was consulted when necessary. Seven domains were assessed, including sequence generation (selection bias), allocation concealment (selection bias), blinding of participants and personnel (performance bias), blinding of outcome assessment (detection bias), incomplete outcome data (attrition bias), selective outcome reporting (reporting bias) and other bias (factors that had potential influence on outcomes but were not evenly distributed across groups or not clearly reported, such as the manufacturer or diameter of implants). Individual studies were categorized as having low, high or unclear risk of bias. The risk of bias across studies was determined according to the risk of bias in each included study.

*2.5 Assessment of heterogeneity and publication bias*

Clinical heterogeneity among the included studies was assessed by comparing study design, participant conditions (residual bone height), intervention (implant length,

diameter, surface structure, surgical method), and outcome measures. Statistical heterogeneity was evaluated using Cochrane's Q test and the $I^2$ statistic. In the Q test, a P value < 0.1 was considered an indication of significant heterogeneity.

*2.6 Publication bias*

If at least ten studies were included in a meta-analysis, We would have used a funnel plot and the Egger's test [34] asymmetry to assess the potential existence of publication bias if at least ten studies were included in a meta-analysis.

*2.7 Synthesis of results*

The unit of analysis was set as participant rather than implant.[35] RevMan 5.3 software was used for data synthesis. Meta-analyses were undertaken only when at least two studies that made similar comparisons reported the same outcomes. The effect measures were risk ratio (RR) for dichotomous outcomes and mean difference (MD) for continuous outcomes. P<0.05 was considered statistically significant. The fixed effect model was used when fewer than four studies were included in a meta-analysis, and the random-effects model was used when four or more studies were included.

*2.8 Additional analysis*

Subgroup analysis by length of follow-up was performed to control for the possibility that function time might influence implant survival.[36] If risks of bias in some studies were serious, we would have performed sensitivity analysis by excluding these studies.

*2.9 Summary of findings (SoF)*

Grading of Recommendations Assessment, Development, and Evaluation (GRADE)

approach [37] was adopted to evaluate quality of evidence in this systematic review. A SoF table was made with an online tool (cebgrade.mcmaster.ca/gradepro). Outcomes were evaluated including survival rate and MBL of one to three-year and three-year or longer follow-up, respectively. Five domains in quality of evidence were assessed: the overall risk of bias, directness of evidence, consistency of results, precision of estimates, as well as the risk of publication bias. The quality of the body of evidence was classified into four categories: high, moderate, low and very low.

*2.10 Patient and Public involvement*

The present work does not include original patient data. Therefore, patients and the public were not involved.

## 3. Results

*3.1 Study selection*

Electronic searches identified a total of 879 titles and abstracts in PubMed and 251 in Embase. After removal of duplicates, the titles and abstracts of 1,013 unique items were screened. We then retrieved the full texts of 25 potentially eligible articles, of which 20 were excluded for reasons described in **figure 1**. Retrospective and prospective hand searches yielded two more studies. Finally, seven studies [30 38-43] met our eligibility criteria and were included in this review.

*3.2 Study characteristics*

The characteristics of the seven included studies are listed in **table 1**. One study was a split-mouth trial, and the rest were two-arm parallel RCTs. The length of follow-up ranged from one year to three years. For sinus floor elevation, either osteotomy-

mediated sinus floor elevation or the lateral window technique was adopted. In two studies, single crowns were used as the rehabilitation method; in the remaining studies, single crowns or fixed partial dentures were used. The outcome measures used in these studies included implant failure, MBL and complications. Overall, 171 participants were included in the ultrashort implant groups, and 159 participants were included in the elevation groups.

*3.3 Risk of bias assessment*

The results of the risks of bias assessment are shown in figures 2 and 3. Selection bias and performance bias were assessed as low in all but one study by Bachara et al[43] due to inadequate description on random sequence generation and blinding of participants. For detection bias, most studies showed high risks because assessors could recognize sites that underwent sinus floor elevation. For attrition bias, only one study[30] was assessed as low because unbalanced drop-out occurred in most studies. Two studies[41] [43] showed high risk of reporting bias. Other risks of bias were considered high or unclear in three studies. Overall, all included studies were at high risk of bias for at least one domain **(table 2)**.

*3.4 Synthesis of results*

3.4.1 Survival rate

Figure 4 shows the results of a meta-analysis for participant unit implant survival rate with a subgroup analysis based on length of follow-up. Four studies reported 100% survival of ultrashort implants within the study period. For this outcome, there was no evidence of a difference between the ultrashort implant group and the elevation group

either one year to three years post-loading (RR=1.01, 95% CI: 0.97, 1.04, p=0.74, $I^2$ = 0%, seven RCTs, 321participants) or three years or longer post-loading (RR=1.00, 95% CI: 0.97, 1.04, p=0.79, $I^2$ = 0%, five RCTs, 237 participants). Further details of the implant failures are summarized in **table 3**.

3.4.2 MBL

The results of the meta-analysis and subgroup analysis regarding peri-implant MBL are shown in figure 5. A significant difference favoring the ultrashort implant group was found for both one year or longer post-loading (MD=-0.13, 95% CI: -0.21, -0.05; p=0.001, $I^2$ = 87%, six RCTs, 249 participants) and three years or longer post loading (MD=-0.25, 95% CI: -0.40, -0.10; p=0.001, $I^2$ = 0%, three RCTs, 88 participants).

3.4.3 Adverse events

Adverse events occurring before and after loading were categorized into "early adverse events" and "late adverse events", respectively. Overall, 23 adverse events occurred in the ultrashort implant group; of these, 4 (17.40%) were early adverse events, and 19 (82.60%) were late adverse events. Fifty-six adverse events were reported for the elevation group; of these, 46 (82.14%) were early adverse events, and 10 (17.86%) were late adverse events. Most early adverse events were related to surgical procedures, whereas late adverse events mainly included prosthesis complications and peri-implantitis. Further details of the reported adverse events are listed in **table 4**.

*3.5 Quality of evidence*

For survival rate, the quality of evidence in both subgroups were downgraded by one level (moderate quality evidence) due to serious risks of bias. For short-term MBL (one

to three-year follow-up), quality of evidence was downgraded by two levels for serious risks of bias and inconsistency. For long-term MBL (three-year or longer follow-up), quality of evidence was downgraded by one level for serious risks of bias. Details are listed in **table 5**.

## 4. Discussion

To the best of our knowledge, this is the first systematic review and meta-analysis to compare the clinical outcome of the use of ultrashort implants in severely atrophic posterior maxilla versus longer implants with sinus floor elevation. At one year or longer post-loading, there is no significant difference in participant unit implant survival rate between the ultrashort implant group and the elevation group. The ultrashort implant group showed less MBL than the elevation group for one to three-year follow-up (low quality evidence) and three-year or longer follow-up (moderate quality evidence). In addition, the ultrashort implant group showed fewer surgery-related adverse events.

The survival rate in this review was evaluated by participant unit as in a previous Cochrane review.[35] In this review, the overall survival rates for the ultrashort implant group and the elevation group were 98.21% and 96.08%, respectively, at one-year to three-year follow-up and 99.20% and 98.23%, respectively, at longer than three-year follow-up; no significant difference in survival rate was found. Other studies that assessed survival rate in implant unit had similar outcomes. A retrospective study[44] with a follow-up period of 17 to 48 months reported a 95.12% implant unit survival rate for 5-mm to 6-mm ultrashort implants. A two-year to three-year prospective study [6] reported that 6-mm ultrashort implants with micro rough surfaces achieved a 100% survival rate in posterior maxilla. Another five- to ten-year retrospective study [45]

reported a 97% implant unit survival rate for 6-mm ultrashort implants supporting single crowns. All these results showed that ultrashort implants represent a promising rehabilitation method with respect to their short-term and long-term survival rates.

In this review, all of the failed ultrashort implants were 4 mm or 5 mm. Although the use of ultrashort implants could avoid complicated surgical procedures and related early failures, reduced implant length was still the major risk factor in survival rate. The authors of the included studies used wider implants (4 mm to 8 mm) to compensate for the short length of the implants. Finite element analyses showed that wider implants had increased functional surface area in cortical bone and decreased stress distribution on the implant neck; these qualities helped improve primary stability, produce a higher survival rate and reduce MBL.[46-49] However, it was not determined whether implant length or diameter contributed more to implant failure. Another factor was implant surface structure. Studies [50-53] have suggested that the implant surface influences bone-to-implant osseointegration, implant primary stability and MBL. In this review, implants 4 mm or 5 mm in length had novel surface structures, but they still presented a lower survival rate. It seemed that implant length had a greater influence than implant surface structure on survival rate.

Significantly less MBL was found in the ultrashort implant group, and the difference was greater at the longer follow-up period. Additionally, in this review, 5-mm-diameter implants tended to induce less MBL than 4-mm-diameter implants. Implants $\leq$ 10 mm [20] and $\leq$ 8 mm [21] were reported to induce MBL similar to that of longer implants, while implants $\leq$ 7 mm [54] showed less MBL. These results contradict a previous theory that ultrashort implants are more likely to have an extreme crown-to-implant ratio (C/I) [55] that induces more peri-implant bone loss and early implant failure.[56 57] According to finite element analyses, inappropriate C/I results in adverse occlusal forces such as non-

axial forces and overloading.[58] Increased C/I was also correlated with more prosthesis complications such as screw loosening, implant or abutment fracture, chipping of the ceramic material, and prosthesis fracture.[59-62] However, the implants in the studies included in this systematic review had wider diameters (4 mm to 8 mm) and different surface structures. These two factors partially compensated for the adverse effects of C/I and contributed to less MBL. Differences in implant diameter and surface structure also introduced heterogeneity among studies with respect to MBL. Ultrashort implants tolerated less MBL because of the limited implant length. As a result, less MBL was not necessarily correlated with better clinical outcome. MBL around ultrashort implants is still a challenging issue, and much effort should be made to resolve it.

With respect to adverse events, the use of ultrashort implants could decrease the incidence of surgery-related early adverse events. Thoma et al. [63] reported that more complications occurred in cases involving longer implants with sinus floor elevation and that the surgical procedure made a major contribution to adverse events. Sinus membrane perforation was common in the elevation group and was troublesome, time-consuming and expensive.[14] In addition, implant migration into the sinus, often with the co-occurrence of sinus infection, had a higher prevalence in the elevation group. When implant migration occurs, implants may be removed, thus leading to implant failure.[64] In contrast, ultrashort implants might lead to more late adverse events, which were mainly associated with inappropriate loading. Problems of overloading could be solved by improving the design of the implants [65] or increasing their diameter. With respect to the prevalence and severity of adverse events, the use of ultrashort implants was acceptable and was a promising alternative to sinus floor elevation.

The present study has several strengths. Firstly, we conducted a comprehensive literature search, and all included studies were RCTs. Secondly, participant was used

as the unit of analysis to ensure logical statistical syntheses and relevant interpretations. Thirdly, subgroup analysis by follow-up length was performed to reduce bias across studies. However, the evidence included in this systematic review was only of moderate or low quality. Serious risks of bias were found within and across studies. The number of participants and the follow-up period were limited. We suggest that researchers in this field carry out more well designed, long-term and large-scale RCTs to provide high quality evidence regarding the effects of ultrashort implants.

## 5. Conclusions

Within its limitations, the present review suggests that the survival rate of maxillary ultrashort implants was comparable to that of longer implants (≥10 mm) with sinus floor elevation. However, ultrashort implants show significantly less MBL and fewer surgery-related adverse events. Ultrashort implants are therefore a promising alternative to sinus floor elevation for posterior maxilla with insufficient bone volume. Additional high-quality studies are needed to evaluate the long-term effectiveness and safety of ultrashort implants.

**Author contributions** Conception and design of the review: FH and BS. Methodology: QY and FH. Drafting protocol, performing search strategies, literature searches, literature screening and data extraction: QY and XW. Original draft preparation: XW. Reviewing and editing draft: MS, QY, FH and BS. All authors critically reviewed and revised the manuscript and approved the final version for publication.

**Funding** This work was supported by the National Clinical Key Specialties Construction Project ([2013]544), National Health Commission of China.

**Competing interests** None declared.

**Patient consent** Not required.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data sharing statement** The data may be obtained from the authors for academic purposes.

## References


1. Spitznagel FA, Horvath SD, Gierthmuehlen PC. Prosthetic protocols in implant-based oral rehabilitations: A systematic review on the clinical outcome of monolithic all-ceramic single- and multi-unit prostheses. European Journal of Oral Implantolantology 2017;10 Suppl 1:89-99.
2. Pjetursson BE, Thoma D, Jung R, et al. A systematic review of the survival and complication rates of implant-supported fixed dental prostheses (FDPs) after a mean observation period of at least 5 years. Clincal Oral Implants Research 2012;23 Suppl 6:22-38.
3. Davarpanah M, Martinez H, Etienne D, et al. A prospective multicenter evaluation of 1,583 3i implants: 1- to 5-year data. International Journal of Oral & Maxillofacial Implants 2002;17(6):820-8.
4. Esposito M, Felice P, Worthington HV. Interventions for replacing missing teeth: augmentation procedures of the maxillary sinus: John Wiley & Sons, Ltd 2014.
5. Morand M, Irinakis T. The challenge of implant therapy in the posterior maxilla: providing a rationale for the use of short implants. Journal of Oral Implantology 2007;33(5):257-66.
6. Malchiodi L, Caricasulo R, Cucchi A, et al. Evaluation of Ultrashort and Longer Implants with Microrough Surfaces: Results of a 24- to 36-Month Prospective Study. International Journal of Oral & Maxillofacial Implants 2017;32(1):171-79.
7. Danesh-Sani SA, Loomer PM, Wallace SS. A comprehensive clinical review of maxillary sinus floor elevation: anatomy, techniques, biomaterials and complications. British Journal of Oral Maxillofacial Surgery 2016;54(7):724-30.
8. PI, Hansson BO, Adell R, et al. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. Scandinavian Journal of Plastic and Reconstructive Surgery Supplementum 1977;16:1-132.
9. Starch-Jensen T, Aludden H, Hallman M, et al. A systematic review and meta-analysis of long-term studies (five or more years) assessing maxillary sinus floor augmentation. International Journal of Oral & Maxillofacial Surgery 2018;47(1):103-16.
10. Starch-Jensen T, Schou S. Maxillary Sinus Membrane Elevation With Simultaneous Installation of Implants Without the Use of a Graft Material: A Systematic Review. Implant dentistry 2017;26(4):621-33.
11. Lee SA, Lee CT, Fu MM, et al. Systematic Review and Meta-Analysis of Randomized Controlled Trials for the Management of Limited Vertical Height in the Posterior Region: Short Implants (5 to 8 mm) vs Longer Implants (> 8 mm) in Vertically Augmented Sites. International Journal of Oral & Maxillofacial Implants 2014;29(5):1085.
12. Cha HS, Kim JW, Hwang JH, et al. Frequency of bone graft in implant surgery.

Maxillofacial plastic and reconstructive surgery 2016;38(1):19.
13. Pjetursson BE, Tan WC, Zwahlen M, et al. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. Journal of Clinical Periodontology 2008;35(Supplement s8):216-40.
14. Tan WC, Lang NP, Zwahlen M, et al. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. Part II: transalveolar technique. Journal of Clinical Periodontology 2008;35(8 Suppl):241-54.
15. Thoma DS, Zeltner M, Husler J, et al. EAO Supplement Working Group 4 - EAO CC 2015 Short implants versus sinus lifting with longer implants to restore the posterior maxilla: a systematic review. Clinical Oral Implants Research 2015;26 Suppl 11:154-69.
16. Lundgren S, Cricchio G, Hallman M, et al. Sinus floor elevation procedures to enable implant placement and integration: techniques, biological aspects and clinical outcomes. Periodontology 2000 2017;73(1):103-20.
17. Pjetursson BE, Tan WC, Zwahlen M, et al. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. Journal of Clinical Periodontology 2010;35(s8):216-40.
18. Huang HL, Fuh LJ, Ko CC, et al. Biomechanical effects of a maxillary implant in the augmented sinus: a three-dimensional finite element analysis. International Journal of Oral Maxillofacial Implants 2009;24(3):455-62.
19. Lin YH, Yang YC, Wen SC, et al. The influence of sinus membrane thickness upon membrane perforation during lateral window sinus augmentation. Clinical Oral Implants Research 2016;27(5):612-17.
20. Monje A, Suarez F, Galindo-Moreno P, et al. A systematic review on marginal bone loss around short dental implants (<10 mm) for implant-supported fixed prostheses. Clinical Oral Implants Research 2015;25(10):1119-24.
21. Nielsen HB, Schou S, Isidor F, et al. Short implants (</=8mm) compared to standard length implants (>8mm) in conjunction with maxillary sinus floor augmentation: a systematic review and meta-analysis. International Journal of Oral & Maxillofacial Surgery 2018
22. Uehara PN, Matsubara VH, Igai F, et al. Short Dental Implants (≤7mm)VersusLonger Implants in Augmented Bone Area: A Meta-Analysis of Randomized Controlled Trials. Open Dentistry Journal 2018;12:354-65.
23. Al Amri MD, Abduljabbar TS, Al-Johany SS, et al. Comparison of clinical and radiographic parameters around short (6 to 8 mm in length) and long (11 mm in length) dental implants placed in patients with and without type 2 diabetes mellitus: 3-year follow-up results. Clinical Oral Implants Research 2016;28
24. Urdaneta RA, Daher S, Leary J, et al. The survival of ultrashort locking-taper

implants. International Journal of Oral & Maxillofacial Implants 2012;27(3):644-54.

25. Markose J, Eshwar S, Srinivas S, et al. Clinical outcomes of ultrashort sloping shoulder implant design: A survival analysis. Clinical Implant Dentistry and Related Research 2018;20(4):646-52.
26. Fan T, Li Y, Deng WW, et al. Short Implants (5 to 8 mm) Versus Longer Implants (>8 mm) with Sinus Lifting in Atrophic Posterior Maxilla: A Meta-Analysis of RCTs. Clinical Implant Dentistry & Related Research 2016;19(1):207-15.
27. Deporter DA, Ogiso B, Sohn DS, et al. Ultrashort sintered porous-surfaced dental implants used to replace posterior teeth. Journal of Periodontology 2008;79(7):1280-86.
28. Sahrmann P, Naenni N, Jung RE, et al. Success of 6-mm Implants with Single-Tooth Restorations: A 3-year Randomized Controlled Clinical Trial. Journal of Dental Research 2016;95(6):623-28.
29. Felice P, Checchi L, Barausse C, et al. Posterior jaws rehabilitated with partial prostheses supported by 4.0 x 4.0 mm or by longer implants: One-year post-loading results from a multicenter randomised controlled trial. European journal of oral implantology 2016;9(1):35-45.
30. Bolle C, Felice P, Barausse C, et al. 4 mm long vs longer implants in augmented bone in posterior atrophic jaws: 1-year post-loading results from a multicentre randomised controlled trial. European Journal of Oral Implantology 2018;11(1):31-47.
31. Calvo-Guirado JL, Lopez Torres JA, Dard M, et al. Evaluation of extrashort 4-mm implants in mandibular edentulous patients with reduced bone height in comparison with standard implants: a 12-month results. Clinical Oral Implants Research 2016;27(7):867-74.
32. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. Bmj British Medical Journal 2009;339:b2700.
33. Higgins JPT GS, editor(s). Cochrane Handbook for Systematic Reviews of Interventions version 5.1.0 (updated March 2011): The Cochrane Collaboration, 2011. Available from www.cochrane-handbook.org.
34. Egger M, Davey SG, Schneider M, et al. Bias in meta-analysis detected by a simple, graphical test. Bmj British Medical Journal 1997;316(7129):469-71.
35. Esposito M, Ardebili Y, Worthington HV. Interventions for replacing missing teeth: different types of dental implants. The Cochrane database of systematic reviews 2014(7):Cd003815.
36. Tolentino da Rosa de Souza P, Binhame Albini Martini M, Reis Azevedo-Alanis L. Do short implants have similar survival rates compared to standard implants in

posterior single crown?: A systematic review and meta-analysis. Clinical Implant Dentistry and Related Research 2018

37. Andrews J, Guyatt G, Oxman AD, et al. GRADE guidelines: 14. Going from evidence to recommendations: the significance and presentation of recommendations. Journal of clinical epidemiology 2013;66(7):719-25.
38. Gastaldi G, Felice P, Pistilli V, et al. Posterior atrophic jaws rehabilitated with prostheses supported by 5 × 5 mm implants with a nanostructured calcium-incorporated titanium surface or by longer implants in augmented bone. 3-year results from a randomised controlled trial. European Journal of Oral Implantology 2018;11(1):49-61.
39. Gastaldi G, Felice P, Pistilli R, et al. Short implants as an alternative to crestal sinus lift: a 3-year multicentre randomised controlled trial. European Journal of Oral Implantology 2017;10(4):391-400.
40. Guljé FL, Raghoebar GM, Vissink A, et al. Single crowns in the resorbed posterior maxilla supported by either 6-mm implants or by 11-mm implants combined with sinus floor elevation surgery: a 1-year randomised controlled trial. European Journal of Oral Implantology 2014;7(3):247-55.
41. Pohl V, Thoma DS, Sporniak-Tutak K, et al. Short dental implants (6 mm) versus long dental implants (11-15 mm) in combination with sinus floor elevation procedures: 3-year results from a multicentre, randomized, controlled clinical trial. Journal of Clinical Periodontology 2017;44(4):438-45.
42. Felice P, Barausse C, Pistilli V, et al. Posterior atrophic jaws rehabilitated with prostheses supported by 6 mm long x 4 mm wide implants or by longer implants in augmented bone. 3-year post-loading results from a randomised controlled trial. European Journal of Oral Implantology 2018;11(2):175-87.
43. Bechara S, Kubilius R, Veronesi G, et al. Short (6-mm) dental implants versus sinus floor elevation and placement of longer (>/=10-mm) dental implants: a randomized controlled trial with a 3-year follow-up. Clinical Oral Implants Research 2017;28(9):1097-107.
44. Lombardo G, Pighi J, Marincola M, et al. Cumulative Success Rate of Short and Ultrashort Implants Supporting Single Crowns in the Posterior Maxilla: A 3-Year Retrospective Study. International journal of dentistry 2017;2017:8434281.
45. Lai HC, Si MS, Zhuang LF, et al. Long-term outcomes of short dental implants supporting single crowns in posterior region: a clinical retrospective study of 5–10years. Clinical Oral Implants Research 2013;24(2):230–37.
46. Himmlova L, Dostalova T, Kacovsky A, et al. Influence of implant length and diameter on stress distribution: a finite element analysis. Journal of Prosthetic Dentistry 2004;91(1):20-5.
47. Moriwaki H, Yamaguchi S, Nakano T, et al. Influence of Implant Length and Diameter, Bicortical Anchorage, and Sinus Augmentation on Bone Stress

Distribution: Three-Dimensional Finite Element Analysis. International Journal of Oral & Maxillofacial Implants 2016;31(4):e84-91.
48. Kim S, Jung UW, Cho KS, et al. Retrospective radiographic observational study of 1692 Straumann tissue-level dental implants over 10 years: I. Implant survival and loss pattern. Clinical Implant Dentistry and Related Research 2018
49. Lin G, Ye S, Liu F, et al. A retrospective study of 30,959 implants: Risk factors associated with early and late implant loss. Journal of Clinical Periodontology 2018;45(6):733-43.
50. Tabassum A, Meijer GJ, Wolke JG, et al. Influence of the surgical technique and surface roughness on the primary stability of an implant in artificial bone with a density equivalent to maxillary bone: a laboratory study. Clinical Oral Implants Research 2009;20(4):327-32.
51. Dos Santos MV, Elias CN, Cavalcanti Lima JH. The effects of superficial roughness and design on the primary stability of dental implants. Clinical Implant Dentistry and Related Research 2011;13(3):215-23.
52. Falco A, Berardini M, Trisi P. Correlation Between Implant Geometry, Implant Surface, Insertion Torque, and Primary Stability: In Vitro Biomechanical Analysis. International Journal of Oral & Maxillofacial Implants 2018;33(4):824-30.
53. Jain N, Gulati M, Garg M, et al. Short Implants: New Horizon in Implant Dentistry. Journal of Clinical and Diagnostic Research 2016;10(9):Ze14-ze17.
54. Uehara PN, Matsubara VH, Igai F, et al. Short Dental Implants (</=7mm) Versus Longer Implants in Augmented Bone Area: A Meta-Analysis of Randomized Controlled Trials. Open Dentistry Journal 2018;12:354-65.
55. Anitua E, Alkhraist MH, Piñas L, et al. Implant survival and crestal bone loss around extra-short implants supporting a fixed denture: the effect of crown height space, crown-to-implant ratio, and offset placement of the prosthesis. International Journal of Oral & Maxillofacial Implants 2014;29:682-89.
56. Quirynen M, Naert I, van Steenberghe D. Fixture design and overload influence marginal bone loss and fixture success in the Branemark system. Clinical Oral Implants Research 1992;3(3):104-11.
57. Blanes RJ. To what extent does the crown-implant ratio affect the survival and complications of implant-supported reconstructions? A systematic review. Clinical Oral Implants Research 2009;20 Suppl 4:67-72.
58. Verri FR, Batista VEdS, Santiago JF, et al. Effect of crown-to-implant ratio on peri-implant stress: A finite element analysis. Materials Science and Engineering: C 2014;45:234-40.
59. Quaranta A, Piemontese M, Rappelli G, et al. Technical and biological complications related to crown to implant ratio: a systematic review. Implant Dentistry 2014;23(2):180-7.
60. Urdaneta RA, Rodriguez S, McNeil DC, et al. The effect of increased crown-to-

implant ratio on single-tooth locking-taper implants. International Journal of Oral & Maxillofacial Implants 2010;25(4):729-43.

61. Tawil G, Aboujaoude N, Younan R. Influence of prosthetic parameters on the survival and complication rates of short implants. International Journal of Oral & Maxillofacial Implants 2006;21(2):275-82.
62. Schneider D, Witt L, Hammerle CHF. Influence of the crown-to-implant length ratio on the clinical performance of implants supporting single crown restorations: a cross-sectional retrospective 5-year investigation. Clinical Oral Implants Research 2012;23(2):169-74.
63. Thoma DS, Cha JK, Jung UW. Treatment concepts for the posterior maxilla and mandible: short implants versus long implants in augmented bone. Journal of periodontal & implant science 2017;47(1):2-12.
64. Manor Y, Anavi Y, Gershonovitch R, et al. Complications and Management of Implants Migrated into the Maxillary Sinus. International Journal of Periodontics and Restorative Dentistry 2018
65. Mangano F, Frezzato I, Frezzato A, et al. The Effect of Crown-to-Implant Ratio on the Clinical Performance of Extra-Short Locking-Taper Implants. Journal of Craniofacial Surgery 2016;27(3):675-81.

# Tables

**Table 1** Characteristics of the included studies.

| Study | Design | Subjects (intervention /control) | Follow-up period PL | Ultrashort implant group | | | Elevation group | | | | Rehabilitation methods | Outcome measures |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Implant (n) | LEN (mm) | DIA (mm) | Implant (n) | LEN (mm) | DIA (mm) | Elevation methods | | |
| Bolle et al., 2018 | RCT (TAP) | 20/20 | 1 year | 37 | 4 | 4 or 4.5 | 41 | 10, 11.5, 13 | 4 or 4.5 | osteotomy approach | SG or FPD | NIF, MBL, AD |
| Gastaldi et al., 2018 | RCT (TAP) | 20/20 | 3 years | 20 | 5 | 5 | 20 | 10, 11.5, 13, 15 | 5 | lateral window technique | SG or FPD | NIF, MBL, AD |
| Gastaldi et al., 2017 | RCT (TAP) | 10/10 | 3 years | 16 | 5 or 6 | 5 | 18 | 10 | 5 | osteotomy approach | SG or FPD | NIF, MBL, AD |
| Guljé et al., 2014 | RCT (TAP) | 21/19 | 1 year | 21 | 6 | 4 | 20 | 11 | 4 | lateral window technique | SG | NIF, MBL, AD |
| Pohl et al., 2017 | RCT (TAP) | 47/50 | 3 years | 67 | 6 | 4 | 70 | 11, 13, 15 | 4 | lateral window technique | SG | NIF, MBL, AD |
| Felice et al., 2018 | RCT (SM) | 20 | 3 years | 39 | 6 | 4 | 44 | 10, 11.5, 13, 15 | 4 | lateral window technique | SG or FPD | NIF, MBL, AD |
| Bechara et al., 2017 | RCT (TAP) | 33/20 | 3 years | 45 | 6 | 4-8 | 45 | 10, 11.5, 13, 15 | 4-8 | lateral window technique | SG or FPD | NIF, MBL, AD |

PL=post-loading; LEN=implant length; DIA=implant diameter; TAP=two-arm parallel; SG=single crowns; FPD=fixed partial dentures; NIF=number of implant failures; MBL=marginal bone loss; AD=adverse events; SM=split mouth.

**Table 2** Details on the risk of bias for each included study

| Study | Random sequence generation | Allocation concealment | Blinding of patients/carers | Blinding of outcome assessment | Incomplete outcome data | Selective reporting | Other |
|---|---|---|---|---|---|---|---|
| Bolle et al., 2018 | Low risk- Quote: “a computer-generated restricted randomization list” | Low risk- Quote: “the information on how to treat each patient was enclosed in sequentially numbered, identical, opaque, sealed envelopes.” | Low risk - Quote: “treatment allocation was concealed to the investigators in charge of enrolling and treating the patients.” | High risk- Quote: "complications were dealt with directly and reported by the responsible clinicians, who were not blinded”; “augmented sites could be easily identified on radiographs due to the different implant lengths." | Low risk- Quote: “one patient from the ultrashort implant group and one from elevation group dropped out.” | Low risk- Comment; All outcome measure in methods were reported in results | Unclear risk- Comment: diameter of implants (4 mm or 4.5 mm) was not controlled |
| Gastaldi et al., 2018 | Low risk- Quote: “a computer-generated restricted randomization list” | Low risk- Quote: “The randomized codes were enclosed in sequentially numbered, identical, opaque, sealed envelopes” | Low risk- Quote: “treatment allocation was concealed to the investigators in charge of enrolling and treating the patients.” | High risk- Quote: "augmented sites could be easily identified because of the different anatomy of the two sides after the augmentation procedure" | High risk- Comment: one patient dropped out of the ultrashort implant group (1/20), and two patients dropped out of the elevation group (2/20) | Low risk- Comment; All outcome measures in methods were reported in results | Unclear risk- Comment: information on ultrashort implants was not reported |
| Gastaldi et al., 2017 | Low risk- Quote: “a computer-generated restricted randomization list” | Low risk- Quote: "The randomized codes were enclosed in sequentially numbered, identical, opaque, sealed envelopes.” | Low risk- Quote: “treatment allocation was concealed to the investigators in charge of enrolling and treating the patients” | High risk- Quote: “sinus-lifted sites could be identified on radiographs because they appeared more radio-opaque and implants were longer.” | High risk- Comment: no patients dropped out of the ultrashort implant group (0/10); two patients dropped out of the elevation group (2/10) | Low risk- Comment; All outcome measures in methods were reported in results | Low risk |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Guljé et al., 2014 | Low risk- Quote: "Randomization was performed using a block randomization sequence to provide equal distribution of subjects." | Low risk- Quote: "A sealed envelope" | Low risk- Quote: "A sealed envelope was opened by the surgical assistant at the beginning of the surgical procedure." | High risk- Quote: "Blinding was possible in the clinical evaluation but not during analysis of the radiographs." | Unclear risk-Comment: no patient dropped out of the ultrashort implant group (0/21); one patient in the elevation group died (1/20) | Low risk- Comment; All outcome measures in methods were reported in results | Low risk |
| Pohl et al., 2017 | Low risk- Quote: "A block randomization sequence was used to provide an equal distribution" | Low risk- Quote: "A sealed envelope" | Low risk- Quote: "After flap elevation, a sealed randomization envelope was opened to allocate the subject to either one of the two treatment | Unclear risk- Quote: "an independent examiner performed all the radiographic measurements." Other information was not reported. | High risk-Comment: The data for marginal bone loss were incomplete, and the author did not explain the reason | High risk- Comment: marginal bone loss at 3-year follow-up was reported at the implant level rather than at the participant level | Low risk |
| Felice et al., 2018 | Low risk- Quote: "a computer-generated restricted randomisation list" | Low risk- Quote: "The information on how to treat site number 1 was enclosed in sequentially numbered, identical, opaque, sealed envelopes." | Low risk- Quote: "Treatment allocation was concealed to the investigators in charge of enrolling and treating the patients." | High risk- Quote: "augmented sites could be easily identified because of the different anatomy" | High risk- Comment: it was a split-mouth design study, and two dropouts (2/20) occurred | Low risk- Comment: All outcome measures in methods were reported in results | Low risk |
| Bechara et al., 2017 | Unclear risk- Quote: "Patients were randomly assigned" | Low risk- Quote: "a sequentially numbered sealed envelope" | Unclear risk- Comment: not mentioned | Unclear risk- Quote: "At each annual inspection, an experienced, calibrated, independent examiner performed a careful clinical examination", but elevation site can be distinguished | Unclear risk- Comment: one patient dropped out of the ultrashort implant group (1/33), and one patient dropped out of the elevation group (0/20) | High risk- Comment: marginal bone loss was reported at the implant level rather than at the participant level | High risk- Comment: diameter of implants was not controlled (4-8 mm) |

**Table 3** Details of implant failures reported in the included studies.

| Study | Ultrashort implant group | | | | Elevation group | | | |
|---|---|---|---|---|---|---|---|---|
| | LEN (mm) | DIA (mm) | PAR/IMP (n) | Details | LEN (mm) | DIA (mm) | PAR/IMP (n) | Details |
| Bolle et al., 2018 | 4 | 4 or 4.5 | 2/3 | PAR1. One implant was mobile 3 months after placement, and another implant migrated into the sinus 4 months after placement. PAR2. One implant was medially tilted 2 weeks after placement | 10,11.5,13 | 4 or 4.5 | 4/6 | PAR1. One implant was mobile 2 months after placement because of a perforation of the sinus lining at its detachment. Another implant was mobile 2 months later. PAR2. One implant migrated into the sinus 3 months after placement. PAR3. Two implants were mobile 3 months after placement because the patient insisted on wearing her removable denture. PAR4. One implant was mobile, and the patient experienced discomfort when chewing 5 months post-loading. |
| Gastaldi et al., 2018 | 5 | 5 | 1/1 | PAR1. One implant failed 3 months post-loading. | 10,11.5, 13,15 | 5 | 0 | None |
| Felice et al., 2018 | 6 | 4 | 0 | None | 10,11.5, 13,15 | 4 | 1/2 | PAR1. Two implants failed due to peri-implantitis 2 years post-loading. |
| Bechara et al., 2017 | 6 | 4-8 | 0 | None | 10,11.5, 13,15 | 4-8 | 1/2 | PAR1. Two implants were lost caused due to chronic sinus infection with loss of integration/implant stability 2 months after surgery |

LEN=implant length; DIA=implant diameter; PAR=participant; PAR/IMP=participant/implant

**Table 4** Details of adverse events reported in the included studies

| Study | LEN (mm) | | DIA (mm) | Early adverse events | | Late adverse events | |
|---|---|---|---|---|---|---|---|
| | UI | SFE | | UI | SFE | UI | SFE |
| Bolle et al., 2018 | 4 | 10, 11.5, 13 | 4 or 4.5 | 1. Implant mobile and medially inclined (1/10) 2. Implant migrated into sinus (1/10) | 1. Membrane perforation (3/10) 2. Implant migrated into sinus (2/10) 3. Implant mobile and painful at pressure (3/10) 4. Pain, swelling, bad odor (1/10) 5. Lost healing screw (1/10) * | 1. Crown loosened (1/10) 2. Screw loosened (1/10) | 1. Implant mobile (1/10) 2. Loosening of prosthetic screw (1/10) |
| Gastaldi et al., 2018 | 5 | 10, 11.5, 13, 15 | 5 | None | Sinus membrane perforation (5/20) | Prosthetic screws loosened (2/17) | Chipping of the prosthetic lining (1/17) |
| Gastaldi et al., 2017 | 5 or 6 | 10 | 5 | None | None | Chipping of the prosthetic lining (1/16) | Peri-implant mucositis (1/16) |
| Guljé et al., 2014 | 6 | 11 | 4 | None | None | Only one year follow-up is reported | |
| Pohl et al., 2017 | 6 | 11, 13, 15 | 4 | Surgically related (2/47) | 1. Implant mobile (1/50) 2. Pronounced hematoma (1/50) 3. Buccal fistula mesial border of flap incision (1/50) 4. Surgically related (6/50) | 1. Loosening or fracture of abutment screw (10/45) 2. Decementation of crown (3/45) | 1. Loosening or fracture of abutment screw (5/49) 2. Decementation of crown (1/49) |
| Felice et al., 2018 | 6 | 10, 11.5, 13, 15 | 4 | None | Membrane perforation (3/20) | Peri-implantitis (1/15) | None |
| Bechara et al., 2017 | 6 | 10, 11.5, 13, 15 | 4-8 | None | 1. Intra-operative bleeding (3/20) 2. Swelling (15/20) 3. Chronic sinus infection with complete graft loss (1/20) | None | None |

UI=ultrashort implant group; SFE=sinus floor elevation group; LEN=implant length; DIA=implant diameter. The incidence rate of adverse events (the number of adverse events/the number of participants) is provided in parenthesis.

* One patient had both membrane perforation and implant mobile and painful. Pain, swelling bad odor and lost healing screw occurred in one patient.

**Table 5** Summary of findings

**Ultrashort implant (≤ 6mm) compared to longer implant (≥ 10mm) with sinus floor elevation for atrophic posterior maxilla**

**Patient or population**: atrophic posterior maxilla
**Setting**: oral implantology
**Intervention**: ultrashort implant
**Comparison**: longer implant with sinus floor elevation

| Outcomes | Anticipated absolute effects* (95% CI) | | Relative effect (95% CI) | № of participants (studies) | Certainty of the evidence (GRADE) | Comments |
|---|---|---|---|---|---|---|
| | **Assumed risk (elevation group)** | **Corresponding risk (ultrashort implant group)** | | | | |
| **Survival rate** follow up: range 1 years to 3 years | **961 per 1,000**[1] | **970 per 1,000** (932 to 999) | **RR 1.01** (0.97 to 1.04) | 321 (7 RCTs) | ⨁⨁⨁◯ MODERATE [2] | - |
| **Survival rate** follow up: range 3 years to longer years | **982 per 1,000**[1] | **982 per 1,000** (953 to 1,000) | **RR 1.00** (0.97 to 1.04) | 237 (5 RCTs) | ⨁⨁⨁◯ MODERATE [2] | - |
| **MBL** follow up: range 1 years to 3 years | The mean MBL ranged from 0.1 to 1.15 mm | The mean MBL in the intervention group was **0.13 mm lower** (0.21 lower to 0.05 lower) | - | 249 (6 RCTs) | ⨁⨁◯◯ LOW [3] | - |
| **MBL** follow up: range 3 years to longer years | The mean MBL ranged from 1.08 to 1.5 mm | The mean MBL in the intervention group was **0.25 mm lower** (0.4 lower to 0.1 lower) | - | 88 (3 RCTs) | ⨁⨁⨁◯ MODERATE [2] | - |

*The basis for the **assumed risk** is provided in footnotes. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95%CI)
**CI:** Confidence interval; **RR:** Risk ratio; **MD:** Mean difference

**GRADE Working Group grades of evidence**
**High certainty:** We are very confident that the true effect lies close to that of the estimate of the effect
**Moderate certainty:** We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
**Low certainty:** Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect
**Very low certainty:** We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

1. Assumed risk is based on the overall event rate in the control groups of the included studies.
2. Downgraded one level due to serious risks of bias.
3. Downgraded two levels due to serious risks of bias and serious inconsistency.

# Figure Legends

**Figure 1** Flow diagram for study selection.

**Figure 2** Risk of bias in each included study.

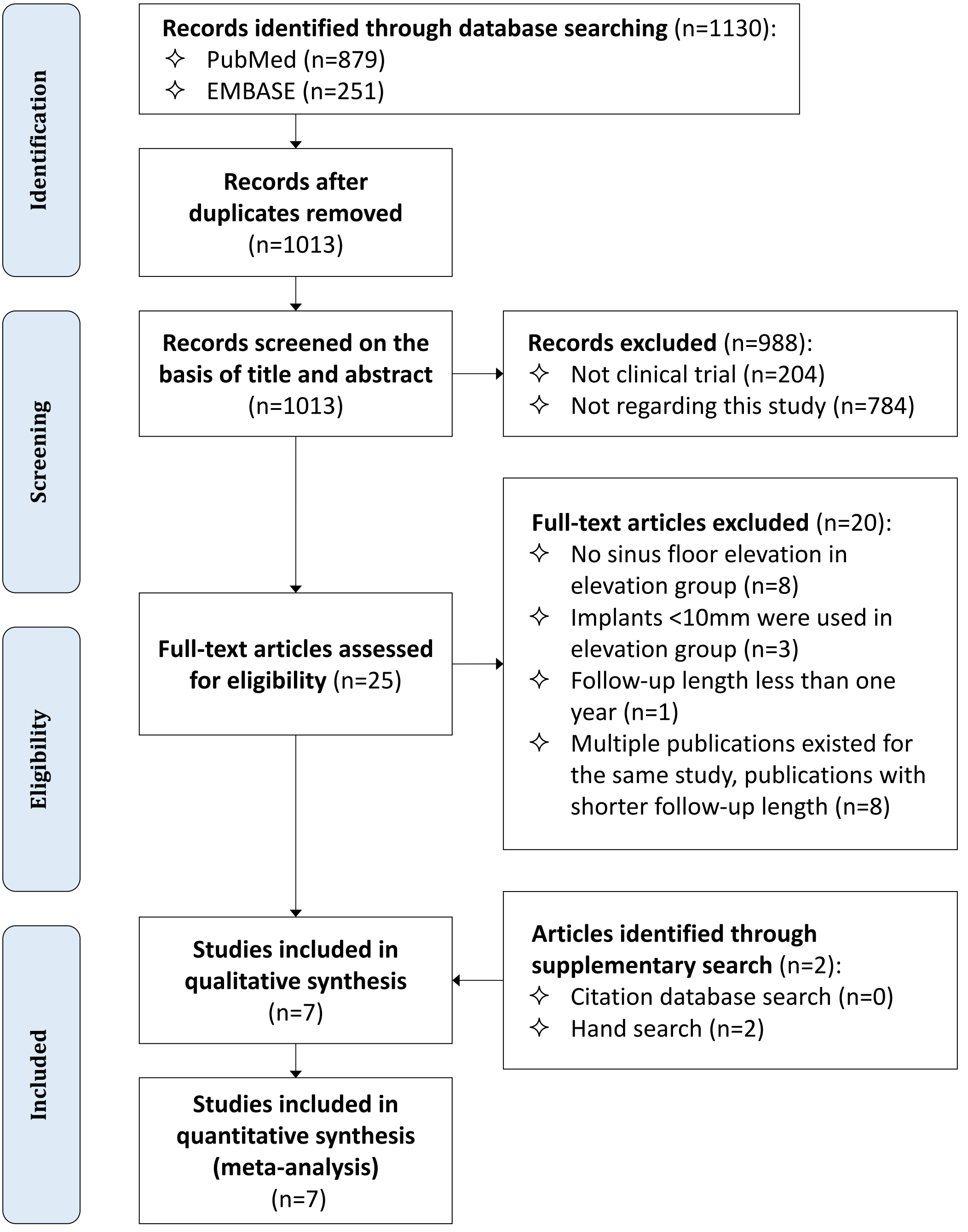
**Figure 3** Risk of bias across included studies.

**Figure 4** Forest plot for implant survival rate.

*Footnote: UI, ultrashort implant group; SFE, sinus floor elevation group.*

**Figure 5** Forest plot for marginal bone loss.

*Footnote: UI, ultrashort implant group; SFE, sinus floor elevation group.*


Identification
Screening
Eligibility
Included
Records identified through database searching (n=1130):
PubMed (n=879)
EMBASE (n=251)
Records after duplicates removed (n=1013)
Records screened on the basis of title and abstract (n=1013)
Records excluded (n=988):
Not clinical trial (n=204)
Not regarding this study (n=784)
Full-text articles assessed for eligibility (n=25)
Full-text articles excluded (n=20):
No sinus floor elevation in elevation group (n=8)
Implants <10mm were used in elevation group (n=3)
Follow-up length less than one year (n=1)
Multiple publications existed for the same study, publications with shorter follow-up length (n=8)
Articles identified through supplementary search (n=2):
Citation database search (n=0)
Hand search (n=2)
Studies included in qualitative synthesis (n=7)
Studies included in quantitative synthesis (meta-analysis) (n=7)

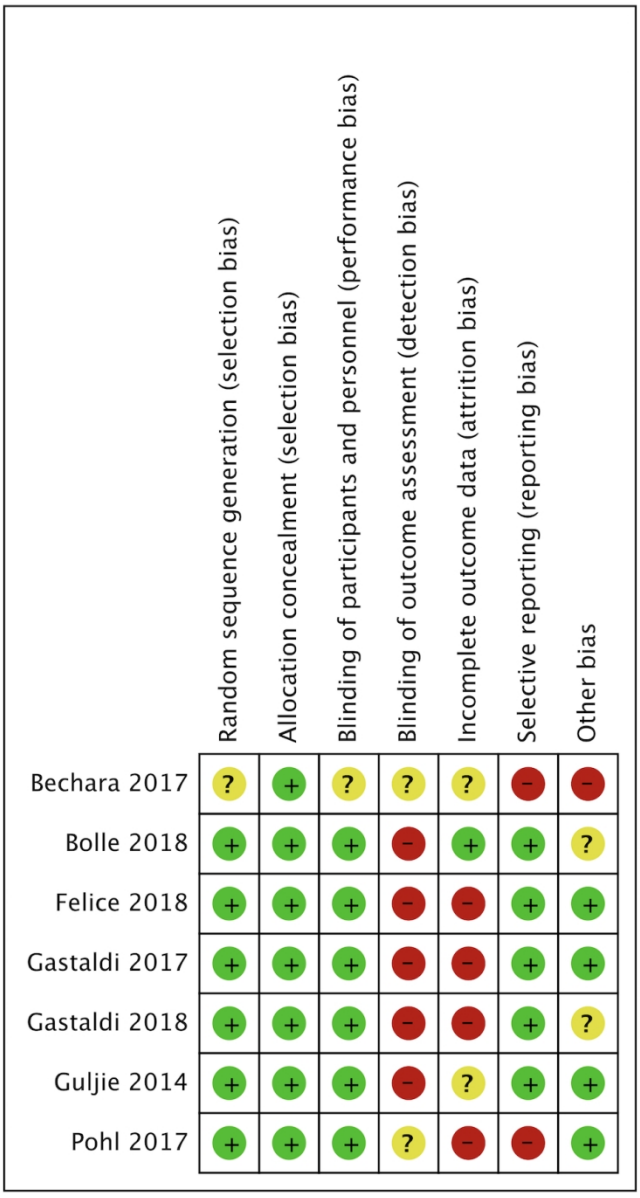



Figure 2. Risk of bias in each included study.

173x316mm (144 x 144 DPI)

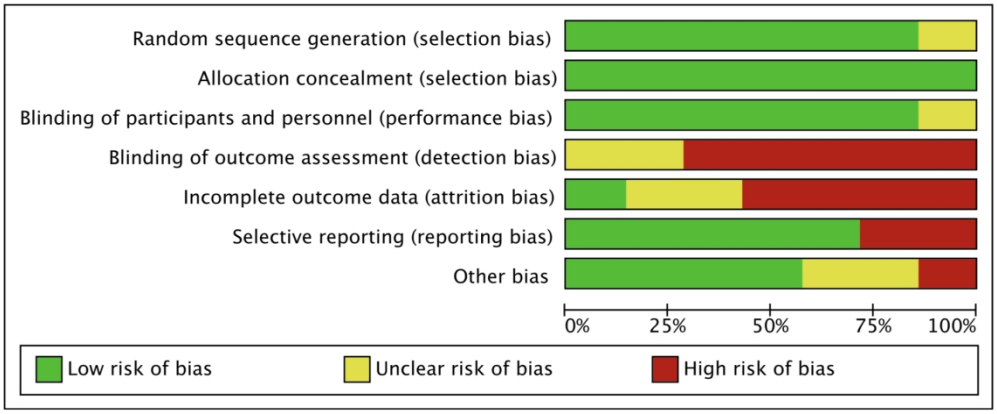



Figure 3. Risk of bias across included studies.

352x147mm (144 x 144 DPI)

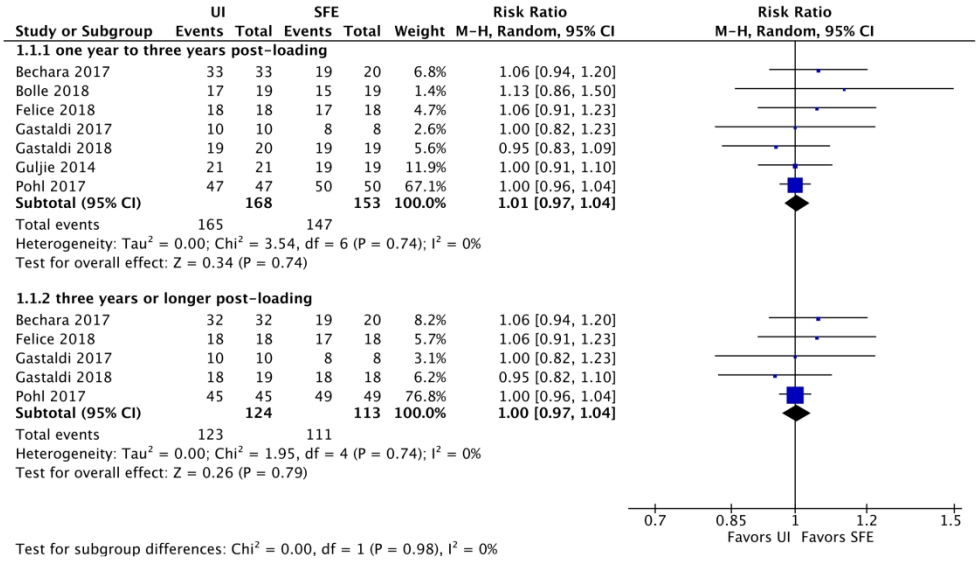



Figure 4. Forest plot for implant survival rate. Footnote: UI, ultrashort implant group; SFE, sinus floor elevation group.

201x118mm (300 x 300 DPI)

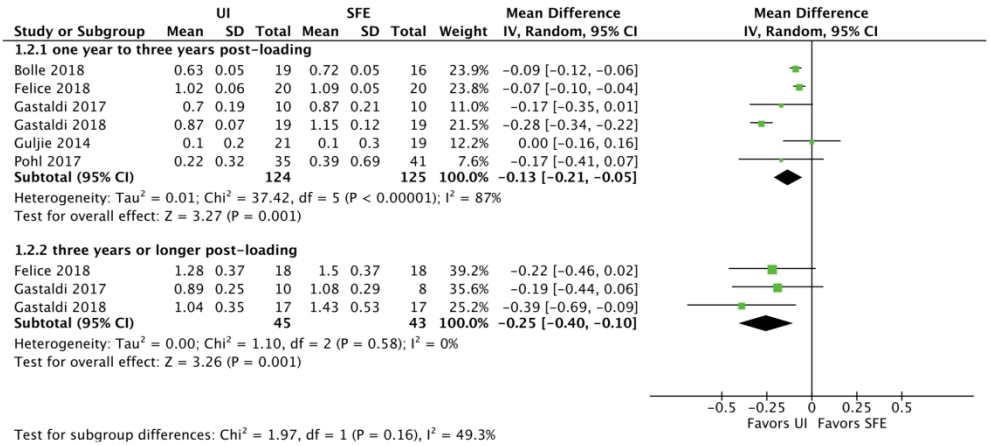



Figure 5. Forest plot for marginal bone loss. Footnote: UI, ultrashort implant group; SFE, sinus floor elevation group.

418x188mm (144 x 144 DPI)

# Appendix 1: Search strategy

**A. The search strategy used for PubMed (as of 31/5/2018):**

1. dental implant [Mesh Terms]
2. dental implantation [Mesh Terms]
3. dental prosthesis, implant supported [Mesh Terms]
4. 1 OR 2 OR 3
5. long implant [Title/Abstract]
6. short implant [Title/Abstract]
7. shorter implant [Title/Abstract]
8. longer implant [Title/Abstract]
9. super short [Title/Abstract]
10. extra short [Title/Abstract]
11. ultrashort [Title/Abstract]
12. 6mm [Title/Abstract]
13. 5mm [Title/Abstract]
14. 4mm [Title/Abstract]
15. 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14
16. 4 OR 15
17. alveolar bone loss [Mesh Terms]
18. alveolar bone atrophy [Mesh Terms]
19. alveolar ridge augmentation [Mesh Terms]
20. bone substitute [Mesh Terms]
21. augmentation, sinus floor [Mesh Terms]
22. 17 OR 18 OR 19 OR 20 OR 21
23. atrophy jaw [Title/Abstract]
24. atrophy maxilla [Title/Abstract]
25. atrophy mandible [Title/Abstract]
26. augmented bone [Title/Abstract]
27. bone augmentation [Title/Abstract]
28. sinus lift [Title/Abstract]

29. sinus floor elevation [Title/Abstract]
30. 23 OR 24 OR 25 OR 26 OR 27 OR 28 OR 29
31. 22 OR 30
32. randomized controlled trial [Publication Type]
33. randomized [Title/Abstract]
34. randomly [Title/Abstract]
35. 32 OR 33 OR 34
36. 16 AND 31 AND 35

**B. The search strategy used for Embase (as of 31/5/2018):**

1. 'alveolar bone loss'/exp/mj
2. 'alveolar ridge augmentation'/exp/mj
3. 'bone prosthesis'/exp/mj
4. 1 OR 2 OR 3
5. 'atrophic jaw': ab, ti
6. 'atrophic maxilla': ab, ti
7. 'atrophic mandible': ab, ti
8. 'posterior maxilla': ab, ti
9. 'posterior mandible': ab, ti
10. 'augmented bone': ab, ti
11. 'bone augmentation': ab, ti
12. 'sinus lift': ab, ti
13. 'sinus floor elevation': ab, ti
14. 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13
15. 4 OR 14
16. 'tooth implantation'/exp/mj
17. 'tooth implant'/exp/mj
18. 'tooth prosthesis'/exp/mj
19. 16 OR 17 OR 18
20. 'short implant': ab, ti
21. 'long implant': ab, ti
22. 'shorter implant': ab, ti

23. ‘longer implant’: ab, ti
24. ‘super short’: ab, ti
25. ‘extra short’: ab, ti
26. ‘ultrashort’: ab, ti
27. ‘6mm’: ab, ti
28. ‘5mm’: ab, ti
29. ‘4mm’: ab, ti
30. 20 OR 21 OR 22 OR 23 OR 24 OR 25 OR 26 OR 27 OR 28 OR 29
31. 19 OR 30
32. ‘controlled clinical trial’/lim
33. ‘randomized controlled trial’/lim
34. 32 OR 33
35. 15 AND 31 AND 34

# PRISMA 2009 Checklist

| Section/topic | # | Checklist item | Reported on page # |
|---|---|---|---|
| **TITLE** | | | |
| Title | 1 | Identify the report as a systematic review, meta-analysis, or both. | 1 |
| **ABSTRACT** | | | |
| Structured summary | 2 | Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number. | 2 |
| **INTRODUCTION** | | | |
| Rationale | 3 | Describe the rationale for the review in the context of what is already known. | 4 |
| Objectives | 4 | Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS). | 5 |
| **METHODS** | | | |
| Protocol and registration | 5 | Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number. | 5 |
| Eligibility criteria | 6 | Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale. | 5 |
| Information sources | 7 | Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched. | 6 |
| Search | 8 | Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated. | 6 |
| Study selection | 9 | State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis). | 6 |
| Data collection process | 10 | Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators. | 7 |
| Data items | 11 | List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made. | 7 |
| Risk of bias in individual studies | 12 | Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis. | 7 |
| Summary measures | 13 | State the principal summary measures (e.g., risk ratio, difference in means). | 8 |
| Synthesis of results | 14 | Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., $I^2$) for each meta-analysis. | 8 |

# PRISMA 2009 Checklist



| Section/topic | # | Checklist item | Reported on page # |
|---|---|---|---|
| Risk of bias across studies | 15 | Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies). | 7 |
| Additional analyses | 16 | Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified. | 8 |
| **RESULTS** | | | |
| Study selection | 17 | Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram. | 9 |
| Study characteristics | 18 | For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations. | 9 |
| Risk of bias within studies | 19 | Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12). | 10 |
| Results of individual studies | 20 | For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot. | 10, 11 |
| Synthesis of results | 21 | Present results of each meta-analysis done, including confidence intervals and measures of consistency. | 10, 11 |
| Risk of bias across studies | 22 | Present results of any assessment of risk of bias across studies (see Item 15). | 10, 11 |
| Additional analysis | 23 | Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]). | 10, 11 |
| **DISCUSSION** | | | |
| Summary of evidence | 24 | Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers). | 11 |
| Limitations | 25 | Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias). | 15 |
| Conclusions | 26 | Provide a general interpretation of the results in the context of other evidence, and implications for future research. | 15 |
| **FUNDING** | | | |
| Funding | 27 | Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review. | 15 |

*From:* Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: www.prisma-statement.org.

BMJ Open

# Short implants (≤6 mm) versus longer implants with sinus floor elevation in atrophic posterior maxilla: a systematic review and meta-analysis

| | |
|---|---|
| Journal: | *BMJ Open* |
| Manuscript ID | bmjopen-2019-029826.R1 |
| Article Type: | Original research |
| Date Submitted by the Author: | 08-Jul-2019 |
| Complete List of Authors: | Yan, Qi; School & Hospital of Stomatology, Wuhan University, Department of Oral Implantology<br>Wu, Xinyu; School & Hospital of Stomatology, Wuhan University, Department of Oral Implantology<br>Su, Meiying; School & Hospital of Stomatology, Wuhan University, Department of Oral Implantology<br>Hua, Fang; School & Hospital of Stomatology, Wuhan University, Centre for Evidence-Based Stomatology; Division of Dentistry, The University of Manchester, Cochrane Oral Health<br>Shi, Bin; School & Hospital of Stomatology, Wuhan University, Department of Oral Implantology |
| Primary Subject Heading: | Dentistry and oral medicine |
| Secondary Subject Heading: | Evidence based practice |
| Keywords: | ORAL & MAXILLOFACIAL SURGERY, SYSTEMATIC REVIEW, Sinus Floor Elevation, Evidence-Based Dentistry, Oral Implantology, Short Dental Implant |
| | |

# Short implants (≤6 mm) versus longer implants with sinus floor elevation in atrophic posterior maxilla: a systematic review and meta-analysis

Qi Yan [1, 2, a], Xinyu Wu [1, 2, a], Meiying Su [2], Fang Hua [3, 4, *], Bin Shi [1, 2, *]

1. Hubei-MOST KLOS & KLOBM, School & Hospital of Stomatology, Wuhan University, Wuhan, China.
2. Department of Oral Implantology, School & Hospital of Stomatology, Wuhan University, Wuhan, China.
3. Centre for Evidence-Based Stomatology, School & Hospital of Stomatology, Wuhan University, Wuhan, China
4. Division of Dentistry, School of Medical Sciences, Faculty of Biology, Medicine and Health, University of Manchester, Manchester Academic Health Science Centre, Oxford Road, Manchester, M13 9PL, UK

[a] Qi Yan and Xinyu Wu contributed equally to this work.

[*] **Corresponding authors:**

Fang Hua

Centre for Evidence-Based Stomatology, School & Hospital of Stomatology,

Wuhan University, 237 Luoyu Rd, Wuhan 430079, China

Tel: +86 27 87686226

Email: huafang@whu.edu.cn

Bin Shi

Department of Oral Implantology, School & Hospital of Stomatology,

Wuhan University, 237 Luoyu Rd, Wuhan 430079, China

Tel: +86 27 87686222

Email: Shibin_dentist@whu.edu.cn

## Abstract

**Objectives:** To compare the use of short implants (≤6 mm) in atrophic posterior maxilla versus longer implants (≥10 mm) with sinus floor elevation. Outcome measures include implant survival (primary outcome), marginal bone loss (MBL), complications and patient satisfaction.

**Sources:** Electronic searches in PubMed, Embase and the Cochrane CENTRAL were conducted by two independent authors. Retrospective and prospective hand searches were also performed. Quality of evidence were assessed according to GRADE.

**Results:** A total of seven randomized controlled trials involving 310 participants were included. No significant difference in survival rate was found for one- to three-year follow-up (RR=1.01, 95% CI: 0.97, 1.04, p=0.74, $I^2$ = 0%, moderate quality evidence) or for three-year or longer follow-up (RR=1.00, 95% CI: 0.97, 1.04, p=0.79, $I^2$ = 0%, moderate quality evidence). However, short implants (≤6 mm) showed significantly less MBL in one- to three-year follow-up (MD=-0.13 mm, 95% CI: -0.21, -0.05; p=0.001, $I^2$ = 87%, low quality evidence) and in three-year or longer follow-up (MD=-0.25 mm, 95% CI: -0.40, -0.10; p=0.001, $I^2$ = 0%, moderate quality evidence). In addition, short implant (≤6 mm) resulted in fewer post-surgery reaction (RR=0.11, 95% CI: 0.03, 0.35, p<0.001, $I^2$ = 4%, moderate quality evidence) and sinus perforation or infection (RR=0.14, 95% CI: 0.03, 0.77, p=0.02, $I^2$ = 0%, low quality evidence). Patients were more satisfied with short implants (≤6 mm) in terms of cost.

**Conclusions:** For atrophic posterior maxilla, short implants (≤6 mm) are a promising alternative to sinus floor elevation, with comparable survival rate and patient satisfaction, less MBL and post-surgery reactions. Additional high-quality studies are needed to evaluate the long-term effectiveness of short implants (≤6 mm).

**Clinical Significance:** Short implants (≤6 mm) could be recommended in atrophic posterior maxilla as an alternative to sinus floor elevation.

**Registration:** PROSPERO (CRD42018103531)

**Keywords:** short dental implant; sinus floor augmentation; systematic review

**Word count:** 3655 (main text); 302 (abstract)

**Strengths**

- Only randomized controlled clinical trials were included.
- Participant-unit data were used for syntheses.
- Subgroup analyses by follow-up length and categories of complications were performed.

**Limitations**

- Serious risks of bias were found within and across studies and the quality of evidence was only low to moderate.

## 1. Introduction

Dental implants supporting prosthesis are commonly considered a promising method for the rehabilitation of missing teeth.[1-3] However, dental implantation in the posterior maxilla is usually challenging due to insufficient vertical bone volume, poor bone quality, limited visibility, reduced inter-arch space, and sinus pneumatisation.[4 5] These conditions are exacerbated if patients have a history of wearing removable dentures.[6]

To achieve sufficient vertical bone volume in the posterior maxilla, sinus floor elevation using the lateral window approach or the osteotomy technique have been introduced and widely used over the past 40 years.[7 8] The lateral window approach is commonly used in dental implantation procedures.[9] Using these techniques with or without bone grafting, conventional implants can be placed in the elevated sites. The implant success rate is typically greater than 90% in long-term evaluation.[10-12] However, sinus floor elevation surgery is usually associated with higher cost, more complicated surgical procedures, and a high prevalence of complications such as infection, sinus membrane perforation and graft failure.[13-15] In addition, the clinical outcome of sinus floor elevation can also be restricted by extremely insufficient residual bone height, abnormal sinus anatomy, thickening of the sinus membrane, stability of the grafted bone and the number of missing teeth.[16-19]

Short implants with improved implant design and surface properties have been successfully applied as an alternative to sinus floor elevation surgery and have shown good results in posterior maxilla. Implants ≤10 mm[20], ≤8 mm[21], ≤7 mm[22], and 6-8 mm[23] are reported to have survival rates comparable to those of longer implants. In addition, short implants ≤6 mm in length have been introduced as another alternative in atrophic posterior maxilla.[6 24 25] Short implants require a less complicated surgical approach and could be used in cases when sinus floor elevation surgery is not applicable,[26 27]

especially in cases of maxillary sinusitis, maxillary cyst, large vessels and other cases involving abnormal sinus anatomy. Studies have explored the short- and long-term survival rates of short implants (≤6 mm).[27-31] Unfortunately, the evidence supporting the use of short implants (≤6 mm) in the posterior maxilla is weak, and no guideline statement is currently recommended.

The present systematic review aims to compare the effectiveness of short implants (≤6 mm) and longer implants (≥10 mm) with sinus floor elevation in atrophic posterior maxilla. Our null hypothesis was that the survival rate, patient satisfaction, MBL and surgery-related complications of short implants (≤6 mm) were comparable to longer implants in combination with sinus floor elevation.

## 2. Materials and methods

### *2.1 Protocol and registration*

This systematic review and meta-analysis was conducted in accordance with the PRISMA guidelines.[32] The protocol has been registered at PROSPERO (CRD42018103531).

### *2.2 Eligible criteria*

Randomized controlled trials (RCTs) meeting the following pre-determined inclusion criteria (PICOS format) were included:

- Population: Partially edentulous patients in the premolar and molar regions of the maxilla, for whom the residual bone height in the atrophic posterior maxilla was sufficient for the insertion of a short implant (≤6 mm) but insufficient for the insertion of longer implants;
- Intervention: One or more short implants (≤6 mm) were placed in the posterior

maxilla without sinus floor elevation in the short implant group;

- Comparison: One or more longer implants were placed in the posterior maxilla after sinus floor elevation by any technique in the elevation group;
- Outcomes: The primary (survival rate) and secondary (MBL, complications and patient satisfaction) outcomes of interest were measured, with a follow-up length of one year or longer post-loading.

*2.3 Information sources and search strategies*

Two content experts (QY and XW) searched PubMed, Embase, and the Cochrane CENTRAL (The Cochrane Central Registration of Controlled Trials) for RCTs, independently and in duplicate. The last search was conducted on 31/05/2018. A methodologist (FH) was consulted to resolve any disagreements. Main search terms included: "dental implant", "short implant", "ultrashort", "alveolar bone loss", "atrophic maxilla", "sinus lift", and "sinus floor elevation". No restriction was set regarding publication year, publication language or status. The detailed search strategies are listed in the supplementary file. In addition, retrospective and prospective searches were conducted by checking the reference lists of key articles and studies citing these key articles, using Google Scholar.

*2.4 Study selection and data collection*

Two review authors (QY and XW) conducted the study selection independently and in duplicate. The titles and abstracts of all records were scanned. Full texts of studies were obtained in cases they appeared to meet the inclusion criteria or further information were needed to determine eligibility. Studies excluded at this or subsequent stages were recorded with the reasons for exclusion. All disagreements were resolved by discussion.

Two review authors (QY and XW) extracted the data independently and in duplicate using specifically designed data extraction forms. The extracted data included citation details (year of publication, country of origin, setting and source of funding), details on the participants (demographic characteristics, residual bone height and inclusion criteria), details of intervention (implant length, diameter, brand, surface structure, surgical method, follow-up time, prosthesis type), outcome assessment, sample size calculation and trial registration. Corresponding authors were contacted for missing data or information.

*2.5 Risk of bias of included studies*

Two authors (QY and XW) assessed the risk of bias of each included study independently and in duplicate using the Cochrane risk of bias assessment tool for RCTs.[33] Disagreements were resolved through discussion. A third review author (F.H.) was consulted when necessary. Seven domains were assessed, including sequence generation (selection bias), allocation concealment (selection bias), blinding of participants and personnel (performance bias), blinding of outcome assessment (detection bias), incomplete outcome data (attrition bias), selective outcome reporting (reporting bias) and other bias (factors that had potential influence on outcomes but were not evenly distributed across groups or not clearly reported, such as the manufacturer or diameter of implants). Individual studies were categorized as having low, high or unclear risk of bias. The risk of bias across studies was determined according to the risk of bias in each included study.

*2.6 Assessment of heterogeneity*

Clinical heterogeneity among the included studies was assessed by comparing study

design, participant conditions (gender, age, residual bone height), intervention (implant length, diameter, surface structure, surgical method), and outcome measures. Statistical heterogeneity was evaluated using Cochrane's Q test and the $I^2$ statistic. In the Q test, a P value < 0.1 was considered an indication of significant heterogeneity.

*2.7 Assessment of publication bias*

If at least ten studies were included in a meta-analysis, We would have used a funnel plot and the Egger's test[34] asymmetry to assess the potential existence of publication bias if at least ten studies were included in a meta-analysis.

*2.8 Synthesis of results*

The unit of analysis was set as participant rather than implant.[35] RevMan 5.3 software was used for data synthesis. Meta-analyses were undertaken only when at least two studies that made similar comparisons reported the same outcomes. The effect measures were risk ratio (RR) for dichotomous outcomes (implant survival and complications) and mean difference (MD) for continuous outcomes (MBL). RR was calculated through Mantel-Haenszel analysis and MD was calculated through inverse variance. P<0.05 was considered statistically significant. The fixed effect model was used when fewer than four studies were included in a meta-analysis, and the random-effects model was used when four or more studies were included [36-39].

*2.9 Additional analysis*

Subgroup analysis by length of follow-up and categories of complications was performed to control for the possibility that function time might influence implant survival [40]. If risks of bias in some studies were serious, we performed sensitivity

analysis by excluding these studies. Considering only three studies were included in the MBL three years or longer follow-up but the meta-analysis for MBL included more than three studies, a sensitivity analysis was conducted for MBL by using fixed-effect model.

*2.10 Summary of findings (SoF)*

Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach[41] was adopted to evaluate quality of evidence in this systematic review. A SoF table was made with an online tool (cebgrade.mcmaster.ca/gradepro.html). Outcomes were evaluated including survival rate and MBL of one to three-year and three-year or longer follow-up, and complications. Five domains in quality of evidence were assessed: the overall risk of bias, directness of evidence, consistency of results, precision of estimates, as well as the risk of publication bias. The quality of the body of evidence was classified into four categories: high, moderate, low and very low.

*2.11 Patient and Public involvement*

No patient or public was involved in this systematic review.

## 3. Results

*3.1 Study selection*

Electronic searches identified a total of 879 titles and abstracts in PubMed and 251 in Embase. After removal of duplicates, the titles and abstracts of 1,013 unique items were screened. We then retrieved the full texts of 25 potentially eligible articles, of which 20 were excluded for the reasons described in figure 1. Retrospective and prospective hand searches yielded two more articles. Finally, seven studies[30 42-47] met our eligibility

criteria and were included in this review (figure 1).

### *3.2 Study characteristics*

The characteristics of the seven included studies are listed in table 1. One study was a split-mouth trial, and the rest were two-arm parallel RCTs. The length of follow-up ranged from one year to three years. For sinus floor elevation, either osteotomy-mediated sinus floor elevation or the lateral window technique was adopted. In two studies, single crowns were used as the rehabilitation method; in the remaining studies, single crowns or splinted prosthetics were used. The outcome measures used in these studies included implant failure, MBL, complications and patient satisfaction. Overall, 171 participants were included in the short implant groups, and 159 participants were included in the elevation groups.

### *3.3 Risk of bias assessment*

The results of the risks of bias assessment are shown in figures 2 and 3. Selection bias and performance bias were assessed as low in all but one study by Bachara et al[47] due to inadequate description on random sequence generation and blinding of participants. For detection bias, most studies showed high risks because assessors could recognize sites that underwent sinus floor elevation. For attrition bias, three studies[43 45 46] was assessed as high. Two studies[45 47] showed high risk of reporting bias. Other risks of bias were considered high or unclear in three studies. Overall, all included studies were at high risk of bias for at least one domain (table 2).

### *3.4 Synthesis of results*

3.4.1 Survival rate

Figure 4 shows the results of a meta-analysis for participant unit implant survival rate with a subgroup analysis based on length of follow-up. Five studies reported 100% survival of short implants (≤6 mm) within the study period. For this outcome, there was no evidence of a difference between the short implant group and the elevation group either one year to three years post-loading (RR=1.01, 95% CI: 0.97, 1.04, p=0.74, $I^2$ = 0%, seven RCTs, 321participants) or three years or longer post-loading (RR=1.00, 95% CI: 0.97, 1.04, p=0.79, $I^2$ = 0%, five RCTs, 237 participants). Further details of the implant failures are summarized in table 3.

3.4.2 MBL

The results of the meta-analysis and subgroup analysis regarding peri-implant MBL are shown in figure 5. A significant difference favoring the short implant group was found for both one year to three years post-loading (MD=-0.13, 95% CI: -0.21, -0.05; p=0.001, $I^2$ = 87%, six RCTs, 249 participants) and three years or longer post loading (MD=-0.25, 95% CI: -0.40, -0.10; p=0.001, $I^2$ = 0%, three RCTs, 88 participants). In sensitivity analysis by using fixed-effect model, results remained significant for both one year to three years post-loading (MD=-0.11, 95% CI: -0.13, -0.08; p<0.001, $I^2$ = 87%) and three years or longer post loading (MD=-0.25, 95% CI: -0.40, -0.10; p=0.001, $I^2$ = 0%).

3.4.3 Complications

Complications were categorized into post-surgery reaction, biological complications and technical complications. Short implant group was found with significantly less post-surgery reaction (RR=0.11, 95% CI: 0.03, 0.35, p<0.001, $I^2$ = 4%, three RCTs, 157participants) (figure 6) and sinus perforation or infection (RR=0.14, 95% CI: 0.03,

0.77, p=0.02, $I^2$ = 0%, three RCTs, 120 participants) (figure 7). Only one study[30] reported implant migrating into sinus in 10% patients (1/10) in short implant group while in 20% patients (1/10) in sinus floor elevation group. No statistically significant difference was found in other complications between short implants (≤6 mm) and longer implants (figures 7, 8).

3.4.4 Patient satisfaction

Three studies [43] [44] [47] reported patient satisfaction. Meta-analysis was not conducted because methods of evaluating patient satisfaction were different. Gulje et al. [44] used a questionnaire to evaluate patient satisfaction before surgery and one year post-loading. Both groups showed improvement of satisfaction after crown placement. Gastaldi et al.[43] evaluated patient satisfaction in function and aesthetic aspects. All patients in the short implant group (10) were satisfied with both function and aesthetic aspects. However, three patients in elevation group (3/10) were partially satisfied with function. Bechara et al.[47] used a questionnaire evaluating patient satisfaction in function, aesthetic, cleaning of the implant-supported restorations, satisfaction, and cost. Significantly more patients in short implant group expressed satisfaction in cost.

*3.5 Quality of evidence*

For survival rate, the quality of evidence in both subgroups were downgraded by one level (moderate quality evidence) due to serious risks of bias. For short-term MBL (one to three-year follow-up), quality of evidence was downgraded by two levels for serious risks of bias and inconsistency. For long-term MBL (three-year or longer follow-up), quality of evidence was downgraded by one level for serious risks of bias. For complications, the quality of evidence in post-surgery reaction was moderate,

downgrading by one level for serious risks of bias. The quality of evidence in other complications was low, downgrading by two levels for serious risks of bias and imprecision. Details are listed in table 4.

## 4. Discussion

To the best of our knowledge, this is the first systematic review and meta-analysis to compare the clinical outcome of the use of short implants (≤6 mm) in atrophic posterior maxilla versus longer implants with sinus floor elevation. At one year or longer post-loading, there is no significant difference in participant unit implant survival rate between the short implant group and the elevation group. The short implant group showed less MBL than the elevation group for one to three-year follow-up (low quality evidence) and three-year or longer follow-up (moderate quality evidence). In addition, the short implant group showed fewer post-surgery reaction and sinus membrane perforation and infection.

The survival rate in this review was evaluated by participant unit as in a previous Cochrane review.[35] In this review, the overall survival rates for the short implant group and the elevation group were 98.21% and 96.08%, respectively, at one-year to three-year follow-up and 99.20% and 98.23%, respectively, at longer than three-year follow-up; no significant difference in survival rate was found. Other studies that assessed survival rate in implant unit had similar outcomes. A retrospective study[48] with a follow-up period of 17 to 48 months reported a 95.12% implant unit survival rate for 5-mm to 6-mm short implants. A two-year to three-year prospective study[6] reported that 6-mm short implants with micro rough surfaces achieved a 100% survival rate in posterior maxilla. Another five- to ten-year retrospective study[49] reported a 97% implant unit survival rate for 6-mm short implants supporting single crowns. All these

results showed that short implants (≤6 mm) represent a promising rehabilitation method with respect to their short-term and long-term survival rates.

In this review, all of the failed short implants were 4 mm or 5 mm. Although the use of short implants (≤6 mm) could avoid complicated surgical procedures and related early failures, reduced implant length was still the major risk factor in survival rate. The authors of the included studies used wider implants (4 mm to 8 mm) to compensate for the short length of the implants. Finite element analyses showed that wider implants had increased functional surface area in cortical bone and decreased stress distribution on the implant neck; these qualities helped improve primary stability, produce a higher survival rate and reduce MBL.[50-53] However, it was not determined whether implant length or diameter contributed more to implant failure. Another factor was implant surface structure. Studies[54-57] have suggested that the implant surface influences bone-to-implant osseointegration, implant primary stability and MBL. In this review, implants 4 mm or 5 mm in length had novel surface structures, but they still presented a lower survival rate.

Significantly less MBL was found in the short implant group, and the difference was greater at the longer follow-up period. Additionally, in this review, 5-mm-diameter implants tended to induce less MBL than 4-mm-diameter implants. Implants ≤ 10 mm [20] and ≤ 8 mm[21] were reported to induce MBL similar to that of longer implants, while implants ≤ 7 mm[58] showed less MBL. These results contradict a previous theory that short implants are more likely to have an extreme crown-to-implant ratio (C/I)[59] that induces more peri-implant bone loss and early implant failure.[60 61] According to finite element analyses, inappropriate C/I results in adverse occlusal forces such as non-axial forces and overloading.[62] Increased C/I was also correlated with more prosthesis complications such as screw loosening, implant or abutment fracture, chipping of the

ceramic material, and prosthesis fracture.[63-66] However, the implants in the studies included in this systematic review had wider diameters (4 mm to 8 mm) and different surface structures. These two factors partially compensated for the complications of C/I and contributed to less MBL. Differences in implant diameter and surface structure also introduced heterogeneity among studies with respect to MBL. Short implants tolerated less MBL because of the limited implant length. As a result, less MBL was not necessarily correlated with better clinical outcome. MBL around short implants is still a challenging issue, and much effort should be made to resolve it.

With respect to complications, the use of short implants (≤6 mm) could decrease the incidence of post-surgery reactions and sinus membrane perforation and infection. Sinus membrane perforation was common in the elevation group.[14] This was in accordance with a previous study[67] that reported more complications in cases involving longer implants with sinus floor elevation and that the surgical procedure made a major contribution to such complications. In this study, incidence of other biological and technical complications was similar between the two groups. Implant migration into the sinus, often with the co-occurrence of sinus infection, had a higher prevalence in the elevation group. When implant migration occurs, implants may be removed, thus leading to implant failure.[68] Technical complications, including screw loosening, crown loosening and chipping, were mainly associated with inappropriate loading, which could be resolved by improving supra rehabilitation structure. In addition, for short implants (≤6 mm), risks relating to reduced length could be partially alleviated by improving the design of the implants[69] or increasing their diameter. With respect to the prevalence and severity of adverse events, the use of short implants (≤6 mm) was acceptable and was a promising alternative to sinus floor elevation.

No data synthesis for patient satisfaction was conducted for methodological difference among studies. In included studies, patients reported equal function and aesthetic satisfaction in both short implant and elevation group. However, patients were more satisfied with the cost of short implants (≤6 mm), which was in accordance with previous studies [13-15 70 71]. Thus, in aspect of patient satisfaction, short implants (≤6 mm) could serve as an alternative for longer implants with sinus floor elevation.

The present study has several strengths. Firstly, we conducted a comprehensive literature search, and all included studies were RCTs. Secondly, participant was used as the unit of analysis to ensure logical statistical syntheses and relevant interpretations. Thirdly, subgroup analysis by follow-up length and categories of complications was performed to reduce bias across studies. However, the evidence included in this systematic review was only of moderate or low quality. Serious risks of bias were found within and across studies. The number of participants and the follow-up period were limited. Due to limited data and methodological heterogeneity among studies, data synthesis for patient satisfaction was not performed. We suggest that researchers in this field carry out more well designed, long-term and large-scale RCTs to provide high quality evidence regarding the effects of short implants (≤6 mm).

## 5. Conclusions

Within its limitations, the present review suggests that the survival rate and patient satisfaction of maxillary short implants (≤6 mm) was comparable to that of longer implants (≥10 mm) with sinus floor elevation. However, short implants (≤6 mm) show significantly less MBL and post-surgery reactions. Short implants (≤6 mm) are therefore a promising alternative to sinus floor elevation for posterior maxilla with insufficient bone volume. Additional high-quality studies are needed to evaluate the

long-term effectiveness and safety of short implants (≤6 mm).

**Author contributions** Conception and design of the review: FH and BS. Methodology: FH. Drafting protocol, performing search strategies, literature searches, literature screening and data extraction: QY and XW. Original draft preparation: XW. Reviewing and editing draft: MS, QY, FH and BS. All authors critically reviewed and revised the manuscript and approved the final version for publication.

**Funding** This research was funded by the National Clinical Key Specialties Construction Project ([2013]544), the National Health Commission of China.

**Competing interests** None declared.

**Patient consent** Not required.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data sharing statement** No additional data are available.

## References


1. Spitznagel FA, Horvath SD, Gierthmuehlen PC. Prosthetic protocols in implant-based oral rehabilitations: A systematic review on the clinical outcome of monolithic all-ceramic single- and multi-unit prostheses. *European Journal of Oral Implantolantology* 2017;10 Suppl 1:89-99.
2. Pjetursson BE, Thoma D, Jung R, et al. A systematic review of the survival and complication rates of implant-supported fixed dental prostheses (FDPs) after a mean observation period of at least 5 years. *Clincal Oral Implants Research* 2012;23 Suppl 6:22-38.
3. Davarpanah M, Martinez H, Etienne D, et al. A prospective multicenter evaluation of 1,583 3i implants: 1- to 5-year data. *International Journal of Oral & Maxillofacial Implants* 2002;17(6):820-8.
4. Esposito M, Felice P, Worthington HV. Interventions for replacing missing teeth: augmentation procedures of the maxillary sinus: John Wiley & Sons, Ltd 2014.
5. Morand M, Irinakis T. The challenge of implant therapy in the posterior maxilla: providing a rationale for the use of short implants. *Journal of Oral Implantology* 2007;33(5):257-66.
6. Malchiodi L, Caricasulo R, Cucchi A, et al. Evaluation of Ultrashort and Longer Implants with Microrough Surfaces: Results of a 24- to 36-Month Prospective Study. *International Journal of Oral & Maxillofacial Implants* 2017;32(1):171-79.
7. Danesh-Sani SA, Loomer PM, Wallace SS. A comprehensive clinical review of maxillary sinus floor elevation: anatomy, techniques, biomaterials and complications. *British Journal of Oral Maxillofacial Surgery* 2016;54(7):724-30.
8. Branemark PI, Hansson BO, Adell R, et al. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. *Scandinavian Journal of Plastic and Reconstructive Surgery Supplementum* 1977;16:1-132.
9. Cha HS, Kim JW, Hwang JH, et al. Frequency of bone graft in implant surgery. *Maxillofacial plastic and reconstructive surgery* 2016;38(1):19.
10. Starch-Jensen T, Aludden H, Hallman M, et al. A systematic review and meta-analysis of long-term studies (five or more years) assessing maxillary sinus floor augmentation. *International Journal of Oral & Maxillofacial Surgery* 2018;47(1):103-16.
11. Starch-Jensen T, Schou S. Maxillary Sinus Membrane Elevation With Simultaneous Installation of Implants Without the Use of a Graft Material: A Systematic Review. *Implant dentistry* 2017;26(4):621-33.
12. Lee SA, Lee CT, Fu MM, et al. Systematic Review and Meta-Analysis of Randomized Controlled Trials for the Management of Limited Vertical Height in the Posterior Region: Short Implants (5 to 8 mm) vs Longer Implants (> 8 mm) in Vertically Augmented Sites. *International Journal of Oral & Maxillofacial Implants* 2014;29(5):1085.
13. Pjetursson BE, Tan WC, Zwahlen M, et al. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. *Journal of Clinical Periodontology* 2008;35(Supplement s8):216-40.
14. Tan WC, Lang NP, Zwahlen M, et al. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. Part II: transalveolar technique. *Journal of Clinical Periodontology* 2008;35(8 Suppl):241-54.
15. Thoma DS, Zeltner M, Husler J, et al. EAO Supplement Working Group 4 - EAO CC 2015 Short implants versus sinus lifting with longer implants to restore the posterior maxilla: a systematic review. *Clinical Oral Implants Research* 2015;26 Suppl 11:154-69.
16. Lundgren S, Cricchio G, Hallman M, et al. Sinus floor elevation procedures to enable implant placement and integration: techniques, biological aspects and clinical outcomes. *Periodontology 2000* 2017;73(1):103-20.
17. Pjetursson BE, Tan WC, Zwahlen M, et al. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. *Journal of Clinical Periodontology* 2010;35(s8):216-40.
18. Huang HL, Fuh LJ, Ko CC, et al. Biomechanical effects of a maxillary implant in the augmented sinus: a three-dimensional finite element analysis. *International Journal of Oral Maxillofacial Implants* 2009;24(3):455-62.
19. Lin YH, Yang YC, Wen SC, et al. The influence of sinus membrane thickness upon membrane perforation during lateral window sinus augmentation. *Clinical Oral Implants Research*

2016;27(5):612-17.
20. Monje A, Suarez F, Galindo-Moreno P, et al. A systematic review on marginal bone loss around short dental implants (<10 mm) for implant-supported fixed prostheses. *Clinical Oral Implants Research* 2015;25(10):1119-24.
21. Nielsen HB, Schou S, Isidor F, et al. Short implants (</=8mm) compared to standard length implants (>8mm) in conjunction with maxillary sinus floor augmentation: a systematic review and meta-analysis. *International Journal of Oral & Maxillofacial Surgery* 2018
22. Uehara PN, Matsubara VH, Igai F, et al. Short Dental Implants (≤7mm)VersusLonger Implants in Augmented Bone Area: A Meta-Analysis of Randomized Controlled Trials. *Open Dentistry Journal* 2018;12:354-65.
23. Al Amri MD, Abduljabbar TS, Al-Johany SS, et al. Comparison of clinical and radiographic parameters around short (6 to 8 mm in length) and long (11 mm in length) dental implants placed in patients with and without type 2 diabetes mellitus: 3-year follow-up results. *Clinical Oral Implants Research* 2016;28
24. Urdaneta RA, Daher S, Leary J, et al. The survival of ultrashort locking-taper implants. *International Journal of Oral & Maxillofacial Implants* 2012;27(3):644-54.
25. Markose J, Eshwar S, Srinivas S, et al. Clinical outcomes of ultrashort sloping shoulder implant design: A survival analysis. *Clinical Implant Dentistry and Related Research* 2018;20(4):646-52.
26. Fan T, Li Y, Deng WW, et al. Short Implants (5 to 8 mm) Versus Longer Implants (>8 mm) with Sinus Lifting in Atrophic Posterior Maxilla: A Meta-Analysis of RCTs. *Clinical Implant Dentistry & Related Research* 2016;19(1):207-15.
27. Deporter DA, Ogiso B, Sohn DS, et al. Ultrashort sintered porous-surfaced dental implants used to replace posterior teeth. *Journal of Periodontology* 2008;79(7):1280-86.
28. Sahrmann P, Naenni N, Jung RE, et al. Success of 6-mm Implants with Single-Tooth Restorations: A 3-year Randomized Controlled Clinical Trial. *Journal of Dental Research* 2016;95(6):623-28.
29. Felice P, Checchi L, Barausse C, et al. Posterior jaws rehabilitated with partial prostheses supported by 4.0 x 4.0 mm or by longer implants: One-year post-loading results from a multicenter randomised controlled trial. *European journal of oral implantology* 2016;9(1):35-45.
30. Bolle C, Felice P, Barausse C, et al. 4 mm long vs longer implants in augmented bone in posterior atrophic jaws: 1-year post-loading results from a multicentre randomised controlled trial. *European Journal of Oral Implantology* 2018;11(1):31-47.
31. Calvo-Guirado JL, Lopez Torres JA, Dard M, et al. Evaluation of extrashort 4-mm implants in mandibular edentulous patients with reduced bone height in comparison with standard implants: a 12-month results. *Clinical Oral Implants Research* 2016;27(7):867-74.
32. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *Bmj British Medical Journal* 2009;339:b2700.
33. Higgins JPT GS, editor(s). Cochrane Handbook for Systematic Reviews of Interventions version 5.1.0 (updated March 2011): The Cochrane Collaboration, 2011. Available from www.cochrane-handbook.org.
34. Egger M, Davey SG, Schneider M, et al. Bias in meta-analysis detected by a simple, graphical test. *Bmj British Medical Journal* 1997;316(7129):469-71.
35. Esposito M, Ardebili Y, Worthington HV. Interventions for replacing missing teeth: different types of dental implants. *The Cochrane database of systematic reviews* 2014(7):Cd003815.
36. Borenstein M, Hedges LV, Higgins JP, et al. A basic introduction to fixed-effect and random-effects models for meta-analysis. *Res Synth Methods* 2010;1(2):97-111.
37. Esposito M, Grusovin MG, Maghaireh H, et al. Interventions for replacing missing teeth: different times for loading dental implants. *The Cochrane database of systematic reviews* 2013(3):CD003878.
38. Esposito M, Worthington HV. Interventions for replacing missing teeth: hyperbaric oxygen therapy for irradiated patients who require dental implants. *The Cochrane database of systematic reviews* 2013(9):CD003603.
39. Esposito M, Felice P, Worthington HV. Interventions for replacing missing teeth:

augmentation procedures of the maxillary sinus. *The Cochrane database of systematic reviews* 2014(5):CD008397.

40. Tolentino da Rosa de Souza P, Binhame Albini Martini M, Reis Azevedo-Alanis L. Do short implants have similar survival rates compared to standard implants in posterior single crown?: A systematic review and meta-analysis. *Clinical Implant Dentistry and Related Research* 2018
41. Andrews J, Guyatt G, Oxman AD, et al. GRADE guidelines: 14. Going from evidence to recommendations: the significance and presentation of recommendations. *Journal of clinical epidemiology* 2013;66(7):719-25.
42. Gastaldi G, Felice P, Pistilli V, et al. Posterior atrophic jaws rehabilitated with prostheses supported by 5 × 5 mm implants with a nanostructured calcium-incorporated titanium surface or by longer implants in augmented bone. 3-year results from a randomised controlled trial. *European Journal of Oral Implantology* 2018;11(1):49-61.
43. Gastaldi G, Felice P, Pistilli R, et al. Short implants as an alternative to crestal sinus lift: a 3-year multicentre randomised controlled trial. *European Journal of Oral Implantology* 2017;10(4):391-400.
44. Guljé FL, Raghoebar GM, Vissink A, et al. Single crowns in the resorbed posterior maxilla supported by either 6-mm implants or by 11-mm implants combined with sinus floor elevation surgery: a 1-year randomised controlled trial. *European Journal of Oral Implantology* 2014;7(3):247-55.
45. Pohl V, Thoma DS, Sporniak-Tutak K, et al. Short dental implants (6 mm) versus long dental implants (11-15 mm) in combination with sinus floor elevation procedures: 3-year results from a multicentre, randomized, controlled clinical trial. *Journal of Clinical Periodontology* 2017;44(4):438-45.
46. Felice P, Barausse C, Pistilli V, et al. Posterior atrophic jaws rehabilitated with prostheses supported by 6 mm long x 4 mm wide implants or by longer implants in augmented bone. 3-year post-loading results from a randomised controlled trial. *European Journal of Oral Implantology* 2018;11(2):175-87.
47. Bechara S, Kubilius R, Veronesi G, et al. Short (6-mm) dental implants versus sinus floor elevation and placement of longer (>/=10-mm) dental implants: a randomized controlled trial with a 3-year follow-up. *Clinical Oral Implants Research* 2017;28(9):1097-107.
48. Lombardo G, Pighi J, Marincola M, et al. Cumulative Success Rate of Short and Ultrashort Implants Supporting Single Crowns in the Posterior Maxilla: A 3-Year Retrospective Study. *International journal of dentistry* 2017;2017:8434281.
49. Lai HC, Si MS, Zhuang LF, et al. Long-term outcomes of short dental implants supporting single crowns in posterior region: a clinical retrospective study of 5–10years. *Clinical Oral Implants Research* 2013;24(2):230–37.
50. Himmlova L, Dostalova T, Kacovsky A, et al. Influence of implant length and diameter on stress distribution: a finite element analysis. *Journal of Prosthetic Dentistry* 2004;91(1):20-5.
51. Moriwaki H, Yamaguchi S, Nakano T, et al. Influence of Implant Length and Diameter, Bicortical Anchorage, and Sinus Augmentation on Bone Stress Distribution: Three-Dimensional Finite Element Analysis. *International Journal of Oral & Maxillofacial Implants* 2016;31(4):e84-91.
52. Kim S, Jung UW, Cho KS, et al. Retrospective radiographic observational study of 1692 Straumann tissue-level dental implants over 10 years: I. Implant survival and loss pattern. *Clinical Implant Dentistry and Related Research* 2018
53. Lin G, Ye S, Liu F, et al. A retrospective study of 30,959 implants: Risk factors associated with early and late implant loss. *Journal of Clinical Periodontology* 2018;45(6):733-43.
54. Tabassum A, Meijer GJ, Wolke JG, et al. Influence of the surgical technique and surface roughness on the primary stability of an implant in artificial bone with a density equivalent to maxillary bone: a laboratory study. *Clinical Oral Implants Research* 2009;20(4):327-32.
55. Dos Santos MV, Elias CN, Cavalcanti Lima JH. The effects of superficial roughness and design on the primary stability of dental implants. *Clinical Implant Dentistry and Related Research* 2011;13(3):215-23.
56. Falco A, Berardini M, Trisi P. Correlation Between Implant Geometry, Implant Surface,

Insertion Torque, and Primary Stability: In Vitro Biomechanical Analysis. *International Journal of Oral & Maxillofacial Implants* 2018;33(4):824-30.
57. Jain N, Gulati M, Garg M, et al. Short Implants: New Horizon in Implant Dentistry. *Journal of Clinical and Diagnostic Research* 2016;10(9):Ze14-ze17.
58. Uehara PN, Matsubara VH, Igai F, et al. Short Dental Implants (</=7mm) Versus Longer Implants in Augmented Bone Area: A Meta-Analysis of Randomized Controlled Trials. *Open Dentistry Journal* 2018;12:354-65.
59. Anitua E, Alkhraist MH, Piñas L, et al. Implant survival and crestal bone loss around extra-short implants supporting a fixed denture: the effect of crown height space, crown-to-implant ratio, and offset placement of the prosthesis. *International Journal of Oral & Maxillofacial Implants* 2014;29:682-89.
60. Quirynen M, Naert I, van Steenberghe D. Fixture design and overload influence marginal bone loss and fixture success in the Branemark system. *Clinical Oral Implants Research* 1992;3(3):104-11.
61. Blanes RJ. To what extent does the crown-implant ratio affect the survival and complications of implant-supported reconstructions? A systematic review. *Clinical Oral Implants Research* 2009;20 Suppl 4:67-72.
62. Verri FR, Batista VEdS, Santiago JF, et al. Effect of crown-to-implant ratio on peri-implant stress: A finite element analysis. *Materials Science and Engineering: C* 2014;45:234-40.
63. Quaranta A, Piemontese M, Rappelli G, et al. Technical and biological complications related to crown to implant ratio: a systematic review. *Implant Dentistry* 2014;23(2):180-7.
64. Urdaneta RA, Rodriguez S, McNeil DC, et al. The effect of increased crown-to-implant ratio on single-tooth locking-taper implants. *International Journal of Oral & Maxillofacial Implants* 2010;25(4):729-43.
65. Tawil G, Aboujaoude N, Younan R. Influence of prosthetic parameters on the survival and complication rates of short implants. *International Journal of Oral & Maxillofacial Implants* 2006;21(2):275-82.
66. Schneider D, Witt L, Hammerle CHF. Influence of the crown-to-implant length ratio on the clinical performance of implants supporting single crown restorations: a cross-sectional retrospective 5-year investigation. *Clinical Oral Implants Research* 2012;23(2):169-74.
67. Thoma DS, Cha JK, Jung UW. Treatment concepts for the posterior maxilla and mandible: short implants versus long implants in augmented bone. *Journal of periodontal & implant science* 2017;47(1):2-12.
68. Manor Y, Anavi Y, Gershonovitch R, et al. Complications and Management of Implants Migrated into the Maxillary Sinus. *International Journal of Periodontics and Restorative Dentistry* 2018
69. Mangano F, Frezzato I, Frezzato A, et al. The Effect of Crown-to-Implant Ratio on the Clinical Performance of Extra-Short Locking-Taper Implants. *Journal of Craniofacial Surgery* 2016;27(3):675-81.
70. Seemann R, Marincola M, Seay D, et al. Preliminary results of fixed, fiber-reinforced resin bridges on four 4- x 5-mm ultrashort implants in compromised bony sites: a pilot study. *Journal of oral and maxillofacial surgery : official journal of the American Association of Oral and Maxillofacial Surgeons* 2015;73(4):630-40.
71. Esposito M, Grusovin MG, Felice P, et al. Interventions for replacing missing teeth: horizontal and vertical bone augmentation techniques for dental implant treatment. *The Cochrane database of systematic reviews* 2009(4):Cd003607.

**Table 1** Characteristics of the included studies.

| Study | Design | Subjects | | | Follow-up period PL | Short implant group | | | Elevation group | | | | Rehabilitation methods | Outcome measures |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Gender (Male/Female) | Age | RBH (mm) | | Implant (n) | LEN (mm) | DIA (mm) | Implant (n) | LEN (mm) | DIA (mm) | Elevation methods | | |
| Bolle et al., 2018 | RCT (TAP) | INT 7/13<br>CON 12/8 | 59.35 (47-73)<br>63.25 (46-72) | 4-5 | 1 year | 37 | 4 | 4 or 4.5 | 41 | 10, 11.5, 13 | 4 or 4.5 | osteotomy approach | SG or SP | NIF, MBL, COM |
| Gastaldi et al., 2018 | RCT (TAP) | INT 3/17<br>CON 7/13 | 58.6 (39-80)<br>52.8 (42-70) | 4-6 | 3 years | 20 | 5 | 5 | 20 | 10, 11.5, 13, 15 | 5 | lateral window technique | SG or SP | NIF, MBL, COM |
| Gastaldi et al., 2017 | RCT (TAP) | INT 3/7<br>CON 5/5 | 53.4 (43-67)<br>58.6 (48-70) | 5-7 | 3 years | 16 | 5 or 6 | 5 | 18 | 10 | 5 | osteotomy approach | SG or SP | NIF, MBL, COM, PS |
| Guljé et al., 2014 | RCT (TAP) | INT 7/14<br>CON 13/7 | 50 (30-71)<br>48 (29-72) | 6-8 | 1 year | 21 | 6 | 4 | 20 | 11 | 4 | lateral window technique | SG | NIF, MBL, COM, PS |
| Pohl et al., 2017 | RCT (TAP) | 49/52* | 50.5 (20-75) * | 5-7 | 3 years | 67 | 6 | 4 | 70 | 11, 13, 15 | 4 | lateral window technique | SG | NIF, MBL, COM |
| Felice et al., 2018 | RCT (SM) | 11/9 | 57.6 (45 – 80) | 5-7 | 3 years | 39 | 6 | 4 | 44 | 10, 11.5, 13, 15 | 4 | lateral window technique | SG or SP | NIF, MBL, COM |
| Bechara et al., 2017 | RCT (TAP) | INT 10/23<br>CON 9/11 | 47.5±16.2<br>49.2±13.4 | ≥4 | 3 years | 45 | 6 | 4-8 | 45 | 10, 11.5, 13, 15 | 4-8 | lateral window technique | SG or SP | NIF, MBL, COM, PS |

RBH=residual bone width under sinus floor; INT=intervention; CON=control; PL=post-loading; LEN=implant length; DIA=implant diameter; TAP=two-arm parallel; SG=single crowns; SP=splinted prosthetics; PS=patient satisfaction; NIF=number of implant failures; MBL=marginal bone loss; COM=complications; SM=split mouth; NR=not reported.

* Details for subject information in intervention and control group were not reported.

**Table 2** Details on the risk of bias for each included study

| Study | Random sequence generation | Allocation concealment | Blinding of patients/carers | Blinding of outcome assessment | Incomplete outcome data | Selective reporting | Other |
|---|---|---|---|---|---|---|---|
| Bolle et al., 2018 | Low risk- Quote: “a computer-generated restricted randomization list” | Low risk- Quote: “the information on how to treat each patient was enclosed in sequentially numbered, identical, opaque, sealed envelopes.” | Low risk - Quote: “treatment allocation was concealed to the investigators in charge of enrolling and treating the patients.” | High risk- Quote: "complications were dealt with directly and reported by the responsible clinicians, who were not blinded”; “augmented sites could be easily identified on radiographs due to the different implant lengths." | Low risk- Quote: “one patient from the short implant group and one from elevation group dropped out.” | Low risk- Comment; All outcome measure in methods were reported in results | Unclear risk- Comment: diameter of implants (4 mm or 4.5 mm) was not controlled |
| Gastaldi et al., 2018 | Low risk- Quote: “a computer-generated restricted randomization list” | Low risk- Quote: “The randomized codes were enclosed in sequentially numbered, identical, opaque, sealed envelopes” | Low risk- Quote: “treatment allocation was concealed to the investigators in charge of enrolling and treating the patients.” | High risk- Quote: "augmented sites could be easily identified because of the different anatomy of the two sides after the augmentation procedure" | Low risk- Comment: one patient dropped out of the short implant group (1/20), and two patients dropped out of the elevation group (2/20) | Low risk- Comment; All outcome measures in methods were reported in results | Unclear risk- Comment: information of short implants was not reported |
| Gastaldi et al., 2017 | Low risk- Quote: “a computer-generated restricted randomization list” | Low risk- Quote: "The randomized codes were enclosed in sequentially numbered, identical, opaque, sealed envelopes.” | Low risk- Quote: “treatment allocation was concealed to the investigators in charge of enrolling and treating the patients” | High risk- Quote: “sinus-lifted sites could be identified on radiographs because they appeared more radio-opaque and implants were longer.” | High risk- Comment: no patients dropped out of the short implant group (0/10); two patients dropped out of the elevation group (2/10) | Low risk- Comment; All outcome measures in methods were reported in results | Low risk |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Guljé et al., 2014 | Low risk- Quote: "Randomization was performed using a block randomization sequence to provide equal distribution of subjects." | Low risk- Quote: “A sealed envelope” | Low risk- Quote: “A sealed envelope was opened by the surgical assistant at the beginning of the surgical procedure.” | High risk- Quote: “Blinding was possible in the clinical evaluation but not during analysis of the radiographs.” | Low risk-Comment: no patient dropped out of the short implant group (0/21); one patient in the elevation group died (1/20) | Low risk- Comment; All outcome measures in methods were reported in results | Low risk |
| Pohl et al., 2017 | Low risk- Quote: “A block randomization sequence was used to provide an equal distribution” | Low risk- Quote: “A sealed envelope” | Low risk- Quote: “After flap elevation, a sealed randomization envelope was opened to allocate the subject to either one of the two treatment | Unclear risk- Quote: “an independent examiner performed all the radiographic measurements.” Other information was not reported. | High risk-Comment: The reasons for incomplete reporting of MBL were not provided. | High risk- Comment: marginal bone loss at 3-year follow-up was reported at the implant level rather than at the participant level | Low risk |
| Felice et al., 2018 | Low risk- Quote: “a computer-generated restricted randomisation list” | Low risk- Quote: “The information on how to treat site number 1 was enclosed in sequentially numbered, identical, opaque, sealed envelopes.” | Low risk- Quote: “Treatment allocation was concealed to the investigators in charge of enrolling and treating the patients.” | High risk- Quote: “augmented sites could be easily identified because of the different anatomy” | High risk- Comment: it was a split-mouth design study, and two dropouts (2/20) occurred | Low risk- Comment: All outcome measures in methods were reported in results | Low risk |
| Bechara et al., 2017 | Unclear risk- Quote: “Patients were randomly assigned” | Low risk- Quote: “a sequentially numbered sealed envelope” | Unclear risk- Comment: not mentioned | Unclear risk- Quote: “At each annual inspection, an experienced, calibrated, independent examiner performed a careful clinical examination”, but elevation site can be distinguished | Low risk- Comment: one patient dropped out of the short implant group (1/33), and one patient dropped out of the elevation group (1/20) | High risk- Comment: marginal bone loss was reported at the implant level rather than at the participant level | High risk- Comment: diameter of implants was not controlled (4-8 mm) |

**Table 3** Details of implant failures reported in the included studies.

| Study | Short implant group | | | | Elevation group | | | |
|---|---|---|---|---|---|---|---|---|
| | LEN (mm) | DIA (mm) | PAR/IMP (n) | Details | LEN (mm) | DIA (mm) | PAR/IMP (n) | Details |
| Bolle et al., 2018 | 4 | 4 or 4.5 | 2/3 | PAR1. One implant was mobile 3 months after placement, and another implant migrated into the sinus 4 months after placement. PAR2. One implant was medially tilted 2 weeks after placement | 10,11.5,13 | 4 or 4.5 | 4/6 | PAR1. One implant was mobile 2 months after placement because of a perforation of the sinus lining at its detachment. Another implant was mobile 2 months later. PAR2. One implant migrated into the sinus 3 months after placement. PAR3. Two implants were mobile 3 months after placement because the patient insisted on wearing her removable denture. PAR4. One implant was mobile, and the patient experienced discomfort when chewing 5 months post-loading. |
| Gastaldi et al., 2018 | 5 | 5 | 1/1 | PAR1. One implant failed 3 months post-loading. | 10,11.5, 13,15 | 5 | 0 | None |
| Felice et al., 2018 | 6 | 4 | 0 | None | 10,11.5, 13,15 | 4 | 1/2 | PAR1. Two implants failed due to peri-implantitis 2 years post-loading. |
| Bechara et al., 2017 | 6 | 4-8 | 0 | None | 10,11.5, 13,15 | 4-8 | 1/2 | PAR1. Two implants were lost caused due to chronic sinus infection with loss of integration/implant stability 2 months after surgery |

LEN=implant length; DIA=implant diameter; PAR=participant; PAR/IMP=participant/implant

Table 4 Summary of findings

**Short implant (≤6 mm) compared to longer implant (≥10 mm) with sinus floor elevation in atrophic posterior maxilla**

**Patient or population**: atrophic posterior maxilla
**Intervention**: short implant (<= 6mm)
**Comparison**: longer implant (>= 10mm) with sinus floor elevation

| Outcomes | Anticipated absolute effects* (95% CI) | | Relative effect (95% CI) | № of participants (studies) | Certainty of the evidence (GRADE) | Comments |
|---|---|---|---|---|---|---|
| | Assumed risk [1] (elevation group) | Corresponding risk (short implant group) | | | | |
| survival rate follow up: range 1 years to 3 years | 961 per 1,000 | **970 per 1,000** (932 to 999) | **RR 1.01** (0.97 to 1.04) | 321 (7 RCTs) | ⊕⊕⊕◯ MODERATE [2] | |
| survival rate follow up: range 3 years to longer years | 982 per 1,000 | **982 per 1,000** (953 to 1,000) | **RR 1.00** (0.97 to 1.04) | 237 (5 RCTs) | ⊕⊕⊕◯ MODERATE [2] | |
| marginal bone loss follow up: range 1 years to 3 years | The mean marginal bone loss ranged from **0.1 to 1.15** mm | The mean marginal bone loss in the intervention group was 0.13 mm lower (0.21 lower to 0.05 lower) | - | 249 (6 RCTs) | ⊕⊕◯◯ LOW [3] | |
| marginal bone loss follow up: range 3 years to longer years | The mean marginal bone loss ranged from **1.08 to 1.5** mm | The mean marginal bone loss in the intervention group was 0.25 mm lower (0.4 lower to 0.1 lower) | - | 88 (3 RCTs) | ⊕⊕⊕◯ MODERATE [2] | |
| post-surgery reaction | 338 per 1,000 | **37 per 1,000** (10 to 118) | **RR 0.11** (0.03 to 0.35) | 157 (3 RCTs) | ⊕⊕⊕◯ MODERATE [2] | |
| biological complications: sinus perforation or infection | 167 per 1,000 | **23 per 1,000** (5 to 128) | **RR 0.14** (0.03 to 0.77) | 120 (3 RCTs) | ⊕⊕◯◯ LOW [4] | |
| biological complications: implant mobile | 67 per 1,000 | **23 per 1,000** (4 to 129) | **RR 0.34** (0.06 to 1.94) | 117 (2 RCTs) | ⊕⊕◯◯ LOW [4] | |
| biological complications: implant migrating into sinus | 200 per 1,000 | **100 per 1,000** (10 to 934) | **RR 0.50** (0.05 to 4.67) | 20 (1 RCT) | ⊕⊕◯◯ LOW [4] | |
| biological complications: peri-implant mucositis or peri-implantitis | 29 per 1,000 | **32 per 1,000** (3 to 326) | **RR 1.09** (0.11 to 11.10) | 65 (2 RCTs) | ⊕⊕◯◯ LOW [4] | |
| technical complications: screw loosening | 92 per 1,000 | **186 per 1,000** (79 to 439) | **RR 2.02** (0.86 to 4.77) | 148 (3 RCTs) | ⊕⊕◯◯ LOW [4] | |
| technical complications: crown loosening, decrementation and chipping | 27 per 1,000 | **35 per 1,000** (10 to 128) | **RR 1.27** (0.35 to 4.69) | 216 (5 RCTs) | ⊕⊕◯◯ LOW [4] | |

***The risk in the intervention group** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI). **CI:** Confidence interval; **RR:** Risk ratio; **MD:** Mean difference

1. Assumed risk is based on the overall event rate in the control groups of the included studies.
2. Downgraded one level due to serious risks of bias.
3. Downgraded two levels due to serious risks of bias and serious inconsistency.
4. Downgraded two levels due to serious risks of bias and imprecision.

## Figure Legends

**Figure 1** Flow diagram for study selection

**Figure 2** Risk of bias in each included study

**Figure 3** Risk of bias across included studies

**Figure 4** Forest plot for implant survival rate

*footnote: SI, short implant group; SFE, sinus floor elevation group.*

**Figure 5** Forest plot for marginal bone loss

*footnote: SI, short implant group; SFE, sinus floor elevation group.*

**Figure 6** Forest plot for post-surgery reaction

*footnote: SI, short implant group; SFE, sinus floor elevation group.*

**Figure 7** Forest plot for biological complications

*footnote: SI, short implant group; SFE, sinus floor elevation group.*

**Figure 8** Forest plot for technical complications

*footnote: SI, short implant group; SFE, sinus floor elevation group.*

Identification

**Records identified through database searching** (n=1130):
PubMed (n=879); EMBASE (n=251)

**Records after duplicates removed** (n=1013)

**Records excluded** (n=988):
- ✧ Not clinical trial (n=204)
- ✧ Not regarding short dental implants (n=463)
- ✧ Intervention in control group not regarding this study (n=269)
- ✧ Not RCT (n=52)

Screening

**Records screened on the basis of title and abstract** (n=1013)

Eligibility

**Full-text articles assessed for eligibility** (n=25)

**Full-text articles excluded** (n=20):
- ✧ No sinus floor elevation in elevation group (n=8)
- ✧ Implants <10mm were used in elevation group (n=3)
- ✧ Follow-up length less than one year (n=1)
- ✧ Multiple publications existed for the same study, publications with shorter follow-up length (n=8)

Included

**Studies included in qualitative synthesis** (n=7)

**Articles identified through supplementary search** (n=2):
- ✧ Citation database search (n=0)
- ✧ Hand search (n=2)

**Studies included in quantitative synthesis (meta-analysis)** (n=7)

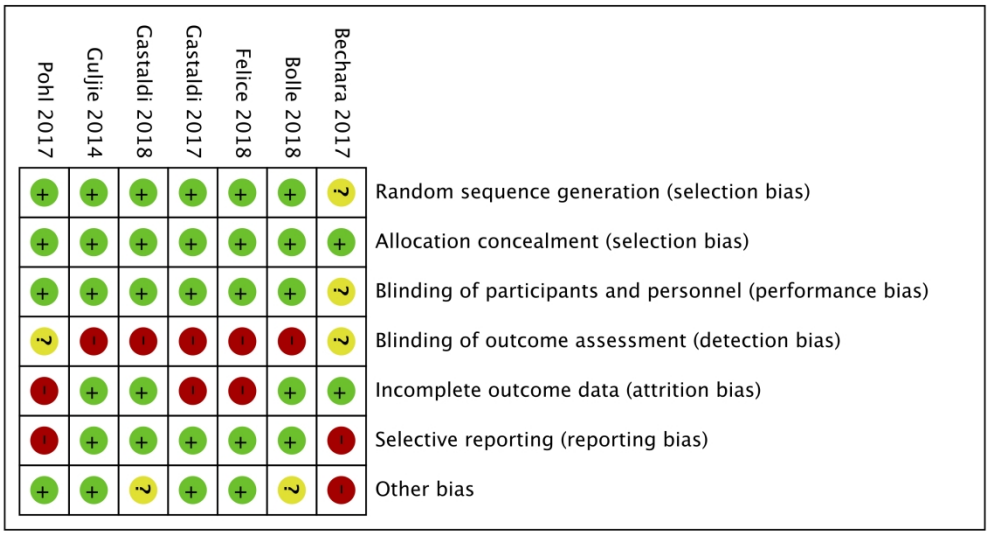



Figure 2 Risk of bias in each included study

269x146mm (300 x 300 DPI)

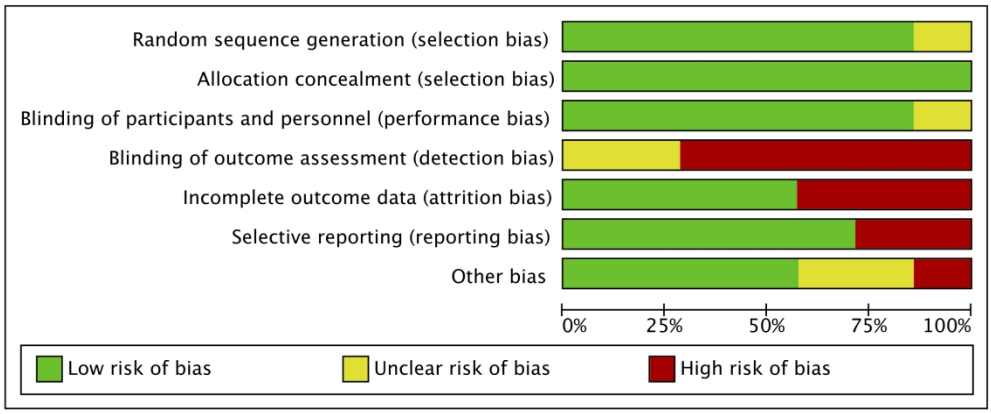



Figure 3 Risk of bias across included studies

199x83mm (300 x 300 DPI)

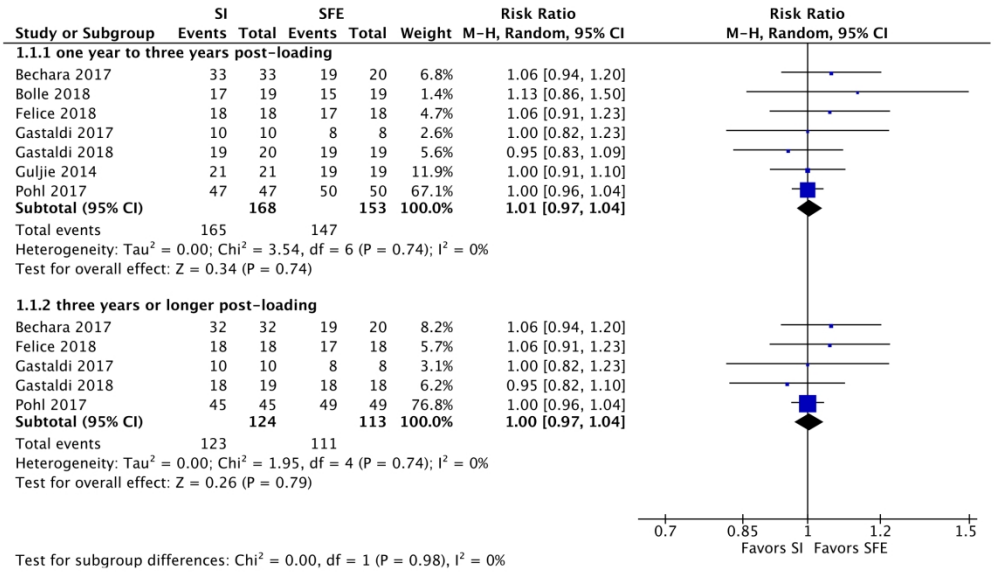



Figure 4 Forest plot for implant survival rate. footnote: SI, short implant group; SFE, sinus floor elevation group.

198x114mm (300 x 300 DPI)

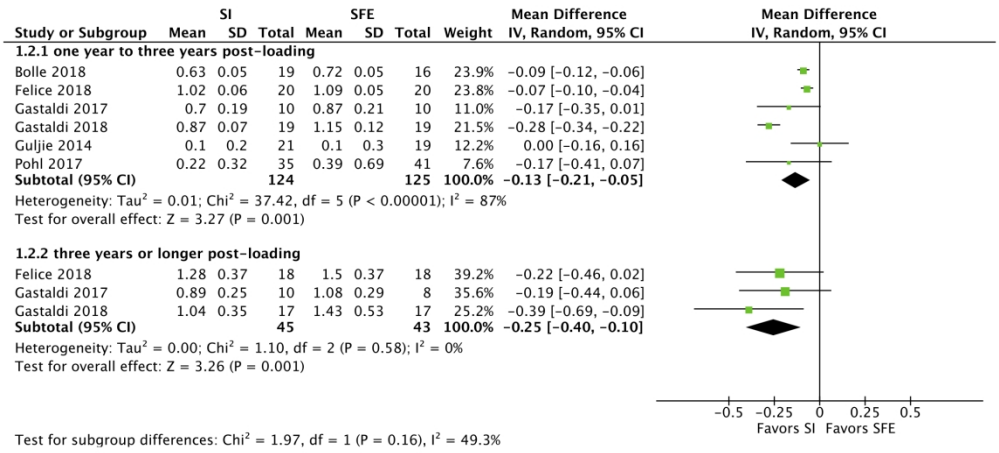



Figure 5 Forest plot for marginal bone loss. footnote: SI, short implant group; SFE, sinus floor elevation group.

197x90mm (300 x 300 DPI)


Figure 6 Forest plot for post-surgery reaction. footnote: SI, short implant group; SFE, sinus floor elevation group.

198x42mm (300 x 300 DPI)

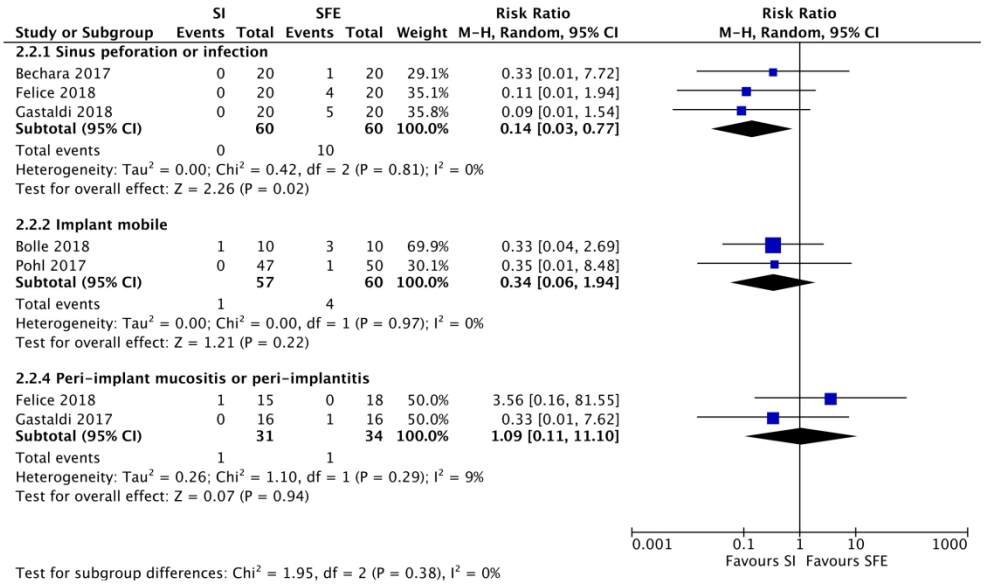



Figure 7 Forest plot for biological complications. footnote: SI, short implant group; SFE, sinus floor elevation group.

200x117mm (300 x 300 DPI)

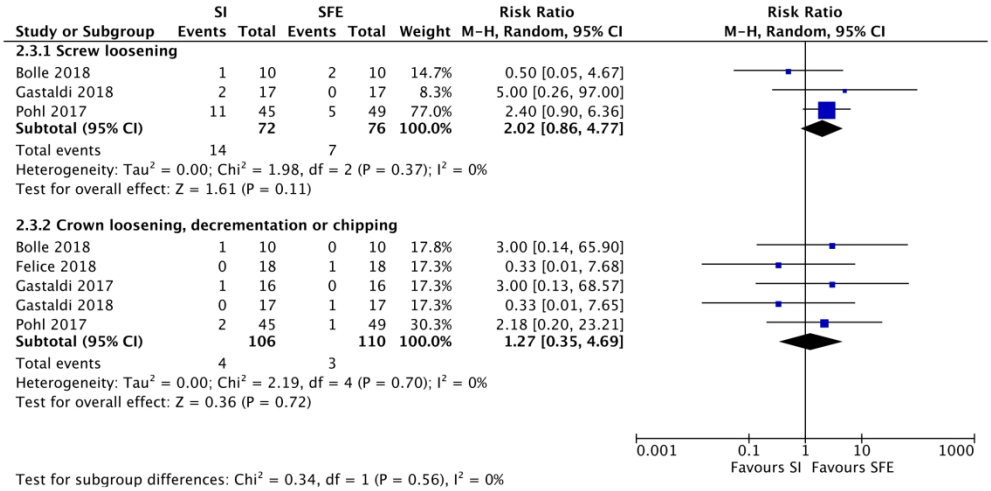



Figure 8 Forest plot for technical complications. footnote: SI, short implant group; SFE, sinus floor elevation group.

198x98mm (300 x 300 DPI)

*Supplementary File*

# Short implants (≤6 mm) versus longer implants with sinus floor elevation in atrophic posterior maxilla: A systematic review and meta-analysis

**The search strategy used for PubMed (1946 to 31 May 2018):**

1. dental implant [Mesh Terms]
2. dental implantation [Mesh Terms]
3. dental prosthesis, implant supported [Mesh Terms]
4. 1 OR 2 OR 3
5. long implant [Title/Abstract]
6. short implant [Title/Abstract]
7. shorter implant [Title/Abstract]
8. longer implant [Title/Abstract]
9. super short [Title/Abstract]
10. extra short [Title/Abstract]
11. ultrashort [Title/Abstract]
12. 6mm [Title/Abstract]
13. 5mm [Title/Abstract]
14. 4mm [Title/Abstract]
15. 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14
16. 4 OR 15
17. alveolar bone loss [Mesh Terms]
18. alveolar bone atrophy [Mesh Terms]
19. alveolar ridge augmentation [Mesh Terms]
20. bone substitute [Mesh Terms]
21. augmentation, sinus floor [Mesh Terms]
22. 17 OR 18 OR 19 OR 20 OR 21
23. atrophy jaw [Title/Abstract]
24. atrophy maxilla [Title/Abstract]
25. atrophy mandible [Title/Abstract]
26. augmented bone [Title/Abstract]

27. bone augmentation [Title/Abstract]
28. sinus lift [Title/Abstract]
29. sinus floor elevation [Title/Abstract]
30. 23 OR 24 OR 25 OR 26 OR 27 OR 28 OR 29
31. 22 OR 30
32. randomized controlled trial [Publication Type]
33. randomized [Title/Abstract]
34. randomly [Title/Abstract]
35. 32 OR 33 OR 34
36. 16 AND 31 AND 35

**The search strategy used for Embase (1980 to 31 May 2018):**

1. 'alveolar bone loss'/exp/mj
2. 'alveolar ridge augmentation'/exp/mj
3. 'bone prosthesis'/exp/mj
4. 1 OR 2 OR 3
5. 'atrophic jaw': ab, ti
6. 'atrophic maxilla': ab, ti
7. 'atrophic mandible': ab, ti
8. 'posterior maxilla': ab, ti
9. 'posterior mandible': ab, ti
10. 'augmented bone': ab, ti
11. 'bone augmentation': ab, ti
12. 'sinus lift': ab, ti
13. 'sinus floor elevation': ab, ti
14. 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13
15. 4 OR 14
16. 'tooth implantation'/exp/mj
17. 'tooth implant'/exp/mj
18. 'tooth prosthesis'/exp/mj
19. 16 OR 17 OR 18
20. 'short implant': ab, ti

21. ‘long implant’: ab, ti
22. ‘shorter implant’: ab, ti
23. ‘longer implant’: ab, ti
24. ‘super short’: ab, ti
25. ‘extra short’: ab, ti
26. ‘ultrashort’: ab, ti
27. ‘6mm’: ab, ti
28. ‘5mm’: ab, ti
29. ‘4mm’: ab, ti
30. 20 OR 21 OR 22 OR 23 OR 24 OR 25 OR 26 OR 27 OR 28 OR 29
31. 19 OR 30
32. ‘controlled clinical trial’/lim
33. ‘randomized controlled trial’/lim
34. 32 OR 33
35. 15 AND 31 AND 34

*Supplementary File*

**Short implants (≤6 mm) versus longer implants with sinus floor elevation in atrophic posterior maxilla: A systematic review and meta-analysis**

| | # | Checklist item | Reported on page # |
|---|---|---|---|
| **TITLE** | | | |
| Title | 1 | Identify the report as a systematic review, meta-analysis, or both. | 1 |
| **ABSTRACT** | | | |
| Structured summary | 2 | Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number. | 2 |
| **INTRODUCTION** | | | |
| Rationale | 3 | Describe the rationale for the review in the context of what is already known. | 4 |
| Objectives | 4 | Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS). | 5 |
| **METHODS** | | | |
| Protocol and registration | 5 | Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number. | 5 |
| Eligibility criteria | 6 | Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale. | 5 |
| Information sources | 7 | Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched. | 6 |
| Search | 8 | Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated. | 6 |

*Supplementary File*

| | | | |
|---|---|---|---|
| Study selection | 9 | State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis). | 6 |
| Data collection process | 10 | Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators. | 7 |
| Data items | 11 | List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made. | 7 |
| Risk of bias in individual studies | 12 | Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis. | 7 |
| Summary measures | 13 | State the principal summary measures (e.g., risk ratio, difference in means). | 8 |
| Synthesis of results | 14 | Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., $I^2$) for each meta-analysis. | 8 |

| Section/topic | # | Checklist item | Reported on page # |
|---|---|---|---|
| Risk of bias across studies | 15 | Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies). | 7 |
| Additional analyses | 16 | Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified. | 8 |
| **RESULTS** | | | |
| Study selection | 17 | Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram. | 9 |
| Study characteristics | 18 | For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations. | 10 |
| Risk of bias | 19 | Present data on risk of bias of each study and, if available, any outcome level assessment | 10 |

*Supplementary File*

| | | | |
|---|---|---|---|
| within studies | | (see item 12). | |
| Results of individual studies | 20 | For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot. | 11-12 |
| Synthesis of results | 21 | Present results of each meta-analysis done, including confidence intervals and measures of consistency. | 11-12 |
| Risk of bias across studies | 22 | Present results of any assessment of risk of bias across studies (see Item 15). | 10 |
| Additional analysis | 23 | Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]). | 11-12 |
| **DISCUSSION** | | | |
| Summary of evidence | 24 | Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers). | 12 |
| Limitations | 25 | Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias). | 16 |
| Conclusions | 26 | Provide a general interpretation of the results in the context of other evidence, and implications for future research. | 16 |
| **FUNDING** | | | |
| Funding | 27 | Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review. | 17 |

*From:* Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: **www.prisma-statement.org**.

BMJ Open

# Short implants (≤6 mm) versus longer implants with sinus floor elevation in atrophic posterior maxilla: a systematic review and meta-analysis

| | |
|---|---|
| Journal: | *BMJ Open* |
| Manuscript ID | bmjopen-2019-029826.R2 |
| Article Type: | Original research |
| Date Submitted by the Author: | 06-Sep-2019 |
| Complete List of Authors: | Yan, Qi; School & Hospital of Stomatology, Wuhan University, Department of Oral Implantology<br>Wu, Xinyu; School & Hospital of Stomatology, Wuhan University, Department of Oral Implantology<br>Su, Meiying; School & Hospital of Stomatology, Wuhan University, Department of Oral Implantology<br>Hua, Fang; School & Hospital of Stomatology, Wuhan University, Centre for Evidence-Based Stomatology; Division of Dentistry, The University of Manchester, Cochrane Oral Health<br>Shi, Bin; School & Hospital of Stomatology, Wuhan University, Department of Oral Implantology |
| Primary Subject Heading: | Dentistry and oral medicine |
| Secondary Subject Heading: | Evidence based practice |
| Keywords: | ORAL & MAXILLOFACIAL SURGERY, SYSTEMATIC REVIEW, Sinus Floor Elevation, Evidence-Based Dentistry, Oral Implantology, Short Dental Implant |
| | |

# Short implants (≤6 mm) versus longer implants with sinus floor elevation in atrophic posterior maxilla: A systematic review and meta-analysis

Qi Yan [1, 2, a], Xinyu Wu [1, 2, a], Meiying Su [2], Fang Hua [3, 4, *], Bin Shi [1, 2, *]

1. Hubei-MOST KLOS & KLOBM, School & Hospital of Stomatology, Wuhan University, Wuhan, China.
2. Department of Oral Implantology, School & Hospital of Stomatology, Wuhan University, Wuhan, China.
3. Centre for Evidence-Based Stomatology, School & Hospital of Stomatology, Wuhan University, Wuhan, China
4. Division of Dentistry, School of Medical Sciences, Faculty of Biology, Medicine and Health, University of Manchester, Manchester Academic Health Science Centre, Oxford Road, Manchester, M13 9PL, UK

[a] Qi Yan and Xinyu Wu contributed equally to this work.

[*] **Corresponding authors:**

Fang Hua

Centre for Evidence-Based Stomatology, School & Hospital of Stomatology,

Wuhan University, 237 Luoyu Rd, Wuhan 430079, China

Tel: +86 27 87686226

Email: huafang@whu.edu.cn

Bin Shi

Department of Oral Implantology, School & Hospital of Stomatology,

Wuhan University, 237 Luoyu Rd, Wuhan 430079, China

Tel: +86 27 87686222

Email: Shibin_dentist@whu.edu.cn

## Abstract

**Objectives:** To compare the use of short implants (≤6 mm) in atrophic posterior maxilla versus longer implants (≥10 mm) with sinus floor elevation.

**Design:** A systematic review and meta-analysis based on randomized controlled trials (RCTs).

**Data sources:** Electronic searches were conducted in PubMed, Embase and the Cochrane CENTRAL. Retrospective and prospective hand searches were also performed.

**Eligibility criteria:** RCTs comparing short implants (≤6 mm) and longer implants (≥10 mm) with sinus floor elevation were included. Outcome measures included implant survival (primary outcome), marginal bone loss (MBL), complications and patient satisfaction.

**Data Extraction and synthesis:** Risks of bias in and across studies were evaluated. Meta-analysis, subgroup analysis and sensitivity analysis were undertaken. Quality of evidence were assessed according to GRADE.

**Results:** A total of seven randomized controlled trials involving 310 participants were included. No significant difference in survival rate was found for one- to three-year follow-up (RR=1.01, 95% CI: 0.97, 1.04, p=0.74, $I^2$ = 0%, moderate quality evidence) or for three-year or longer follow-up (RR=1.00, 95% CI: 0.97, 1.04, p=0.79, $I^2$ = 0%, moderate quality evidence). However, short implants (≤6 mm) showed significantly less MBL in one- to three-year follow-up (MD=-0.13 mm, 95% CI: -0.21, -0.05; p=0.001, $I^2$ = 87%, low quality evidence) and in three-year or longer follow-up (MD=-0.25 mm, 95% CI: -0.40, -0.10; p=0.001, $I^2$ = 0%, moderate quality evidence). In addition, short implant (≤6 mm) resulted in fewer post-surgery reaction (RR=0.11, 95% CI: 0.14, 0.31, p<0.001, $I^2$ = 40%, moderate quality evidence) and sinus perforation or infection (RR=0.11, 95% CI: 0.02, 0.63, p=0.01, $I^2$ = 0%, moderate quality evidence).

**Conclusions:** For atrophic posterior maxilla, short implants (≤6 mm) are a promising alternative to sinus floor elevation, with comparable survival rate, less MBL and post-surgery reactions. Additional high-quality studies are needed to evaluate the long-term effectiveness of short implants (≤6 mm).

**Keywords:** short dental implant; sinus floor augmentation; systematic review

**Word count:** 3627 (main text); 308 (abstract)

**Strengths**

- Only randomized controlled clinical trials were included.
- Participant-unit data were used for syntheses.
- Subgroup analyses by follow-up length and categories of complications were performed.

**Limitations**

- Serious risks of bias were found within and across studies and the quality of evidence was only low to moderate.

## 1. Introduction

Dental implants supporting prosthesis are commonly considered a promising method for the rehabilitation of missing teeth.[1-3] However, dental implantation in the posterior maxilla is usually challenging due to insufficient vertical bone volume, poor bone quality, limited visibility, reduced inter-arch space, and sinus pneumatisation.[4 5] These conditions are exacerbated if patients have a history of wearing removable dentures.[6]

To achieve sufficient vertical bone volume in the posterior maxilla, sinus floor elevation using the lateral window approach or the osteotomy technique have been introduced and widely used over the past 40 years.[7 8] The lateral window approach is commonly used in dental implantation procedures.[9] Using these techniques with or without bone grafting, conventional implants can be placed in the elevated sites. The implant success rate is typically greater than 90% in long-term evaluation.[10-12] However, sinus floor elevation surgery is usually associated with higher cost, more complicated surgical procedures, and a high prevalence of complications such as infection, sinus membrane perforation and graft failure.[13-15] In addition, the clinical outcome of sinus floor elevation can also be restricted by extremely insufficient residual bone height, abnormal sinus anatomy, thickening of the sinus membrane, stability of the grafted bone and the number of missing teeth.[16-19]

Short implants with improved implant design and surface properties have been successfully applied as an alternative to sinus floor elevation surgery and have shown good results in posterior maxilla. Implants ≤10 mm[20], ≤8 mm[21], ≤7 mm[22], and 6-8 mm[23] are reported to have survival rates comparable to those of longer implants. In addition, short implants ≤6 mm in length have been introduced as another alternative in atrophic posterior maxilla.[6 24 25] Short implants require a less complicated surgical approach and could be used in cases when sinus floor elevation surgery is not applicable,[26 27]

especially in cases of maxillary sinusitis, maxillary cyst, large vessels and other cases involving abnormal sinus anatomy. Studies have explored the short- and long-term survival rates of short implants (≤6 mm).[27-31] Unfortunately, the evidence supporting the use of short implants (≤6 mm) in the posterior maxilla is weak, and no guideline statement is currently recommended.

The present systematic review aims to compare the effectiveness of short implants (≤6 mm) and longer implants (≥10 mm) with sinus floor elevation in atrophic posterior maxilla. Our null hypothesis was that the survival rate, patient satisfaction, MBL and surgery-related complications of short implants (≤6 mm) were comparable to longer implants in combination with sinus floor elevation.

## 2. Materials and methods

### *2.1 Protocol and registration*

This systematic review and meta-analysis was conducted in accordance with the PRISMA guidelines.[32] The protocol has been registered at PROSPERO (CRD42018103531).

### *2.2 Eligible criteria*

Randomized controlled trials (RCTs) meeting the following pre-determined inclusion criteria (PICOS format) were included:

- Population: Partially edentulous patients in the premolar and molar regions of the maxilla, for whom the residual bone height in the atrophic posterior maxilla was sufficient for the insertion of a short implant (≤6 mm) but insufficient for the insertion of longer implants;
- Intervention: One or more short implants (≤6 mm) were placed in the posterior

maxilla without sinus floor elevation in the short implant group;

- Comparison: One or more longer implants were placed in the posterior maxilla after sinus floor elevation by any technique in the elevation group;
- Outcomes: The primary (survival rate) and secondary (MBL, complications and patient satisfaction) outcomes of interest were measured, with a follow-up length of one year or longer post-loading.

*2.3 Information sources and search strategies*

Two content experts (QY and XW) searched PubMed, Embase, and the Cochrane CENTRAL (The Cochrane Central Registration of Controlled Trials) for RCTs, independently and in duplicate. The last search was conducted on 31/05/2018. A methodologist (FH) was consulted to resolve any disagreements. Main search terms included: "dental implant", "short implant", "ultrashort", "alveolar bone loss", "atrophic maxilla", "sinus lift", and "sinus floor elevation". No restriction was set regarding publication year, publication language or status. The detailed search strategies are listed in the supplementary file. In addition, retrospective and prospective searches were conducted by checking the reference lists of key articles and studies citing these key articles, using Google Scholar.

*2.4 Study selection and data collection*

Two review authors (QY and XW) conducted the study selection independently and in duplicate. The titles and abstracts of all records were scanned. Full texts of studies were obtained in cases they appeared to meet the inclusion criteria or further information were needed to determine eligibility. Studies excluded at this or subsequent stages were recorded with the reasons for exclusion. All disagreements were resolved by discussion.

Two review authors (QY and XW) extracted the data independently and in duplicate using specifically designed data extraction forms. The extracted data included citation details (year of publication, country of origin, setting and source of funding), details on the participants (demographic characteristics, residual bone height and inclusion criteria), details of intervention (implant length, diameter, brand, surface structure, surgical method, follow-up time, prosthesis type), outcome assessment, sample size calculation and trial registration. Corresponding authors were contacted for missing data or information.

*2.5 Risk of bias of included studies*

Two authors (QY and XW) assessed the risk of bias of each included study independently and in duplicate using the Cochrane risk of bias assessment tool for RCTs.[33] Disagreements were resolved through discussion. A third review author (F.H.) was consulted when necessary. Seven domains were assessed, including sequence generation (selection bias), allocation concealment (selection bias), blinding of participants and personnel (performance bias), blinding of outcome assessment (detection bias), incomplete outcome data (attrition bias), selective outcome reporting (reporting bias) and other bias (factors that had potential influence on outcomes but were not evenly distributed across groups or not clearly reported, such as the manufacturer or diameter of implants). Individual studies were categorized as having low, high or unclear risk of bias. The risk of bias across studies was determined according to the risk of bias in each included study.

*2.6 Assessment of heterogeneity*

Clinical heterogeneity among the included studies was assessed by comparing study

design, participant conditions (gender, age, residual bone height), intervention (implant length, diameter, surface structure, surgical method), and outcome measures. Statistical heterogeneity was evaluated using Cochrane's Q test and the $I^2$ statistic. In the Q test, a P value < 0.1 was considered an indication of significant heterogeneity.

*2.7 Assessment of publication bias*

If at least ten studies were included in a meta-analysis, We would have used a funnel plot and the Egger's test[34] asymmetry to assess the potential existence of publication bias if at least ten studies were included in a meta-analysis.

*2.8 Synthesis of results*

The unit of analysis was set as participant rather than implant.[35] RevMan 5.3 software was used for data synthesis. Meta-analyses were undertaken only when at least two studies that made similar comparisons reported the same outcomes. The effect measures were risk ratio (RR) for dichotomous outcomes (implant survival and complications) and mean difference (MD) for continuous outcomes (MBL). RR was calculated through Mantel-Haenszel analysis and MD was calculated through inverse variance. P<0.05 was considered statistically significant. The fixed effect model was used when fewer than four studies were included in a meta-analysis, and the random-effects model was used when four or more studies were included [36-39].

*2.9 Additional analysis*

Subgroup analysis by length of follow-up was performed to control for the possibility that function time might influence implant survival [40]. In addition, subgroup analysis by categories of complications was performed. Complications were categorized

according to into post-surgery reaction (bleeding, swelling and discomfort), biological complications (sinus perforation or infection, implant mobile, peri-implant mucositis and peri-implantitis) and technical complications (complications related to screws and crowns). If risks of bias in some studies were serious, we performed sensitivity analysis by excluding these studies. Considering only three studies were included in the MBL three years or longer follow-up but the meta-analysis for MBL included more than three studies, a sensitivity analysis was conducted for MBL by using fixed-effect model.

*2.10 Summary of findings (SoF)*

Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach[41] was adopted to evaluate quality of evidence in this systematic review. A SoF table was made with an online tool (cebgrade.mcmaster.ca/gradepro.html). Outcomes were evaluated including survival rate and MBL of one to three-year and three-year or longer follow-up, and complications. Five domains in quality of evidence were assessed: the overall risk of bias, directness of evidence, consistency of results, precision of estimates, as well as the risk of publication bias. The quality of the body of evidence was classified into four categories: high, moderate, low and very low.

*2.11 Patient and Public involvement*

No patient or public was involved in this systematic review.

## 3. Results

*3.1 Study selection*

Electronic searches identified a total of 879 titles and abstracts in PubMed and 251 in Embase. After removal of duplicates, the titles and abstracts of 1,013 unique items were

screened. We then retrieved the full texts of 25 potentially eligible articles, of which 20 were excluded for the reasons described in figure 1. Retrospective and prospective hand searches yielded two more articles. Finally, seven studies[30 42-47] met our eligibility criteria and were included in this review (figure 1).

*3.2 Study characteristics*

The characteristics of the seven included studies are listed in table 1. One study was a split-mouth trial, and the rest were two-arm parallel RCTs. The length of follow-up ranged from one year to three years. For sinus floor elevation, either osteotomy-mediated sinus floor elevation or the lateral window technique was adopted. In two studies, single crowns were used as the rehabilitation method; in the remaining studies, single crowns or splinted prosthetics were used. The outcome measures used in these studies included implant failure, MBL, complications and patient satisfaction. Overall, 171 participants were included in the short implant groups, and 159 participants were included in the elevation groups.

*3.3 Risk of bias assessment*

The results of the risks of bias assessment are shown in figures 2 and 3. Selection bias and performance bias were assessed as low in all but one study by Bachara et al[47] due to inadequate description on random sequence generation and blinding of participants. For detection bias, most studies showed high risks because assessors could recognize sites that underwent sinus floor elevation. For attrition bias, three studies[43 45 46] was assessed as high. Two studies[45 47] showed high risk of reporting bias. Other risks of bias were considered high or unclear in three studies. Overall, all included studies were at high risk of bias for at least one domain (table 2).

*3.4 Synthesis of results*

3.4.1 Survival rate

Figure 4 shows the results of a meta-analysis for participant unit implant survival rate with a subgroup analysis based on length of follow-up. Five studies reported 100% survival of short implants (≤6 mm) within the study period. For this outcome, there was no evidence of a difference between the short implant group and the elevation group either one year to three years post-loading (RR=1.01, 95% CI: 0.97, 1.04, p=0.74, $I^2$ = 0%, seven RCTs, 321participants) or three years or longer post-loading (RR=1.00, 95% CI: 0.97, 1.04, p=0.79, $I^2$ = 0%, five RCTs, 237 participants). Further details of the implant failures are summarized in table 3.

3.4.2 MBL

The results of the meta-analysis and subgroup analysis regarding peri-implant MBL are shown in figure 5. A significant difference favoring the short implant group was found for both one year to three years post-loading (MD=-0.13, 95% CI: -0.21, -0.05; p=0.001, $I^2$ = 87%, six RCTs, 249 participants) and three years or longer post loading (MD=-0.25, 95% CI: -0.40, -0.10; p=0.001, $I^2$ = 0%, three RCTs, 88 participants). In sensitivity analysis by using fixed-effect model, results remained significant for both one year to three years post-loading (MD=-0.11, 95% CI: -0.13, -0.08; p<0.001, $I^2$ = 87%) and three years or longer post loading (MD=-0.25, 95% CI: -0.40, -0.10; p=0.001, $I^2$ = 0%).

3.4.3 Complications

Complications were categorized into post-surgery reaction, biological complications

and technical complications (table 4). Short implant group was found with significantly less post-surgery reaction (RR=0.11, 95% CI: 0.14, 0.31, p<0.001, $I^2$ = 40%, three RCTs, 184 participants) and sinus perforation or infection (RR=0.11, 95% CI: 0.02, 0.63, p=0.01, $I^2$ = 0%). Only one study[30] reported implant migrating into sinus in 5% patients (1/19) in short implant group while in 10.5% patients (2/19) in sinus floor elevation group. No statistically significant difference was found in other complications between short implants (≤6 mm) and longer implants.

3.4.4 Patient satisfaction

Three studies [43] [44] [47] reported patient satisfaction. Meta-analysis was not conducted because methods of evaluating patient satisfaction were different. Gulje et al. [44] used a questionnaire to evaluate patient satisfaction before surgery and one year post-loading. Both groups showed improvement of satisfaction after crown placement. Gastaldi et al.[43] evaluated patient satisfaction in function and aesthetic aspects. All patients in the short implant group (10) were satisfied with both function and aesthetic aspects. However, three patients in elevation group (3/10) were partially satisfied with function. Bechara et al.[47] used a questionnaire evaluating patient satisfaction in function, aesthetic, cleaning of the implant-supported restorations, satisfaction, and cost. Significantly more patients in short implant group expressed satisfaction in cost. In the other four aspects, no significant difference was found between short implant group and sinus floor elevation group.

*3.5 Quality of evidence*

For survival rate, the quality of evidence in both subgroups were downgraded by one level (moderate quality evidence) due to serious risks of bias. For short-term MBL (one

to three-year follow-up), quality of evidence was downgraded by two levels for serious risks of bias and inconsistency. For long-term MBL (three-year or longer follow-up), quality of evidence was downgraded by one level for serious risks of bias. For complications, the quality of evidence in post-surgery reaction was moderate, downgrading by one level for serious risks of bias. The quality of evidence in other complications was low, downgrading by two levels for serious risks of bias and imprecision. Details are listed in table 5.

## 4. Discussion

To the best of our knowledge, this is the first systematic review and meta-analysis to compare the clinical outcome of the use of short implants (≤6 mm) in atrophic posterior maxilla versus longer implants with sinus floor elevation. At one year or longer post-loading, there is no significant difference in participant unit implant survival rate between the short implant group and the elevation group. The short implant group showed less MBL than the elevation group for one to three-year follow-up (low quality evidence) and three-year or longer follow-up (moderate quality evidence). In addition, the short implant group showed fewer post-surgery reaction and sinus membrane perforation and infection.

The survival rate in this review was evaluated by participant unit as in a previous Cochrane review.[35] In this review, the overall survival rates for the short implant group and the elevation group were 98.21% and 96.08%, respectively, at one-year to three-year follow-up and 99.20% and 98.23%, respectively, at longer than three-year follow-up; no significant difference in survival rate was found. Other studies that assessed survival rate in implant unit had similar outcomes. A retrospective study[48] with a follow-up period of 17 to 48 months reported a 95.12% implant unit survival rate for

5-mm to 6-mm short implants. A two-year to three-year prospective study[6] reported that 6-mm short implants with micro rough surfaces achieved a 100% survival rate in posterior maxilla. Another five- to ten-year retrospective study[49] reported a 97% implant unit survival rate for 6-mm short implants supporting single crowns. All these results showed that short implants (≤6 mm) represent a promising rehabilitation method with respect to their short-term and long-term survival rates.

In this review, all of the failed short implants were 4 mm or 5 mm. Although the use of short implants (≤6 mm) could avoid complicated surgical procedures and related early failures, reduced implant length was still the major risk factor in survival rate. The authors of the included studies used wider implants (4 mm to 8 mm) to compensate for the short length of the implants. Finite element analyses showed that wider implants had increased functional surface area in cortical bone and decreased stress distribution on the implant neck; these qualities helped improve primary stability, produce a higher survival rate and reduce MBL.[50-53] However, it was not determined whether implant length or diameter contributed more to implant failure. Another factor was implant surface structure. Studies[54-57] have suggested that the implant surface influences bone-to-implant osseointegration, implant primary stability and MBL. In this review, implants 4 mm or 5 mm in length had novel surface structures, but they still presented a lower survival rate.

Significantly less MBL was found in the short implant group, and the difference was greater at the longer follow-up period. Additionally, in this review, 5-mm-diameter implants tended to induce less MBL than 4-mm-diameter implants. Implants ≤ 10 mm [20] and ≤ 8 mm[21] were reported to induce MBL similar to that of longer implants, while implants ≤ 7 mm[58] showed less MBL. These results contradict a previous theory that short implants are more likely to have an extreme crown-to-implant ratio (C/I)[59] that

induces more peri-implant bone loss and early implant failure.[60 61] According to finite element analyses, inappropriate C/I results in adverse occlusal forces such as non-axial forces and overloading.[62] Increased C/I was also correlated with more prosthesis complications such as screw loosening, implant or abutment fracture, chipping of the ceramic material, and prosthesis fracture.[63-66] However, the implants in the studies included in this systematic review had wider diameters (4 mm to 8 mm) and different surface structures. These two factors partially compensated for the complications of C/I and contributed to less MBL. Differences in implant diameter and surface structure also introduced heterogeneity among studies with respect to MBL. Short implants tolerated less MBL because of the limited implant length. As a result, less MBL was not necessarily correlated with better clinical outcome. MBL around short implants is still a challenging issue, and much effort should be made to resolve it.

With respect to complications, the use of short implants (≤6 mm) could decrease the incidence of post-surgery reactions and sinus membrane perforation and infection. Sinus membrane perforation was common in the elevation group.[14] This was in accordance with a previous study[67] that reported more complications in cases involving longer implants with sinus floor elevation and that the surgical procedure made a major contribution to such complications. In this study, incidence of other biological and technical complications was similar between the two groups. Implant migration into the sinus, often with the co-occurrence of sinus infection, had a higher prevalence in the elevation group. When implant migration occurs, implants may be removed, thus leading to implant failure.[68] Technical complications, including screw loosening, crown loosening and chipping, were mainly associated with inappropriate loading, which could be resolved by improving supra rehabilitation structure. In addition, for short implants (≤6 mm), risks relating to reduced length could be partially alleviated by

improving the design of the implants[69] or increasing their diameter. With respect to the prevalence and severity of adverse events, the use of short implants (≤6 mm) was acceptable and was a promising alternative to sinus floor elevation.

The present study has several strengths. Firstly, we conducted a comprehensive literature search, and all included studies were RCTs. Secondly, participant was used as the unit of analysis to ensure logical statistical syntheses and relevant interpretations. Thirdly, subgroup analysis by follow-up length and categories of complications was performed to reduce bias across studies. However, the evidence included in this systematic review was only of moderate or low quality. Serious risks of bias were found within and across studies. The number of participants and the follow-up period were limited. Due to limited data and methodological heterogeneity among studies, data synthesis for patient satisfaction was not performed. We suggest that researchers in this field carry out more well designed, long-term and large-scale RCTs to provide high quality evidence regarding the effects of short implants (≤6 mm).

## 5. Conclusions

Within its limitations, the present review suggests that the survival rate of maxillary short implants (≤6 mm) was comparable to that of longer implants (≥10 mm) with sinus floor elevation. However, short implants (≤6 mm) show significantly less MBL and post-surgery reactions. Short implants (≤6 mm) are therefore a promising alternative to sinus floor elevation for posterior maxilla with insufficient bone volume. Additional high-quality studies are needed to evaluate the long-term effectiveness and safety of short implants (≤6 mm).

**Author contributions** Conception and design of the review: FH and BS. Methodology: FH. Drafting protocol, performing search strategies, literature searches, literature screening and data extraction: QY and XW. Original draft preparation: XW. Reviewing and editing draft: MS, QY, FH and BS. All authors critically reviewed and revised the manuscript and approved the final version for publication.

**Funding** This research was funded by the National Clinical Key Specialties Construction Project ([2013]544), the National Health Commission of China.

**Competing interests** None declared.

**Patient consent** Not required.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data sharing statement** No additional data are available.

## References


1. Spitznagel FA, Horvath SD, Gierthmuehlen PC. Prosthetic protocols in implant-based oral rehabilitations: A systematic review on the clinical outcome of monolithic all-ceramic single- and multi-unit prostheses. *European Journal of Oral Implantolantology* 2017;10 Suppl 1:89-99.
2. Pjetursson BE, Thoma D, Jung R, et al. A systematic review of the survival and complication rates of implant-supported fixed dental prostheses (FDPs) after a mean observation period of at least 5 years. *Clincal Oral Implants Research* 2012;23 Suppl 6:22-38.
3. Davarpanah M, Martinez H, Etienne D, et al. A prospective multicenter evaluation of 1,583 3i implants: 1- to 5-year data. *International Journal of Oral & Maxillofacial Implants* 2002;17(6):820-8.
4. Esposito M, Felice P, Worthington HV. Interventions for replacing missing teeth: augmentation procedures of the maxillary sinus: John Wiley & Sons, Ltd 2014.
5. Morand M, Irinakis T. The challenge of implant therapy in the posterior maxilla: providing a rationale for the use of short implants. *Journal of Oral Implantology* 2007;33(5):257-66.
6. Malchiodi L, Caricasulo R, Cucchi A, et al. Evaluation of Ultrashort and Longer Implants with Microrough Surfaces: Results of a 24- to 36-Month Prospective Study. *International Journal of Oral & Maxillofacial Implants* 2017;32(1):171-79.
7. Danesh-Sani SA, Loomer PM, Wallace SS. A comprehensive clinical review of maxillary sinus floor elevation: anatomy, techniques, biomaterials and complications. *British Journal of Oral Maxillofacial Surgery* 2016;54(7):724-30.
8. Branemark PI, Hansson BO, Adell R, et al. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. *Scandinavian Journal of Plastic and Reconstructive Surgery Supplementum* 1977;16:1-132.
9. Cha HS, Kim JW, Hwang JH, et al. Frequency of bone graft in implant surgery. *Maxillofacial plastic and reconstructive surgery* 2016;38(1):19.
10. Starch-Jensen T, Aludden H, Hallman M, et al. A systematic review and meta-analysis of long-term studies (five or more years) assessing maxillary sinus floor augmentation. *International Journal of Oral & Maxillofacial Surgery* 2018;47(1):103-16.
11. Starch-Jensen T, Schou S. Maxillary Sinus Membrane Elevation With Simultaneous Installation of Implants Without the Use of a Graft Material: A Systematic Review. *Implant dentistry* 2017;26(4):621-33.
12. Lee SA, Lee CT, Fu MM, et al. Systematic Review and Meta-Analysis of Randomized Controlled Trials for the Management of Limited Vertical Height in the Posterior Region: Short Implants (5 to 8 mm) vs Longer Implants (> 8 mm) in Vertically Augmented Sites. *International Journal of Oral & Maxillofacial Implants* 2014;29(5):1085.
13. Pjetursson BE, Tan WC, Zwahlen M, et al. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. *Journal of Clinical Periodontology* 2008;35(Supplement s8):216-40.
14. Tan WC, Lang NP, Zwahlen M, et al. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. Part II: transalveolar technique. *Journal of Clinical Periodontology* 2008;35(8 Suppl):241-54.
15. Thoma DS, Zeltner M, Husler J, et al. EAO Supplement Working Group 4 - EAO CC 2015 Short implants versus sinus lifting with longer implants to restore the posterior maxilla: a systematic review. *Clinical Oral Implants Research* 2015;26 Suppl 11:154-69.
16. Lundgren S, Cricchio G, Hallman M, et al. Sinus floor elevation procedures to enable implant placement and integration: techniques, biological aspects and clinical outcomes. *Periodontology 2000* 2017;73(1):103-20.

17. Pjetursson BE, Tan WC, Zwahlen M, et al. A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. *Journal of Clinical Periodontology* 2010;35(s8):216-40.
18. Huang HL, Fuh LJ, Ko CC, et al. Biomechanical effects of a maxillary implant in the augmented sinus: a three-dimensional finite element analysis. *International Journal of Oral Maxillofacial Implants* 2009;24(3):455-62.
19. Lin YH, Yang YC, Wen SC, et al. The influence of sinus membrane thickness upon membrane perforation during lateral window sinus augmentation. *Clinical Oral Implants Research* 2016;27(5):612-17.
20. Monje A, Suarez F, Galindo-Moreno P, et al. A systematic review on marginal bone loss around short dental implants (<10 mm) for implant-supported fixed prostheses. *Clinical Oral Implants Research* 2015;25(10):1119-24.
21. Nielsen HB, Schou S, Isidor F, et al. Short implants (</=8mm) compared to standard length implants (>8mm) in conjunction with maxillary sinus floor augmentation: a systematic review and meta-analysis. *International Journal of Oral & Maxillofacial Surgery* 2018
22. Uehara PN, Matsubara VH, Igai F, et al. Short Dental Implants (≤7mm)VersusLonger Implants in Augmented Bone Area: A Meta-Analysis of Randomized Controlled Trials. *Open Dentistry Journal* 2018;12:354-65.
23. Al Amri MD, Abduljabbar TS, Al-Johany SS, et al. Comparison of clinical and radiographic parameters around short (6 to 8 mm in length) and long (11 mm in length) dental implants placed in patients with and without type 2 diabetes mellitus: 3-year follow-up results. *Clinical Oral Implants Research* 2016;28
24. Urdaneta RA, Daher S, Leary J, et al. The survival of ultrashort locking-taper implants. *International Journal of Oral & Maxillofacial Implants* 2012;27(3):644-54.
25. Markose J, Eshwar S, Srinivas S, et al. Clinical outcomes of ultrashort sloping shoulder implant design: A survival analysis. *Clinical Implant Dentistry and Related Research* 2018;20(4):646-52.
26. Fan T, Li Y, Deng WW, et al. Short Implants (5 to 8 mm) Versus Longer Implants (>8 mm) with Sinus Lifting in Atrophic Posterior Maxilla: A Meta-Analysis of RCTs. *Clinical Implant Dentistry & Related Research* 2016;19(1):207-15.
27. Deporter DA, Ogiso B, Sohn DS, et al. Ultrashort sintered porous-surfaced dental implants used to replace posterior teeth. *Journal of Periodontology* 2008;79(7):1280-86.
28. Sahrmann P, Naenni N, Jung RE, et al. Success of 6-mm Implants with Single-Tooth Restorations: A 3-year Randomized Controlled Clinical Trial. *Journal of Dental Research* 2016;95(6):623-28.
29. Felice P, Checchi L, Barausse C, et al. Posterior jaws rehabilitated with partial prostheses supported by 4.0 x 4.0 mm or by longer implants: One-year post-loading results from a multicenter randomised controlled trial. *European journal of oral implantology* 2016;9(1):35-45.
30. Bolle C, Felice P, Barausse C, et al. 4 mm long vs longer implants in augmented bone in posterior atrophic jaws: 1-year post-loading results from a multicentre randomised controlled trial. *European Journal of Oral Implantology* 2018;11(1):31-47.
31. Calvo-Guirado JL, Lopez Torres JA, Dard M, et al. Evaluation of extrashort 4-mm implants in mandibular edentulous patients with reduced bone height in comparison with standard implants: a 12-month results. *Clinical Oral Implants Research* 2016;27(7):867-74.
32. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *Bmj British Medical Journal* 2009;339:b2700.
33. Higgins JPT GS, editor(s). Cochrane Handbook for Systematic Reviews of Interventions version 5.1.0 (updated March 2011): The Cochrane Collaboration, 2011. Available from www.cochrane-handbook.org.
34. Egger M, Davey SG, Schneider M, et al. Bias in meta-analysis detected by a simple,

graphical test. *Bmj British Medical Journal* 1997;316(7129):469-71.
35. Esposito M, Ardebili Y, Worthington HV. Interventions for replacing missing teeth: different types of dental implants. *The Cochrane database of systematic reviews* 2014(7):Cd003815.
36. Borenstein M, Hedges LV, Higgins JP, et al. A basic introduction to fixed-effect and random-effects models for meta-analysis. *Res Synth Methods* 2010;1(2):97-111.
37. Esposito M, Grusovin MG, Maghaireh H, et al. Interventions for replacing missing teeth: different times for loading dental implants. *The Cochrane database of systematic reviews* 2013(3):CD003878.
38. Esposito M, Worthington HV. Interventions for replacing missing teeth: hyperbaric oxygen therapy for irradiated patients who require dental implants. *The Cochrane database of systematic reviews* 2013(9):CD003603.
39. Esposito M, Felice P, Worthington HV. Interventions for replacing missing teeth: augmentation procedures of the maxillary sinus. *The Cochrane database of systematic reviews* 2014(5):CD008397.
40. Tolentino da Rosa de Souza P, Binhame Albini Martini M, Reis Azevedo-Alanis L. Do short implants have similar survival rates compared to standard implants in posterior single crown?: A systematic review and meta-analysis. *Clinical Implant Dentistry and Related Research* 2018
41. Andrews J, Guyatt G, Oxman AD, et al. GRADE guidelines: 14. Going from evidence to recommendations: the significance and presentation of recommendations. *Journal of clinical epidemiology* 2013;66(7):719-25.
42. Gastaldi G, Felice P, Pistilli V, et al. Posterior atrophic jaws rehabilitated with prostheses supported by 5 × 5 mm implants with a nanostructured calcium-incorporated titanium surface or by longer implants in augmented bone. 3-year results from a randomised controlled trial. *European Journal of Oral Implantology* 2018;11(1):49-61.
43. Gastaldi G, Felice P, Pistilli R, et al. Short implants as an alternative to crestal sinus lift: a 3-year multicentre randomised controlled trial. *European Journal of Oral Implantology* 2017;10(4):391-400.
44. Guljé FL, Raghoebar GM, Vissink A, et al. Single crowns in the resorbed posterior maxilla supported by either 6-mm implants or by 11-mm implants combined with sinus floor elevation surgery: a 1-year randomised controlled trial. *European Journal of Oral Implantology* 2014;7(3):247-55.
45. Pohl V, Thoma DS, Sporniak-Tutak K, et al. Short dental implants (6 mm) versus long dental implants (11-15 mm) in combination with sinus floor elevation procedures: 3-year results from a multicentre, randomized, controlled clinical trial. *Journal of Clinical Periodontology* 2017;44(4):438-45.
46. Felice P, Barausse C, Pistilli V, et al. Posterior atrophic jaws rehabilitated with prostheses supported by 6 mm long x 4 mm wide implants or by longer implants in augmented bone. 3-year post-loading results from a randomised controlled trial. *European Journal of Oral Implantology* 2018;11(2):175-87.
47. Bechara S, Kubilius R, Veronesi G, et al. Short (6-mm) dental implants versus sinus floor elevation and placement of longer (>/=10-mm) dental implants: a randomized controlled trial with a 3-year follow-up. *Clinical Oral Implants Research* 2017;28(9):1097-107.
48. Lombardo G, Pighi J, Marincola M, et al. Cumulative Success Rate of Short and Ultrashort Implants Supporting Single Crowns in the Posterior Maxilla: A 3-Year Retrospective Study. *International journal of dentistry* 2017;2017:8434281.
49. Lai HC, Si MS, Zhuang LF, et al. Long-term outcomes of short dental implants supporting single crowns in posterior region: a clinical retrospective study of 5–10years. *Clinical Oral Implants Research* 2013;24(2):230–37.
50. Himmlova L, Dostalova T, Kacovsky A, et al. Influence of implant length and diameter on stress distribution: a finite element analysis. *Journal of Prosthetic Dentistry* 2004;91(1):20-5.
51. Moriwaki H, Yamaguchi S, Nakano T, et al. Influence of Implant Length and Diameter,

Bicortical Anchorage, and Sinus Augmentation on Bone Stress Distribution: Three-Dimensional Finite Element Analysis. *International Journal of Oral & Maxillofacial Implants* 2016;31(4):e84-91.

52. Kim S, Jung UW, Cho KS, et al. Retrospective radiographic observational study of 1692 Straumann tissue-level dental implants over 10 years: I. Implant survival and loss pattern. *Clinical Implant Dentistry and Related Research* 2018
53. Lin G, Ye S, Liu F, et al. A retrospective study of 30,959 implants: Risk factors associated with early and late implant loss. *Journal of Clinical Periodontology* 2018;45(6):733-43.
54. Tabassum A, Meijer GJ, Wolke JG, et al. Influence of the surgical technique and surface roughness on the primary stability of an implant in artificial bone with a density equivalent to maxillary bone: a laboratory study. *Clinical Oral Implants Research* 2009;20(4):327-32.
55. Dos Santos MV, Elias CN, Cavalcanti Lima JH. The effects of superficial roughness and design on the primary stability of dental implants. *Clinical Implant Dentistry and Related Research* 2011;13(3):215-23.
56. Falco A, Berardini M, Trisi P. Correlation Between Implant Geometry, Implant Surface, Insertion Torque, and Primary Stability: In Vitro Biomechanical Analysis. *International Journal of Oral & Maxillofacial Implants* 2018;33(4):824-30.
57. Jain N, Gulati M, Garg M, et al. Short Implants: New Horizon in Implant Dentistry. *Journal of Clinical and Diagnostic Research* 2016;10(9):Ze14-ze17.
58. Uehara PN, Matsubara VH, Igai F, et al. Short Dental Implants (</=7mm) Versus Longer Implants in Augmented Bone Area: A Meta-Analysis of Randomized Controlled Trials. *Open Dentistry Journal* 2018;12:354-65.
59. Anitua E, Alkhraist MH, Piñas L, et al. Implant survival and crestal bone loss around extra-short implants supporting a fixed denture: the effect of crown height space, crown-to-implant ratio, and offset placement of the prosthesis. *International Journal of Oral & Maxillofacial Implants* 2014;29:682-89.
60. Quirynen M, Naert I, van Steenberghe D. Fixture design and overload influence marginal bone loss and fixture success in the Branemark system. *Clinical Oral Implants Research* 1992;3(3):104-11.
61. Blanes RJ. To what extent does the crown-implant ratio affect the survival and complications of implant-supported reconstructions? A systematic review. *Clinical Oral Implants Research* 2009;20 Suppl 4:67-72.
62. Verri FR, Batista VEdS, Santiago JF, et al. Effect of crown-to-implant ratio on peri-implant stress: A finite element analysis. *Materials Science and Engineering: C* 2014;45:234-40.
63. Quaranta A, Piemontese M, Rappelli G, et al. Technical and biological complications related to crown to implant ratio: a systematic review. *Implant Dentistry* 2014;23(2):180-7.
64. Urdaneta RA, Rodriguez S, McNeil DC, et al. The effect of increased crown-to-implant ratio on single-tooth locking-taper implants. *International Journal of Oral & Maxillofacial Implants* 2010;25(4):729-43.
65. Tawil G, Aboujaoude N, Younan R. Influence of prosthetic parameters on the survival and complication rates of short implants. *International Journal of Oral & Maxillofacial Implants* 2006;21(2):275-82.
66. Schneider D, Witt L, Hammerle CHF. Influence of the crown-to-implant length ratio on the clinical performance of implants supporting single crown restorations: a cross-sectional retrospective 5-year investigation. *Clinical Oral Implants Research* 2012;23(2):169-74.
67. Thoma DS, Cha JK, Jung UW. Treatment concepts for the posterior maxilla and mandible: short implants versus long implants in augmented bone. *Journal of periodontal & implant science* 2017;47(1):2-12.
68. Manor Y, Anavi Y, Gershonovitch R, et al. Complications and Management of Implants Migrated into the Maxillary Sinus. *International Journal of Periodontics and*

*Restorative Dentistry* 2018
69. Mangano F, Frezzato I, Frezzato A, et al. The Effect of Crown-to-Implant Ratio on the Clinical Performance of Extra-Short Locking-Taper Implants. *Journal of Craniofacial Surgery* 2016;27(3):675-81.

**Table 1** Characteristics of the included studies.

| Study | Design | Subjects | | | Follow-up period PL | Short implant group | | | Elevation group | | | | Rehabilitation methods | Outcome measures |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Gender (Male/Female) | Age | RBH (mm) | | Implant (n) | LEN (mm) | DIA (mm) | Implant (n) | LEN (mm) | DIA (mm) | Elevation methods | | |
| Bolle et al., 2018 | RCT (TAP) | INT 7/13 CON 12/8 | 59.35 (47-73) 63.25 (46-72) | 4-5 | 1 year | 37 | 4 | 4 or 4.5 | 41 | 10, 11.5, 13 | 4 or 4.5 | osteotomy approach | SG or SP | NIF, MBL, COM |
| Gastaldi et al., 2018 | RCT (TAP) | INT 3/17 CON 7/13 | 58.6 (39-80) 52.8 (42-70) | 4-6 | 3 years | 20 | 5 | 5 | 20 | 10, 11.5, 13, 15 | 5 | lateral window technique | SG or SP | NIF, MBL, COM |
| Gastaldi et al., 2017 | RCT (TAP) | INT 3/7 CON 5/5 | 53.4 (43-67) 58.6 (48-70) | 5-7 | 3 years | 16 | 5 or 6 | 5 | 18 | 10 | 5 | osteotomy approach | SG or SP | NIF, MBL, COM, PS |
| Guljé et al., 2014 | RCT (TAP) | INT 7/14 CON 13/7 | 50 (30-71) 48 (29-72) | 6-8 | 1 year | 21 | 6 | 4 | 20 | 11 | 4 | lateral window technique | SG | NIF, MBL, COM, PS |
| Pohl et al., 2017 | RCT (TAP) | 49/52* | 50.5 (20-75) * | 5-7 | 3 years | 67 | 6 | 4 | 70 | 11, 13, 15 | 4 | lateral window technique | SG | NIF, MBL, COM |
| Felice et al., 2018 | RCT (SM) | 11/9 | 57.6 (45 – 80) | 5-7 | 3 years | 39 | 6 | 4 | 44 | 10, 11.5, 13, 15 | 4 | lateral window technique | SG or SP | NIF, MBL, COM |
| Bechara et al., 2017 | RCT (TAP) | INT 10/23 CON 9/11 | 47.5±16.2 49.2±13.4 | ≥4 | 3 years | 45 | 6 | 4-8 | 45 | 10, 11.5, 13, 15 | 4-8 | lateral window technique | SG or SP | NIF, MBL, COM, PS |

RBH=residual bone width under sinus floor; INT=intervention; CON=control; PL=post-loading; LEN=implant length; DIA=implant diameter; TAP=two-arm parallel; SG=single crowns; SP=splinted prosthetics; PS=patient satisfaction; NIF=number of implant failures; MBL=marginal bone loss; COM=complications; SM=split mouth; NR=not reported.

* Details for subject information in intervention and control group were not reported.

**Table 2** Details on the risk of bias for each included study

| Study | Random sequence generation | Allocation concealment | Blinding of patients/carers | Blinding of outcome assessment | Incomplete outcome data | Selective reporting | Other |
|---|---|---|---|---|---|---|---|
| Bolle et al., 2018 | Low risk- Quote: “a computer-generated restricted randomization list” | Low risk- Quote: “the information on how to treat each patient was enclosed in sequentially numbered, identical, opaque, sealed envelopes.” | Low risk - Quote: “treatment allocation was concealed to the investigators in charge of enrolling and treating the patients.” | High risk- Quote: "complications were dealt with directly and reported by the responsible clinicians, who were not blinded”; “augmented sites could be easily identified on radiographs due to the different implant lengths." | Low risk- Quote: “one patient from the short implant group and one from elevation group dropped out.” | Low risk- Comment; All outcome measure in methods were reported in results | Unclear risk- Comment: diameter of implants (4 mm or 4.5 mm) was not controlled |
| Gastaldi et al., 2018 | Low risk- Quote: “a computer-generated restricted randomization list” | Low risk- Quote: “The randomized codes were enclosed in sequentially numbered, identical, opaque, sealed envelopes” | Low risk- Quote: “treatment allocation was concealed to the investigators in charge of enrolling and treating the patients.” | High risk- Quote: "augmented sites could be easily identified because of the different anatomy of the two sides after the augmentation procedure" | Low risk- Comment: one patient dropped out of the short implant group (1/20), and two patients dropped out of the elevation group (2/20) | Low risk- Comment; All outcome measures in methods were reported in results | Unclear risk- Comment: information of short implants was not reported |
| Gastaldi et al., 2017 | Low risk- Quote: “a computer-generated restricted randomization list” | Low risk- Quote: "The randomized codes were enclosed in sequentially numbered, identical, opaque, sealed envelopes.” | Low risk- Quote: “treatment allocation was concealed to the investigators in charge of enrolling and treating the patients” | High risk- Quote: “sinus-lifted sites could be identified on radiographs because they appeared more radio-opaque and implants were longer.” | High risk- Comment: no patients dropped out of the short implant group (0/10); two patients dropped out of the elevation group (2/10) | Low risk- Comment; All outcome measures in methods were reported in results | Low risk |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Guljé et al., 2014 | Low risk- Quote: "Randomization was performed using a block randomization sequence to provide equal distribution of subjects." | Low risk- Quote: “A sealed envelope” | Low risk- Quote: “A sealed envelope was opened by the surgical assistant at the beginning of the surgical procedure.” | High risk- Quote: “Blinding was possible in the clinical evaluation but not during analysis of the radiographs.” | Low risk-Comment: no patient dropped out of the short implant group (0/21); one patient in the elevation group died (1/20) | Low risk- Comment; All outcome measures in methods were reported in results | Low risk |
| Pohl et al., 2017 | Low risk- Quote: “A block randomization sequence was used to provide an equal distribution” | Low risk- Quote: “A sealed envelope” | Low risk- Quote: “After flap elevation, a sealed randomization envelope was opened to allocate the subject to either one of the two treatment | Unclear risk- Quote: “an independent examiner performed all the radiographic measurements.” Other information was not reported. | High risk-Comment: The reasons for incomplete reporting of MBL were not provided. | High risk- Comment: marginal bone loss at 3-year follow-up was reported at the implant level rather than at the participant level | Low risk |
| Felice et al., 2018 | Low risk- Quote: “a computer-generated restricted randomisation list” | Low risk- Quote: “The information on how to treat site number 1 was enclosed in sequentially numbered, identical, opaque, sealed envelopes.” | Low risk- Quote: “Treatment allocation was concealed to the investigators in charge of enrolling and treating the patients.” | High risk- Quote: “augmented sites could be easily identified because of the different anatomy” | High risk- Comment: it was a split-mouth design study, and two dropouts (2/20) occurred | Low risk- Comment: All outcome measures in methods were reported in results | Low risk |
| Bechara et al., 2017 | Unclear risk- Quote: “Patients were randomly assigned” | Low risk- Quote: “a sequentially numbered sealed envelope” | Unclear risk- Comment: not mentioned | Unclear risk- Quote: “At each annual inspection, an experienced, calibrated, independent examiner performed a careful clinical examination”, but elevation site can be distinguished | Low risk- Comment: one patient dropped out of the short implant group (1/33), and one patient dropped out of the elevation group (1/20) | High risk- Comment: marginal bone loss was reported at the implant level rather than at the participant level | High risk- Comment: diameter of implants was not controlled (4-8 mm) |

**Table 3** Details of implant failures reported in the included studies.

| Study | Short implant group | | | | Elevation group | | | |
|---|---|---|---|---|---|---|---|---|
| | LEN (mm) | DIA (mm) | PAR/IMP (n) | Details | LEN (mm) | DIA (mm) | PAR/IMP (n) | Details |
| Bolle et al., 2018 | 4 | 4 or 4.5 | 2/3 | PAR1. One implant was mobile 3 months after placement, and another implant migrated into the sinus 4 months after placement. PAR2. One implant was medially tilted 2 weeks after placement | 10,11.5,13 | 4 or 4.5 | 4/6 | PAR1. One implant was mobile 2 months after placement because of a perforation of the sinus lining at its detachment. Another implant was mobile 2 months later. PAR2. One implant migrated into the sinus 3 months after placement. PAR3. Two implants were mobile 3 months after placement because the patient insisted on wearing her removable denture. PAR4. One implant was mobile, and the patient experienced discomfort when chewing 5 months post-loading. |
| Gastaldi et al., 2018 | 5 | 5 | 1/1 | PAR1. One implant failed 3 months post-loading. | 10,11.5, 13,15 | 5 | 0 | None |
| Felice et al., 2018 | 6 | 4 | 0 | None | 10,11.5, 13,15 | 4 | 1/2 | PAR1. Two implants failed due to peri-implantitis 2 years post-loading. |
| Bechara et al., 2017 | 6 | 4-8 | 0 | None | 10,11.5, 13,15 | 4-8 | 1/2 | PAR1. Two implants were lost caused due to chronic sinus infection with loss of integration/implant stability 2 months after surgery |

LEN=implant length; DIA=implant diameter; PAR=participant; PAR/IMP=participant/implant

Table 4 Comparisons of complications

| Outcome or subgroup titles | No. of studies | No. of participants | Statistical methods | Effect size |
|---|---|---|---|---|
| 1.Post-surgery reaction | 3 | 184 | Risk Ratio (Fixed, M-H, 95% CI) | 0.11 (0.14, 0.31) * |
| 2.Biological complications | | | | |
| Sinus perforation or infection | 3 | 125 | Risk Ratio (Fixed, M-H, 95% CI) | 0.11 (0.02, 0.63) * |
| Implant mobile | 2 | 132 | Risk Ratio (Fixed, M-H, 95% CI) | 0.34 (0.06,2.06) |
| Peri-implant mucositis and peri-implantitis | 2 | 54 | Risk Ratio (Fixed, M-H, 95% CI) | 0.91 (0.14, 5.79) |
| 3.Technical complications | | | Risk Ratio (Fixed, M-H, 95% CI) | |
| Screw loosening | 3 | 169 | Risk Ratio (Fixed, M-H, 95% CI) | 2.66 (0.93, 7.60) |
| Crown loosening, decementation or chipping | 5 | 223 | Risk Ratio (Random, M-H, 95% CI) | 1.22 (0.33, 4.49) |

* Difference between the two groups was significant.

Table 5 Summary of findings

**Short implant (≤6 mm) compared to longer implant (≥10 mm) with sinus floor elevation in atrophic posterior maxilla**

**Patient or population**: atrophic posterior maxilla
**Intervention**: short implant (<= 6mm)
**Comparison**: longer implant (>= 10mm) with sinus floor elevation

| Outcomes | Anticipated absolute effects* (95% CI) | | Relative effect (95% CI) | № of participants (studies) | Certainty of the evidence (GRADE) | Comments |
|---|---|---|---|---|---|---|
| | Assumed risk [1] (elevation group) | Corresponding risk (short implant group) | | | | |
| survival rate follow up: range 1 years to 3 years | 961 per 1,000 | **970 per 1,000** (932 to 999) | **RR 1.01** (0.97 to 1.04) | 321 (7 RCTs) | ⊕⊕⊕◯ MODERATE [2] | |
| survival rate follow up: range 3 years to longer years | 982 per 1,000 | **982 per 1,000** (953 to 1,000) | **RR 1.00** (0.97 to 1.04) | 237 (5 RCTs) | ⊕⊕⊕◯ MODERATE [2] | |
| marginal bone loss follow up: range 1 years to 3 years | The mean marginal bone loss ranged from **0.1 to 1.15** mm | The mean marginal bone loss in the intervention group was 0.13 mm lower (0.21 lower to 0.05 lower) | - | 249 (6 RCTs) | ⊕⊕◯◯ LOW [3] | |
| marginal bone loss follow up: range 3 years to longer years | The mean marginal bone loss ranged from **1.08 to 1.5** mm | The mean marginal bone loss in the intervention group was 0.25 mm lower (0.4 lower to 0.1 lower) | - | 88 (3 RCTs) | ⊕⊕⊕◯ MODERATE [2] | |
| post-surgery reaction | 307 per 1,000 | **34 per 1,000** (12 to 59) | **RR 0.11** (0.04 to 0.31) | 184 (3 RCTs) | ⊕⊕⊕◯ MODERATE [2] | |
| biological complications: sinus perforation or infection | 197 per 1,000 | **20 per 1,000** (4 to 113) | **RR 0.11** (0.02 to 0.63) | 125 (3 RCTs) | ⊕⊕◯◯ LOW [4] | |
| biological complications: implant mobile | 59 per 1,000 | **20 per 1,000** (4 to 121) | **RR 0.34** (0.06 to 2.06) | 132 (2 RCTs) | ⊕⊕◯◯ LOW [4] | |
| biological complications: peri-implant mucositis or peri-implantitis | 200 per 1,000 | **100 per 1,000** (10 to 934) | **RR 0.91** (0.14 to 5.79) | 54 (2 RCTs) | ⊕⊕◯◯ LOW [4] | |
| technical complications: screw loosening | 81 per 1,000 | **217 per 1,000** (76 to 916) | **RR 2.66** (0.93 to 7.60) | 169 (3 RCTs) | ⊕⊕◯◯ LOW [4] | |
| technical complications: crown loosening, decementation and chipping | 27 per 1,000 | **33 per 1,000** (9 to 120) | **RR 1.22** (0.33 to 4.49) | 223 (5 RCTs) | ⊕⊕◯◯ LOW [4] | |

***The risk in the intervention group** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI). **CI:** Confidence interval; **RR:** Risk ratio; **MD:** Mean difference

1. Assumed risk is based on the overall event rate in the control groups of the included studies.
2. Downgraded one level due to serious risks of bias.
3. Downgraded two levels due to serious risks of bias and serious inconsistency.
4. Downgraded two levels due to serious risks of bias and imprecision.

## Figure Legends

**Figure 1** Flow diagram for study selection

**Figure 2** Risk of bias in each included study

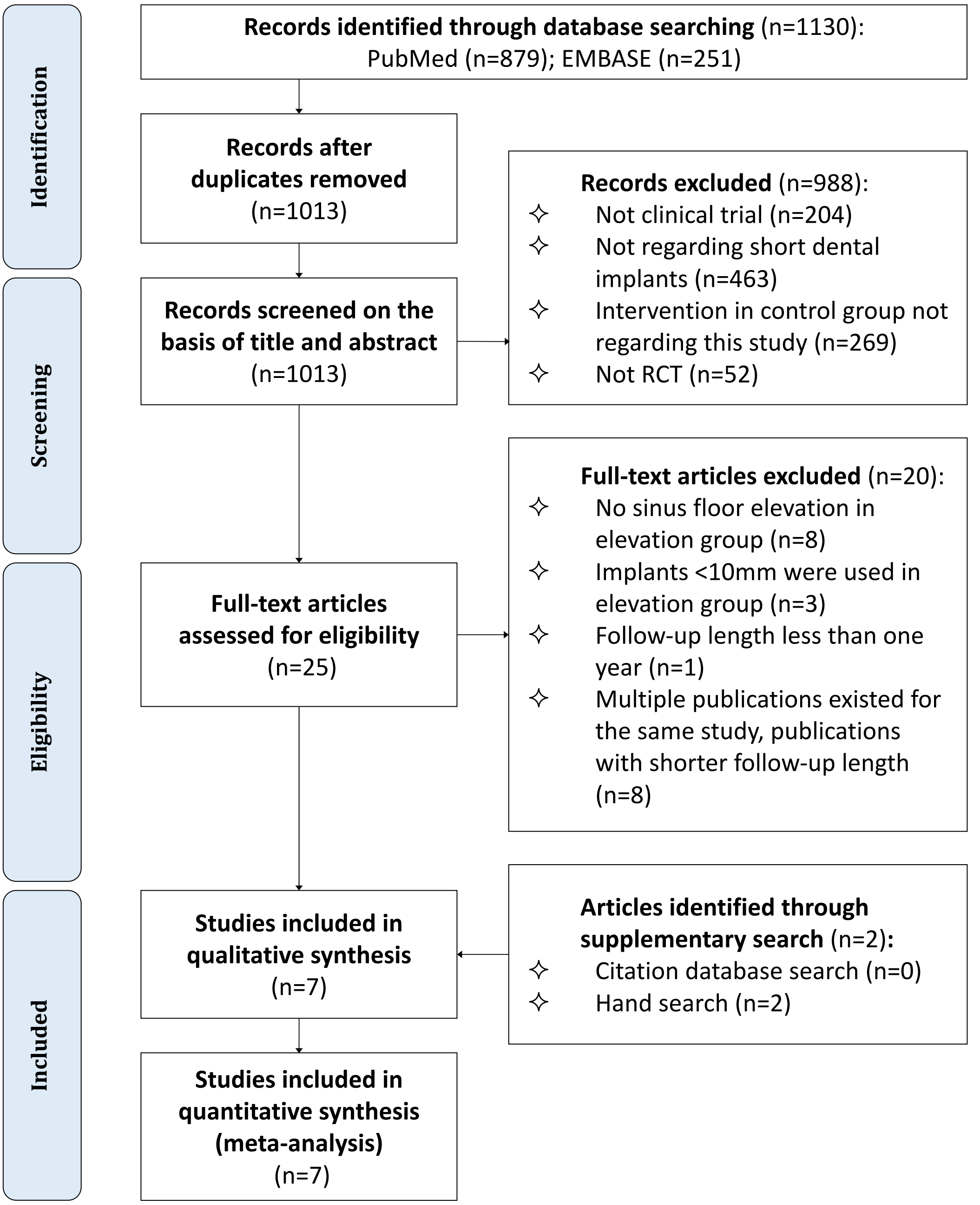
**Figure 3** Risk of bias across included studies

**Figure 4** Forest plot for implant survival rate

*footnote: SI, short implant group; SFE, sinus floor elevation group.*

**Figure 5** Forest plot for marginal bone loss

*footnote: SI, short implant group; SFE, sinus floor elevation group.*


Identification
Screening
Eligibility
Included
Records identified through database searching (n=1130):
PubMed (n=879); EMBASE (n=251)
Records after duplicates removed (n=1013)
Records screened on the basis of title and abstract (n=1013)
Records excluded (n=988):
Not clinical trial (n=204)
Not regarding short dental implants (n=463)
Intervention in control group not regarding this study (n=269)
Not RCT (n=52)
Full-text articles assessed for eligibility (n=25)
Full-text articles excluded (n=20):
No sinus floor elevation in elevation group (n=8)
Implants <10mm were used in elevation group (n=3)
Follow-up length less than one year (n=1)
Multiple publications existed for the same study, publications with shorter follow-up length (n=8)
Articles identified through supplementary search (n=2):
Citation database search (n=0)
Hand search (n=2)
Studies included in qualitative synthesis (n=7)
Studies included in quantitative synthesis (meta-analysis) (n=7)

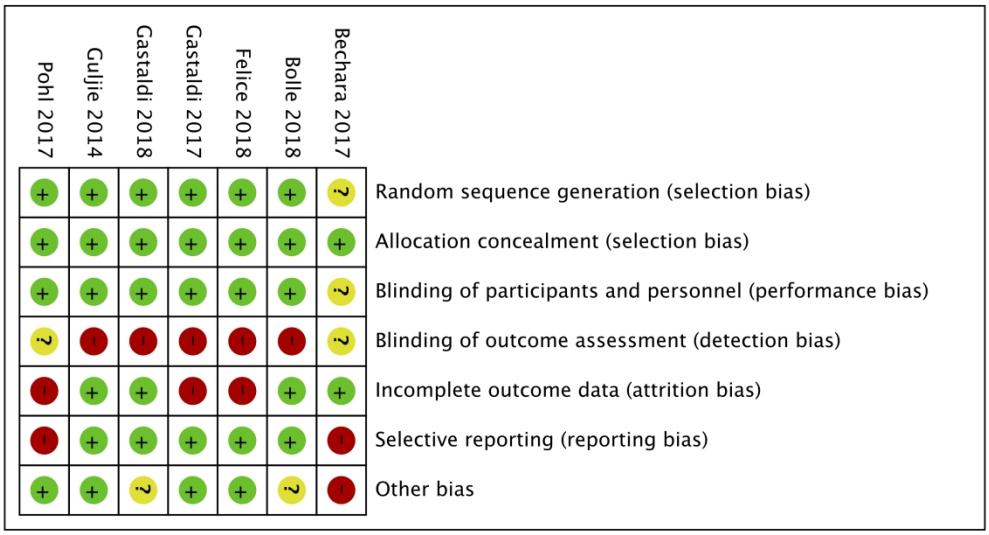



Figure 2 Risk of bias in each included study

269x146mm (300 x 300 DPI)

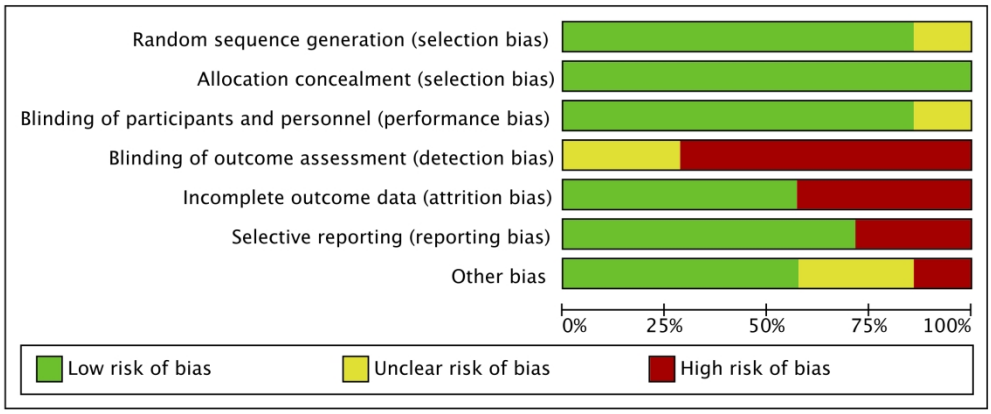



Figure 3 Risk of bias across included studies

199x83mm (300 x 300 DPI)

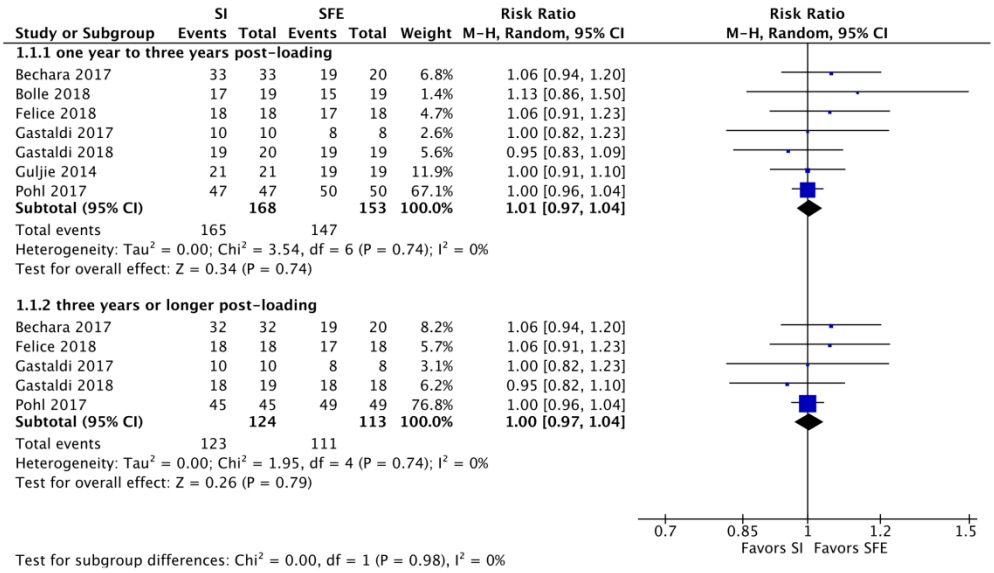



Figure 4 Forest plot for implant survival rate. footnote: SI, short implant group; SFE, sinus floor elevation group.

198x114mm (300 x 300 DPI)

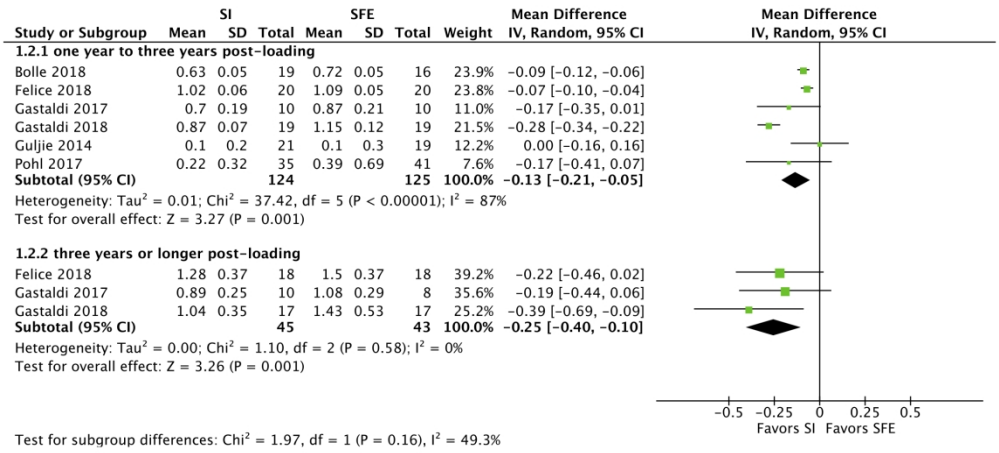



Figure 5 Forest plot for marginal bone loss. footnote: SI, short implant group; SFE, sinus floor elevation group.

197x90mm (300 x 300 DPI)

*Supplementary File*

# Short implants (≤6 mm) versus longer implants with sinus floor elevation in atrophic posterior maxilla: A systematic review and meta-analysis

**The search strategy used for PubMed (1946 to 31 May 2018):**

1. dental implant [Mesh Terms]
2. dental implantation [Mesh Terms]
3. dental prosthesis, implant supported [Mesh Terms]
4. 1 OR 2 OR 3
5. long implant [Title/Abstract]
6. short implant [Title/Abstract]
7. shorter implant [Title/Abstract]
8. longer implant [Title/Abstract]
9. super short [Title/Abstract]
10. extra short [Title/Abstract]
11. ultrashort [Title/Abstract]
12. 6mm [Title/Abstract]
13. 5mm [Title/Abstract]
14. 4mm [Title/Abstract]
15. 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14
16. 4 OR 15
17. alveolar bone loss [Mesh Terms]
18. alveolar bone atrophy [Mesh Terms]
19. alveolar ridge augmentation [Mesh Terms]
20. bone substitute [Mesh Terms]
21. augmentation, sinus floor [Mesh Terms]
22. 17 OR 18 OR 19 OR 20 OR 21
23. atrophy jaw [Title/Abstract]
24. atrophy maxilla [Title/Abstract]
25. atrophy mandible [Title/Abstract]
26. augmented bone [Title/Abstract]

27. bone augmentation [Title/Abstract]
28. sinus lift [Title/Abstract]
29. sinus floor elevation [Title/Abstract]
30. 23 OR 24 OR 25 OR 26 OR 27 OR 28 OR 29
31. 22 OR 30
32. randomized controlled trial [Publication Type]
33. randomized [Title/Abstract]
34. randomly [Title/Abstract]
35. 32 OR 33 OR 34
36. 16 AND 31 AND 35

**The search strategy used for Embase (1980 to 31 May 2018):**

1. 'alveolar bone loss'/exp/mj
2. 'alveolar ridge augmentation'/exp/mj
3. 'bone prosthesis'/exp/mj
4. 1 OR 2 OR 3
5. 'atrophic jaw': ab, ti
6. 'atrophic maxilla': ab, ti
7. 'atrophic mandible': ab, ti
8. 'posterior maxilla': ab, ti
9. 'posterior mandible': ab, ti
10. 'augmented bone': ab, ti
11. 'bone augmentation': ab, ti
12. 'sinus lift': ab, ti
13. 'sinus floor elevation': ab, ti
14. 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13
15. 4 OR 14
16. 'tooth implantation'/exp/mj
17. 'tooth implant'/exp/mj
18. 'tooth prosthesis'/exp/mj
19. 16 OR 17 OR 18
20. 'short implant': ab, ti

21. ‘long implant’: ab, ti
22. ‘shorter implant’: ab, ti
23. ‘longer implant’: ab, ti
24. ‘super short’: ab, ti
25. ‘extra short’: ab, ti
26. ‘ultrashort’: ab, ti
27. ‘6mm’: ab, ti
28. ‘5mm’: ab, ti
29. ‘4mm’: ab, ti
30. 20 OR 21 OR 22 OR 23 OR 24 OR 25 OR 26 OR 27 OR 28 OR 29
31. 19 OR 30
32. ‘controlled clinical trial’/lim
33. ‘randomized controlled trial’/lim
34. 32 OR 33
35. 15 AND 31 AND 34

*Supplementary File*

**Short implants (≤6 mm) versus longer implants with sinus floor elevation in atrophic posterior maxilla: A systematic review and meta-analysis**

| | # | Checklist item | Reported on page # |
|---|---|---|---|
| **TITLE** | | | |
| Title | 1 | Identify the report as a systematic review, meta-analysis, or both. | 1 |
| **ABSTRACT** | | | |
| Structured summary | 2 | Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number. | 2 |
| **INTRODUCTION** | | | |
| Rationale | 3 | Describe the rationale for the review in the context of what is already known. | 4 |
| Objectives | 4 | Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS). | 5 |
| **METHODS** | | | |
| Protocol and registration | 5 | Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number. | 5 |
| Eligibility criteria | 6 | Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale. | 5 |
| Information sources | 7 | Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched. | 6 |
| Search | 8 | Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated. | 6 |

*Supplementary File*

| | | | |
|---|---|---|---|
| Study selection | 9 | State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis). | 6 |
| Data collection process | 10 | Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators. | 7 |
| Data items | 11 | List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made. | 7 |
| Risk of bias in individual studies | 12 | Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis. | 7 |
| Summary measures | 13 | State the principal summary measures (e.g., risk ratio, difference in means). | 8 |
| Synthesis of results | 14 | Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., $I^2$) for each meta-analysis. | 8 |

| Section/topic | # | Checklist item | Reported on page # |
|---|---|---|---|
| Risk of bias across studies | 15 | Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies). | 7 |
| Additional analyses | 16 | Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified. | 8 |
| **RESULTS** | | | |
| Study selection | 17 | Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram. | 9 |
| Study characteristics | 18 | For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations. | 10 |
| Risk of bias | 19 | Present data on risk of bias of each study and, if available, any outcome level assessment | 10 |

*Supplementary File*

| | | | |
|---|---|---|---|
| within studies | | (see item 12). | |
| Results of individual studies | 20 | For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot. | 11-12 |
| Synthesis of results | 21 | Present results of each meta-analysis done, including confidence intervals and measures of consistency. | 11-12 |
| Risk of bias across studies | 22 | Present results of any assessment of risk of bias across studies (see Item 15). | 10 |
| Additional analysis | 23 | Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]). | 11-12 |
| **DISCUSSION** | | | |
| Summary of evidence | 24 | Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers). | 12 |
| Limitations | 25 | Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias). | 16 |
| Conclusions | 26 | Provide a general interpretation of the results in the context of other evidence, and implications for future research. | 16 |
| **FUNDING** | | | |
| Funding | 27 | Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review. | 17 |

*From:* Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: **www.prisma-statement.org**.