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

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

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## Abstract

**Objectives:** To compare the use of ultrashort implants ( $\leq 6$  mm) in severely atrophic posterior maxilla versus longer implants ( $\geq 10$  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.<sup>1-3</sup> 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.<sup>4,5</sup> These conditions are exacerbated if patients have a history of wearing removable dentures.<sup>6</sup>

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.<sup>7,8</sup> 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.<sup>9-11</sup> The lateral window approach is used in up to 22.1% of all dental implantation procedures.<sup>12</sup> 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.<sup>13-15</sup> 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.<sup>16-19</sup>

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,<sup>20</sup>  $\leq 8$  mm,<sup>21</sup>  $\leq 7$  mm,<sup>22</sup> and 6-8 mm<sup>23</sup> 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.<sup>6,24,25</sup> Ultrashort implants require a less complicated

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3 surgical approach and are used in cases when sinus floor elevation surgery is not  
4 applicable,<sup>26 27</sup> especially in cases of maxillary sinusitis, maxillary cyst, large vessels  
5 and other cases involving abnormal sinus anatomy. Studies have explored the short-  
6 and long-term survival rates of ultrashort implants.<sup>27-31</sup> Unfortunately, evidence  
7 supporting the use of ultrashort implants in the posterior maxilla is weak, and no  
8 guideline statement is currently recommended.  
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17 The present systematic review aimed to compare the effectiveness of ultrashort  
18 implants and longer implants ( $\geq 10$  mm) with sinus floor elevation in atrophic  
19 posterior maxilla. Outcome measures of interest included survival rate, marginal bone  
20 loss (MBL) and adverse events.  
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## 28 29 **2. Materials and methods**

### 30 31 *2.1 Protocol and registration*

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33 This systematic review and meta-analysis was reported in accordance with the  
34 PRISMA guidelines.<sup>32</sup> The review protocol has been registered at PROSPERO  
35 (CRD42018103531).  
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### 42 43 *2.2 Eligible criteria*

44  
45 Randomized controlled trials (RCTs) meeting the following pre-determined inclusion  
46 criteria were included:  
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49 • Partially edentulous patients in the premolar and molar regions of the maxilla,  
50 for whom the residual bone height in the atrophic posterior maxilla was  
51 sufficient for the insertion of an ultrashort implant but insufficient for the  
52 insertion of longer implants;  
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54 • One or more ultrashort implants were placed in the posterior maxilla without  
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3 sinus floor elevation in the ultrashort implant group;

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6 • One or more longer implants were placed in the posterior maxilla after sinus  
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8 floor elevation by any technique in the elevation group;
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10 • One year or longer follow-up period; and
- 11  
12 • The primary (survival rate) and secondary (MBL and adverse events) outcomes  
13  
14 of interest were measured.
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### 20 *2.3 Information sources and search strategies*

21  
22 Two authors (QY and XW) searched PubMed, Embase, and the Cochrane CENTRAL  
23  
24 (The Cochrane Central Registration of Controlled Trials) for RCTs, independently and  
25  
26 in duplicate. A third author (FH) was consulted to resolve any disagreements. Main  
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28 search terms included: “dental implant”, “short implant”, “ultrashort”, “alveolar bone  
29  
30 loss”, “atrophic maxilla”, “sinus lift”, and “sinus floor elevation”. No restriction was  
31  
32 set regarding publication year, publication language or status. The last search was  
33  
34 conducted on 31/05/2018. The detailed search strategies are listed in **appendix 1**. In  
35  
36 addition, retrospective and prospective searches were conducted by checking the  
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38 reference lists of key articles and studies citing these key articles, using Google Scholar.  
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### 45 *2.3 Study selection and data collection*

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47 Two review authors (QY and XW) conducted the study selection independently and in  
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49 duplicate. The titles and abstracts of all records were scanned. Full texts of studies were  
50  
51 obtained in cases they appeared to meet the inclusion criteria or further information  
52  
53 were needed to determine eligibility. Studies excluded at this or subsequent stages were  
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55 recorded with the reasons for exclusion. All disagreements were resolved by discussion.

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58 Two review authors extracted the data independently and in duplicate using  
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3 specifically designed data extraction forms. The extracted data included citation details  
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5 (year of publication, country of origin, setting and source of funding), details on the  
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7 participants (demographic characteristics, residual bone height and inclusion criteria),  
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10 details of intervention (implant length, diameter, brand, surface structure, surgical  
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12 method, follow-up time, prosthesis type), outcome assessment, sample size calculation  
13  
14 and trial registration. Corresponding authors were contacted for missing data or  
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16 information.  
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#### 21 *2.4 Risk of bias of included studies*

22  
23 Two authors (QY and XW) assessed the risk of bias of each included study  
24  
25 independently and in duplicate using the Cochrane risk of bias assessment tool for  
26  
27 RCTs.<sup>33</sup> Disagreements were resolved through discussion. A third review author (F.H.)  
28  
29 was consulted when necessary. Seven domains were assessed, including sequence  
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31 generation (selection bias), allocation concealment (selection bias), blinding of  
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33 participants and personnel (performance bias), blinding of outcome assessment  
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35 (detection bias), incomplete outcome data (attrition bias), selective outcome reporting  
36  
37 (reporting bias) and other bias (factors that had potential influence on outcomes but  
38  
39 were not evenly distributed across groups or not clearly reported, such as the  
40  
41 manufacturer or diameter of implants). Individual studies were categorized as having  
42  
43 low, high or unclear risk of bias. The risk of bias across studies was determined  
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45 according to the risk of bias in each included study.  
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#### 54 *2.5 Assessment of heterogeneity and publication bias*

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56 Clinical heterogeneity among the included studies was assessed by comparing study  
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58 design, participant conditions (residual bone height), intervention (implant length,  
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3 diameter, surface structure, surgical method), and outcome measures. Statistical  
4 heterogeneity was evaluated using Cochrane's Q test and the I<sup>2</sup> statistic. In the Q test,  
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6 a P value < 0.1 was considered an indication of significant heterogeneity.  
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## 10 11 12 *2.6 Publication bias*

13  
14 If at least ten studies were included in a meta-analysis, We would have used a funnel  
15 plot and the Egger's test<sup>34</sup> asymmetry to assess the potential existence of publication  
16 bias if at least ten studies were included in a meta-analysis.  
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## 23 24 *2.7 Synthesis of results*

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26 The unit of analysis was set as participant rather than implant.<sup>35</sup> RevMan 5.3 software  
27 was used for data synthesis. Meta-analyses were undertaken only when at least two  
28 studies that made similar comparisons reported the same outcomes. The effect measures  
29 were risk ratio (RR) for dichotomous outcomes and mean difference (MD) for  
30 continuous outcomes. P<0.05 was considered statistically significant. The fixed effect  
31 model was used when fewer than four studies were included in a meta-analysis, and the  
32 random-effects model was used when four or more studies were included.  
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## 45 46 *2.8 Additional analysis*

47 Subgroup analysis by length of follow-up was performed to control for the possibility  
48 that function time might influence implant survival.<sup>36</sup> If risks of bias in some studies  
49 were serious, we would have performed sensitivity analysis by excluding these studies.  
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## 56 57 *2.9 Summary of findings (SoF)*

58 Grading of Recommendations Assessment, Development, and Evaluation (GRADE)  
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3 approach <sup>37</sup> was adopted to evaluate quality of evidence in this systematic review. A  
4  
5 SoF table was made with an online tool (cebgrade.mcmaster.ca/gradepr). Outcomes  
6  
7 were evaluated including survival rate and MBL of one to three-year and three-year or  
8  
9 longer follow-up, respectively. Five domains in quality of evidence were assessed: the  
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11 overall risk of bias, directness of evidence, consistency of results, precision of estimates,  
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13 as well as the risk of publication bias. The quality of the body of evidence was classified  
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15 into four categories: high, moderate, low and very low.  
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## 22 *2.10 Patient and Public involvement*

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24 The present work does not include original patient data. Therefore, patients and the  
25  
26 public were not involved.  
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## 30 **3. Results**

### 31 *3.1 Study selection*

32  
33 Electronic searches identified a total of 879 titles and abstracts in PubMed and 251 in  
34  
35 Embase. After removal of duplicates, the titles and abstracts of 1,013 unique items were  
36  
37 screened. We then retrieved the full texts of 25 potentially eligible articles, of which 20  
38  
39 were excluded for reasons described in **figure 1**. Retrospective and prospective hand  
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41 searches yielded two more studies. Finally, seven studies <sup>30 38-43</sup> met our eligibility  
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43 criteria and were included in this review.  
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### 50 *3.2 Study characteristics*

51  
52 The characteristics of the seven included studies are listed in **table 1**. One study was a  
53  
54 split-mouth trial, and the rest were two-arm parallel RCTs. The length of follow-up  
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56 ranged from one year to three years. For sinus floor elevation, either osteotomy-  
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3 mediated sinus floor elevation or the lateral window technique was adopted. In two  
4 studies, single crowns were used as the rehabilitation method; in the remaining studies,  
5 single crowns or fixed partial dentures were used. The outcome measures used in these  
6 studies included implant failure, MBL and complications. Overall, 171 participants  
7 were included in the ultrashort implant groups, and 159 participants were included in  
8 the elevation groups.  
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### 10 11 12 13 14 15 16 17 18 19 *3.3 Risk of bias assessment*

20  
21 The results of the risks of bias assessment are shown in figures 2 and 3. Selection bias  
22 and performance bias were assessed as low in all but one study by Bachara et al<sup>43</sup> due  
23 to inadequate description on random sequence generation and blinding of participants.  
24 For detection bias, most studies showed high risks because assessors could recognize  
25 sites that underwent sinus floor elevation. For attrition bias, only one study<sup>30</sup> was  
26 assessed as low because unbalanced drop-out occurred in most studies. Two studies<sup>41</sup>  
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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

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3 either one year to three years post-loading (RR=1.01, 95% CI: 0.97, 1.04, p=0.74, I<sup>2</sup> =  
4 0%, seven RCTs, 321 participants) or three years or longer post-loading (RR=1.00, 95%  
5 CI: 0.97, 1.04, p=0.79, I<sup>2</sup> = 0%, five RCTs, 237 participants). Further details of the  
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10 implant failures are summarized in **table 3**.

### 11 12 13 14 15 3.4.2 MBL

16  
17 The results of the meta-analysis and subgroup analysis regarding peri-implant MBL are  
18 shown in figure 5. A significant difference favoring the ultrashort implant group was  
19 found for both one year or longer post-loading (MD=-0.13, 95% CI: -0.21, -0.05;  
20 p=0.001, I<sup>2</sup> = 87%, six RCTs, 249 participants) and three years or longer post loading  
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22 (MD=-0.25, 95% CI: -0.40, -0.10; p=0.001, I<sup>2</sup> = 0%, three RCTs, 88 participants).  
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### 31 3.4.3 Adverse events

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33 Adverse events occurring before and after loading were categorized into “early adverse  
34 events” and “late adverse events”, respectively. Overall, 23 adverse events occurred in  
35 the ultrashort implant group; of these, 4 (17.40%) were early adverse events, and 19  
36 (82.60%) were late adverse events. Fifty-six adverse events were reported for the  
37 elevation group; of these, 46 (82.14%) were early adverse events, and 10 (17.86%) were  
38 late adverse events. Most early adverse events were related to surgical procedures,  
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### 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

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

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16 To the best of our knowledge, this is the first systematic review and meta-analysis to  
17 compare the clinical outcome of the use of ultrashort implants in severely atrophic  
18 posterior maxilla versus longer implants with sinus floor elevation. At one year or  
19 longer post-loading, there is no significant difference in participant unit implant  
20 survival rate between the ultrashort implant group and the elevation group. The  
21 ultrashort implant group showed less MBL than the elevation group for one to three-  
22 year follow-up (low quality evidence) and three-year or longer follow-up (moderate  
23 quality evidence). In addition, the ultrashort implant group showed fewer surgery-  
24 related adverse events.  
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38 The survival rate in this review was evaluated by participant unit as in a previous  
39 Cochrane review.<sup>35</sup> In this review, the overall survival rates for the ultrashort implant  
40 group and the elevation group were 98.21% and 96.08%, respectively, at one-year to  
41 three-year follow-up and 99.20% and 98.23%, respectively, at longer than three-year  
42 follow-up; no significant difference in survival rate was found. Other studies that  
43 assessed survival rate in implant unit had similar outcomes. A retrospective study<sup>44</sup> with  
44 a follow-up period of 17 to 48 months reported a 95.12% implant unit survival rate for  
45 5-mm to 6-mm ultrashort implants. A two-year to three-year prospective study<sup>6</sup>  
46 reported that 6-mm ultrashort implants with micro rough surfaces achieved a 100%  
47 survival rate in posterior maxilla. Another five- to ten-year retrospective study<sup>45</sup>  
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3 reported a 97% implant unit survival rate for 6-mm ultrashort implants supporting  
4 single crowns. All these results showed that ultrashort implants represent a promising  
5 rehabilitation method with respect to their short-term and long-term survival rates.  
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10 In this review, all of the failed ultrashort implants were 4 mm or 5 mm. Although  
11 the use of ultrashort implants could avoid complicated surgical procedures and related  
12 early failures, reduced implant length was still the major risk factor in survival rate. The  
13 authors of the included studies used wider implants (4 mm to 8 mm) to compensate for  
14 the short length of the implants. Finite element analyses showed that wider implants  
15 had increased functional surface area in cortical bone and decreased stress distribution  
16 on the implant neck; these qualities helped improve primary stability, produce a higher  
17 survival rate and reduce MBL.<sup>46-49</sup> However, it was not determined whether implant  
18 length or diameter contributed more to implant failure. Another factor was implant  
19 surface structure. Studies<sup>50-53</sup> have suggested that the implant surface influences bone-  
20 to-implant osseointegration, implant primary stability and MBL. In this review,  
21 implants 4 mm or 5 mm in length had novel surface structures, but they still presented  
22 a lower survival rate. It seemed that implant length had a greater influence than implant  
23 surface structure on survival rate.  
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42 Significantly less MBL was found in the ultrashort implant group, and the difference  
43 was greater at the longer follow-up period. Additionally, in this review, 5-mm-diameter  
44 implants tended to induce less MBL than 4-mm-diameter implants. Implants  $\leq 10$  mm  
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20 and  $\leq 8$  mm<sup>21</sup> were reported to induce MBL similar to that of longer implants,  
while implants  $\leq 7$  mm<sup>54</sup> 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)  
<sup>55</sup> that induces more peri-implant bone loss and early implant failure.<sup>56 57</sup> According to  
finite element analyses, inappropriate C/I results in adverse occlusal forces such as non-

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

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

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56 The present study has several strengths. Firstly, we conducted a comprehensive  
57 literature search, and all included studies were RCTs. Secondly, participant was used  
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3 as the unit of analysis to ensure logical statistical syntheses and relevant interpretations.  
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6 Thirdly, subgroup analysis by follow-up length was performed to reduce bias across  
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8 studies. However, the evidence included in this systematic review was only of moderate  
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10 or low quality. Serious risks of bias were found within and across studies. The number  
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12 of participants and the follow-up period were limited. We suggest that researchers in  
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14 this field carry out more well designed, long-term and large-scale RCTs to provide high  
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16 quality evidence regarding the effects of ultrashort implants.  
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## 22 **5. Conclusions**

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24 Within its limitations, the present review suggests that the survival rate of maxillary  
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26 ultrashort implants was comparable to that of longer implants ( $\geq 10$  mm) with sinus  
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28 floor elevation. However, ultrashort implants show significantly less MBL and fewer  
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30 surgery-related adverse events. Ultrashort implants are therefore a promising  
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32 alternative to sinus floor elevation for posterior maxilla with insufficient bone volume.  
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35 Additional high-quality studies are needed to evaluate the long-term effectiveness and  
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37 safety of ultrashort implants.  
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3 **Author contributions** Conception and design of the review: FH and BS. Methodology:  
4 QY and FH. Drafting protocol, performing search strategies, literature searches,  
5 literature screening and data extraction: QY and XW. Original draft preparation: XW.  
6 Reviewing and editing draft: MS, QY, FH and BS. All authors critically reviewed and  
7 revised the manuscript and approved the final version for publication.  
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25 **Data sharing statement** The data may be obtained from the authors for academic  
26 purposes.  
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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

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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)				
<b>Survival rate</b> follow up: range 1 years to 3 years	961 per 1,000 <sup>1</sup>	970 per 1,000 (932 to 999)	RR 1.01 (0.97 to 1.04)	321 (7 RCTs)	⊕⊕⊕○ MODERATE <sub>2</sub>	-
<b>Survival rate</b> follow up: range 3 years to longer years	982 per 1,000 <sup>1</sup>	982 per 1,000 (953 to 1,000)	RR 1.00 (0.97 to 1.04)	237 (5 RCTs)	⊕⊕⊕○ MODERATE <sub>2</sub>	-
<b>MBL</b> 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 <b>0.13 mm lower</b> (0.21 lower to 0.05 lower)	-	249 (6 RCTs)	⊕⊕○○○ LOW <sup>3</sup>	-
<b>MBL</b> 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 <b>0.25 mm lower</b> (0.4 lower to 0.1 lower)	-	88 (3 RCTs)	⊕⊕⊕○ MODERATE <sub>2</sub>	-

\*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.

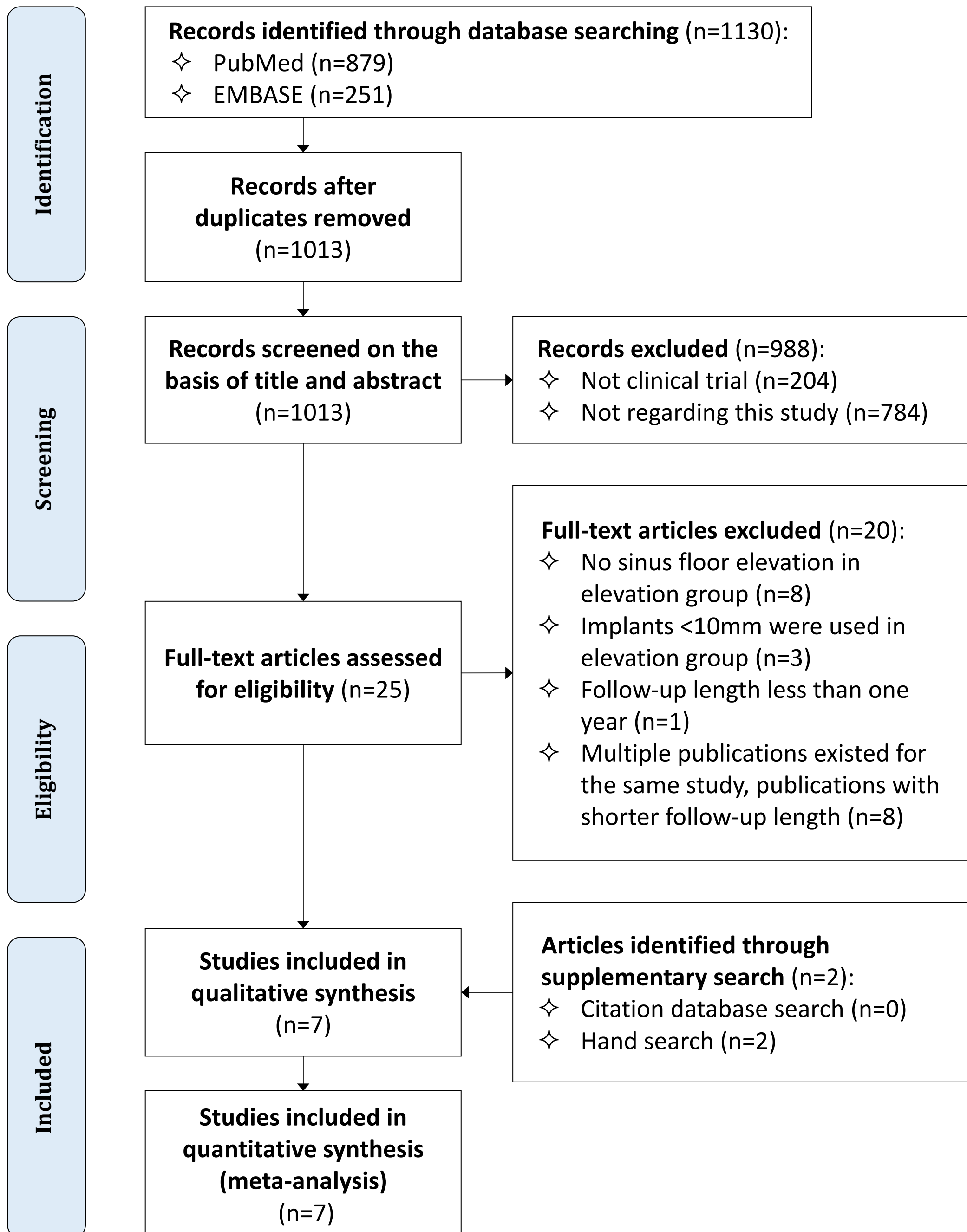
**Figure 3** Risk of bias across included studies.

**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.*

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	Random 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 reporting (reporting bias)	Other bias
Bechara 2017	?	+	?	?	?	-	-
Bolle 2018	+	+	+	-	+	+	?
Felice 2018	+	+	+	-	-	+	+
Gastaldi 2017	+	+	+	-	-	+	+
Gastaldi 2018	+	+	+	-	-	+	?
Guljie 2014	+	+	+	-	?	+	+
Pohl 2017	+	+	+	?	-	-	+

Figure 2. Risk of bias in each included study.

173x316mm (144 x 144 DPI)

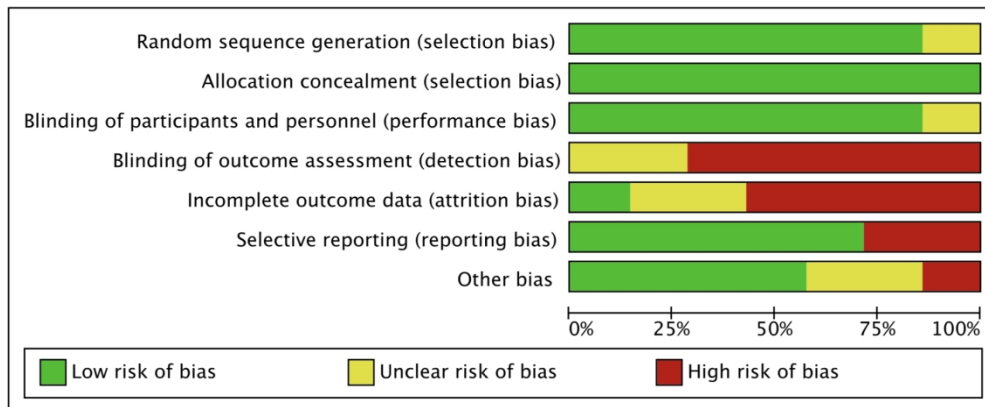


Figure 3. Risk of bias across included studies.

352x147mm (144 x 144 DPI)

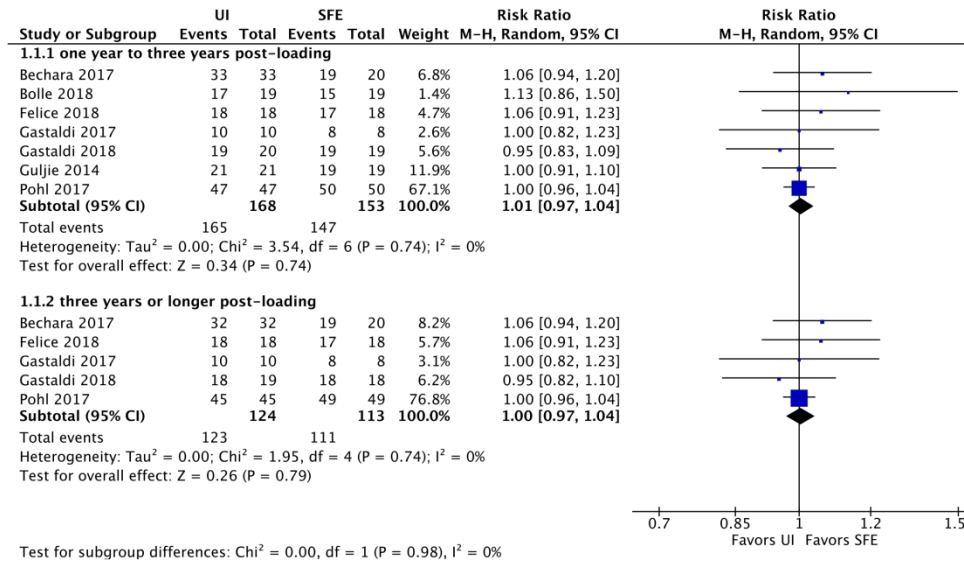


Figure 4. Forest plot for implant survival rate. Footnote: UI, ultrashort implant group; SFE, sinus floor elevation group.

201x118mm (300 x 300 DPI)

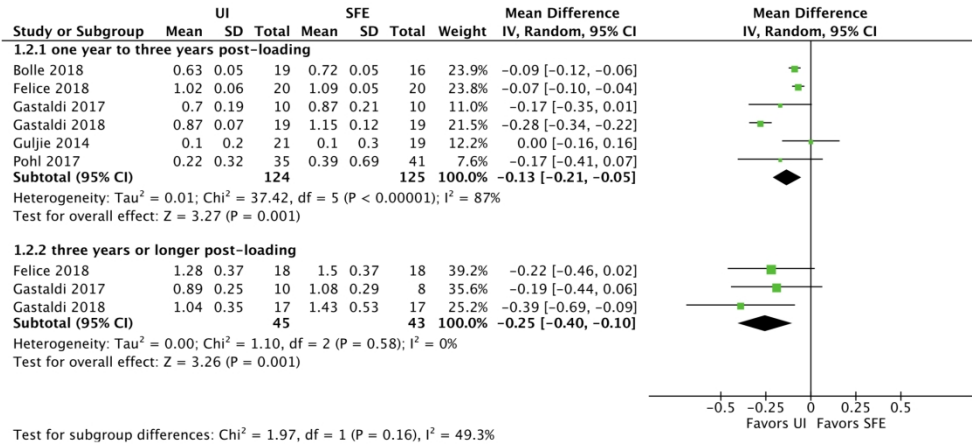


Figure 5. Forest plot for marginal bone loss. Footnote: UI, ultrashort implant group; SFE, sinus floor elevation group.

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]

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- 9 32. randomized controlled trial [Publication Type]
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- 11 33. randomized [Title/Abstract]
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- 13 34. randomly [Title/Abstract]
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- 15 35. 32 OR 33 OR 34
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- 17 36. 16 AND 31 AND 35
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19 **B. The search strategy used for Embase (as of 31/5/2018):**

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- 23 1. 'alveolar bone loss'/exp/mj
- 24 2. 'alveolar ridge augmentation'/exp/mj
- 25 3. 'bone prosthesis'/exp/mj
- 26 4. 1 OR 2 OR 3
- 27 5. 'atrophic jaw': ab, ti
- 28 6. 'atrophic maxilla': ab, ti
- 29 7. 'atrophic mandible': ab, ti
- 30 8. 'posterior maxilla': ab, ti
- 31 9. 'posterior mandible': ab, ti
- 32 10. 'augmented bone': ab, ti
- 33 11. 'bone augmentation': ab, ti
- 34 12. 'sinus lift': ab, ti
- 35 13. 'sinus floor elevation': ab, ti
- 36 14. 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13
- 37 15. 4 OR 14
- 38 16. 'tooth implantation'/exp/mj
- 39 17. 'tooth implant'/exp/mj
- 40 18. 'tooth prosthesis'/exp/mj
- 41 19. 16 OR 17 OR 18
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- 11 27. '6mm': ab, ti
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- 13 28. '5mm': ab, ti
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- 15 29. '4mm': ab, ti
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# PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
<b>TITLE</b>			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
<b>ABSTRACT</b>			
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
<b>INTRODUCTION</b>			
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
<b>METHODS</b>			
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

Page 1 of 2

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
<b>RESULTS</b>			
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
<b>DISCUSSION</b>			
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
<b>FUNDING</b>			
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

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# BMJ Open

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

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

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## Abstract

**Objectives:** To compare the use of short implants ( $\leq 6$  mm) in atrophic posterior maxilla versus longer implants ( $\geq 10$  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 ( $\leq 6$  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 ( $\leq 6$  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 ( $\leq 6$  mm) in terms of cost.

**Conclusions:** For atrophic posterior maxilla, short implants ( $\leq 6$  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 ( $\leq 6$  mm).

**Clinical Significance:** Short implants ( $\leq 6$  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.<sup>1-3</sup> 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.<sup>4,5</sup> These conditions are exacerbated if patients have a history of wearing removable dentures.<sup>6</sup>

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.<sup>7,8</sup> The lateral window approach is commonly used in dental implantation procedures.<sup>9</sup> 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.<sup>10-12</sup> 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.<sup>13-15</sup> 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.<sup>16-19</sup>

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<sup>20</sup>,  $\leq 8$  mm<sup>21</sup>,  $\leq 7$  mm<sup>22</sup>, and 6-8 mm<sup>23</sup> are reported to have survival rates comparable to those of longer implants. In addition, short implants  $\leq 6$  mm in length have been introduced as another alternative in atrophic posterior maxilla.<sup>6,24,25</sup> Short implants require a less complicated surgical approach and could be used in cases when sinus floor elevation surgery is not applicable,<sup>26,27</sup>

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3 especially in cases of maxillary sinusitis, maxillary cyst, large vessels and other cases  
4 involving abnormal sinus anatomy. Studies have explored the short- and long-term  
5 survival rates of short implants ( $\leq 6$  mm).<sup>27-31</sup> Unfortunately, the evidence supporting  
6 the use of short implants ( $\leq 6$  mm) in the posterior maxilla is weak, and no guideline  
7 statement is currently recommended.  
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15 The present systematic review aims to compare the effectiveness of short implants  
16 ( $\leq 6$  mm) and longer implants ( $\geq 10$  mm) with sinus floor elevation in atrophic posterior  
17 maxilla. Our null hypothesis was that the survival rate, patient satisfaction, MBL and  
18 surgery-related complications of short implants ( $\leq 6$  mm) were comparable to longer  
19 implants in combination with sinus floor elevation.  
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## 30 **2. Materials and methods**

### 31 *2.1 Protocol and registration*

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34 This systematic review and meta-analysis was conducted in accordance with the  
35 PRISMA guidelines.<sup>32</sup> The protocol has been registered at PROSPERO  
36 (CRD42018103531).  
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### 43 *2.2 Eligible criteria*

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46 Randomized controlled trials (RCTs) meeting the following pre-determined inclusion  
47 criteria (PICOS format) were included:  
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- 50 • Population: Partially edentulous patients in the premolar and molar regions of  
51 the maxilla, for whom the residual bone height in the atrophic posterior maxilla  
52 was sufficient for the insertion of a short implant ( $\leq 6$  mm) but insufficient for  
53 the insertion of longer implants;  
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- 59 • Intervention: One or more short implants ( $\leq 6$  mm) were placed in the posterior  
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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.



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3 Two review authors (QY and XW) extracted the data independently and in duplicate  
4 using specifically designed data extraction forms. The extracted data included citation  
5 details (year of publication, country of origin, setting and source of funding), details on  
6 the participants (demographic characteristics, residual bone height and inclusion  
7 criteria), details of intervention (implant length, diameter, brand, surface structure,  
8 surgical method, follow-up time, prosthesis type), outcome assessment, sample size  
9 calculation and trial registration. Corresponding authors were contacted for missing  
10 data or information.  
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### 23 24 *2.5 Risk of bias of included studies*

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26 Two authors (QY and XW) assessed the risk of bias of each included study  
27 independently and in duplicate using the Cochrane risk of bias assessment tool for  
28 RCTs.<sup>33</sup> Disagreements were resolved through discussion. A third review author (F.H.)  
29 was consulted when necessary. Seven domains were assessed, including sequence  
30 generation (selection bias), allocation concealment (selection bias), blinding of  
31 participants and personnel (performance bias), blinding of outcome assessment  
32 (detection bias), incomplete outcome data (attrition bias), selective outcome reporting  
33 (reporting bias) and other bias (factors that had potential influence on outcomes but  
34 were not evenly distributed across groups or not clearly reported, such as the  
35 manufacturer or diameter of implants). Individual studies were categorized as having  
36 low, high or unclear risk of bias. The risk of bias across studies was determined  
37 according to the risk of bias in each included study.  
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### 56 *2.6 Assessment of heterogeneity*

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58 Clinical heterogeneity among the included studies was assessed by comparing study  
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3 design, participant conditions (gender, age, residual bone height), intervention (implant  
4 length, diameter, surface structure, surgical method), and outcome measures. Statistical  
5 heterogeneity was evaluated using Cochrane's Q test and the  $I^2$  statistic. In the Q test,  
6 a P value < 0.1 was considered an indication of significant heterogeneity.  
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### 10 11 12 13 14 15 *2.7 Assessment of publication bias*

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17 If at least ten studies were included in a meta-analysis, We would have used a funnel  
18 plot and the Egger's test<sup>34</sup> asymmetry to assess the potential existence of publication  
19 bias if at least ten studies were included in a meta-analysis.  
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### 24 25 26 *2.8 Synthesis of results*

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28 The unit of analysis was set as participant rather than implant.<sup>35</sup> RevMan 5.3 software  
29 was used for data synthesis. Meta-analyses were undertaken only when at least two  
30 studies that made similar comparisons reported the same outcomes. The effect measures  
31 were risk ratio (RR) for dichotomous outcomes (implant survival and complications)  
32 and mean difference (MD) for continuous outcomes (MBL). RR was calculated through  
33 Mantel-Haenszel analysis and MD was calculated through inverse variance.  $P < 0.05$   
34 was considered statistically significant. The fixed effect model was used when fewer  
35 than four studies were included in a meta-analysis, and the random-effects model was  
36 used when four or more studies were included<sup>36-39</sup>.  
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### 50 51 *2.9 Additional analysis*

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53 Subgroup analysis by length of follow-up and categories of complications was  
54 performed to control for the possibility that function time might influence implant  
55 survival<sup>40</sup>. If risks of bias in some studies were serious, we performed sensitivity  
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3 analysis by excluding these studies. Considering only three studies were included in the  
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5 MBL three years or longer follow-up but the meta-analysis for MBL included more  
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7 than three studies, a sensitivity analysis was conducted for MBL by using fixed-effect  
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9 model.  
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### 14 *2.10 Summary of findings (SoF)*

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16 Grading of Recommendations Assessment, Development, and Evaluation (GRADE)  
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18 approach<sup>41</sup> was adopted to evaluate quality of evidence in this systematic review. A  
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20 SoF table was made with an online tool ([cebgrade.mcmaster.ca/gradepr.html](http://cebgrade.mcmaster.ca/gradepr.html)).  
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23 Outcomes were evaluated including survival rate and MBL of one to three-year and  
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25 three-year or longer follow-up, and complications. Five domains in quality of evidence  
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27 were assessed: the overall risk of bias, directness of evidence, consistency of results,  
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29 precision of estimates, as well as the risk of publication bias. The quality of the body  
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31 of evidence was classified into four categories: high, moderate, low and very low.  
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### 38 *2.11 Patient and Public involvement*

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40 No patient or public was involved in this systematic review.  
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## 44 **3. Results**

### 45 *3.1 Study selection*

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47 Electronic searches identified a total of 879 titles and abstracts in PubMed and 251 in  
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49 Embase. After removal of duplicates, the titles and abstracts of 1,013 unique items were  
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51 screened. We then retrieved the full texts of 25 potentially eligible articles, of which 20  
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53 were excluded for the reasons described in figure 1. Retrospective and prospective hand  
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55 searches yielded two more articles. Finally, seven studies<sup>30 42-47</sup> met our eligibility  
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3 criteria and were included in this review ([figure 1](#)).  
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### 7 8 *3.2 Study characteristics* 9

10 The characteristics of the seven included studies are listed in [table 1](#). One study was a  
11 split-mouth trial, and the rest were two-arm parallel RCTs. The length of follow-up  
12 ranged from one year to three years. For sinus floor elevation, either osteotomy-  
13 mediated sinus floor elevation or the lateral window technique was adopted. In two  
14 studies, single crowns were used as the rehabilitation method; in the remaining studies,  
15 single crowns or splinted prosthetics were used. The outcome measures used in these  
16 studies included implant failure, MBL, complications and patient satisfaction. Overall,  
17 171 participants were included in the short implant groups, and 159 participants were  
18 included in the elevation groups.  
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### 33 *3.3 Risk of bias assessment* 34

35 The results of the risks of bias assessment are shown in [figures 2](#) and [3](#). Selection bias  
36 and performance bias were assessed as low in all but one study by Bachara et al<sup>47</sup> due  
37 to inadequate description on random sequence generation and blinding of participants.  
38 For detection bias, most studies showed high risks because assessors could recognize  
39 sites that underwent sinus floor elevation. For attrition bias, three studies<sup>43 45 46</sup> was  
40 assessed as high. Two studies<sup>45 47</sup> showed high risk of reporting bias. Other risks of bias  
41 were considered high or unclear in three studies. Overall, all included studies were at  
42 high risk of bias for at least one domain ([table 2](#)).  
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### 56 *3.4 Synthesis of results* 57 58 59 60

### 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 ( $\leq 6$  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, 321 participants) 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, 157 participants) (**figure 6**) and sinus perforation or infection (RR=0.14, 95% CI: 0.03,

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3 0.77,  $p=0.02$ ,  $I^2 = 0\%$ , three RCTs, 120 participants) (figure 7). Only one study<sup>30</sup>  
4 reported implant migrating into sinus in 10% patients (1/10) in short implant group  
5 while in 20% patients (1/10) in sinus floor elevation group. No statistically significant  
6 difference was found in other complications between short implants ( $\leq 6$  mm) and  
7 longer implants (figures 7, 8).  
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#### 15 16 17 18 3.4.4 Patient satisfaction

19 Three studies<sup>43 44 47</sup> reported patient satisfaction. Meta-analysis was not conducted  
20 because methods of evaluating patient satisfaction were different. Gulje et al.<sup>44</sup> used a  
21 questionnaire to evaluate patient satisfaction before surgery and one year post-loading.  
22 Both groups showed improvement of satisfaction after crown placement. Gastaldi et  
23 al.<sup>43</sup> evaluated patient satisfaction in function and aesthetic aspects. All patients in the  
24 short implant group (10) were satisfied with both function and aesthetic aspects.  
25 However, three patients in elevation group (3/10) were partially satisfied with function.  
26 Bechara et al.<sup>47</sup> used a questionnaire evaluating patient satisfaction in function,  
27 aesthetic, cleaning of the implant-supported restorations, satisfaction, and cost.  
28 Significantly more patients in short implant group expressed satisfaction in cost.  
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#### 46 3.5 Quality of evidence

47 For survival rate, the quality of evidence in both subgroups were downgraded by one  
48 level (moderate quality evidence) due to serious risks of bias. For short-term MBL (one  
49 to three-year follow-up), quality of evidence was downgraded by two levels for serious  
50 risks of bias and inconsistency. For long-term MBL (three-year or longer follow-up),  
51 quality of evidence was downgraded by one level for serious risks of bias. For  
52 complications, the quality of evidence in post-surgery reaction was moderate,  
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3 downgrading by one level for serious risks of bias. The quality of evidence in other  
4 complications was low, downgrading by two levels for serious risks of bias and  
5 imprecision. Details are listed in [table 4](#).  
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#### 12 **4. Discussion**

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14 To the best of our knowledge, this is the first systematic review and meta-analysis to  
15 compare the clinical outcome of the use of short implants ( $\leq 6$  mm) in atrophic posterior  
16 maxilla versus longer implants with sinus floor elevation. At one year or longer post-  
17 loading, there is no significant difference in participant unit implant survival rate  
18 between the short implant group and the elevation group. The short implant group  
19 showed less MBL than the elevation group for one to three-year follow-up (low quality  
20 evidence) and three-year or longer follow-up (moderate quality evidence). In addition,  
21 the short implant group showed fewer post-surgery reaction and sinus membrane  
22 perforation and infection.  
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35 The survival rate in this review was evaluated by participant unit as in a previous  
36 Cochrane review.<sup>35</sup> In this review, the overall survival rates for the short implant group  
37 and the elevation group were 98.21% and 96.08%, respectively, at one-year to three-  
38 year follow-up and 99.20% and 98.23%, respectively, at longer than three-year follow-  
39 up; no significant difference in survival rate was found. Other studies that assessed  
40 survival rate in implant unit had similar outcomes. A retrospective study<sup>48</sup> with a  
41 follow-up period of 17 to 48 months reported a 95.12% implant unit survival rate for  
42 5-mm to 6-mm short implants. A two-year to three-year prospective study<sup>6</sup> reported  
43 that 6-mm short implants with micro rough surfaces achieved a 100% survival rate in  
44 posterior maxilla. Another five- to ten-year retrospective study<sup>49</sup> reported a 97%  
45 implant unit survival rate for 6-mm short implants supporting single crowns. All these  
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3 results showed that short implants ( $\leq 6$  mm) represent a promising rehabilitation method  
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5 with respect to their short-term and long-term survival rates.  
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8 In this review, all of the failed short implants were 4 mm or 5 mm. Although the  
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10 use of short implants ( $\leq 6$  mm) could avoid complicated surgical procedures and related  
11  
12 early failures, reduced implant length was still the major risk factor in survival rate. The  
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14 authors of the included studies used wider implants (4 mm to 8 mm) to compensate for  
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16 the short length of the implants. Finite element analyses showed that wider implants  
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18 had increased functional surface area in cortical bone and decreased stress distribution  
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20 on the implant neck; these qualities helped improve primary stability, produce a higher  
21  
22 survival rate and reduce MBL.<sup>50-53</sup> However, it was not determined whether implant  
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24 length or diameter contributed more to implant failure. Another factor was implant  
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26 surface structure. Studies<sup>54-57</sup> have suggested that the implant surface influences bone-  
27  
28 to-implant osseointegration, implant primary stability and MBL. In this review,  
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30 implants 4 mm or 5 mm in length had novel surface structures, but they still presented  
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32 a lower survival rate.  
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37 Significantly less MBL was found in the short implant group, and the difference was  
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39 greater at the longer follow-up period. Additionally, in this review, 5-mm-diameter  
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41 implants tended to induce less MBL than 4-mm-diameter implants. Implants  $\leq 10$  mm  
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43 <sup>20</sup> and  $\leq 8$  mm<sup>21</sup> were reported to induce MBL similar to that of longer implants, while  
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45 implants  $\leq 7$  mm<sup>58</sup> showed less MBL. These results contradict a previous theory that  
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47 short implants are more likely to have an extreme crown-to-implant ratio (C/I)<sup>59</sup> that  
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49 induces more peri-implant bone loss and early implant failure.<sup>60 61</sup> According to finite  
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51 element analyses, inappropriate C/I results in adverse occlusal forces such as non-axial  
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53 forces and overloading.<sup>62</sup> Increased C/I was also correlated with more prosthesis  
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55 complications such as screw loosening, implant or abutment fracture, chipping of the  
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3 ceramic material, and prosthesis fracture.<sup>63-66</sup> However, the implants in the studies  
4 included in this systematic review had wider diameters (4 mm to 8 mm) and different  
5 surface structures. These two factors partially compensated for the complications of C/I  
6 and contributed to less MBL. Differences in implant diameter and surface structure also  
7 introduced heterogeneity among studies with respect to MBL. Short implants tolerated  
8 less MBL because of the limited implant length. As a result, less MBL was not  
9 necessarily correlated with better clinical outcome. MBL around short implants is still  
10 a challenging issue, and much effort should be made to resolve it.

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

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3 No data synthesis for patient satisfaction was conducted for methodological  
4 difference among studies. In included studies, patients reported equal function and  
5 aesthetic satisfaction in both short implant and elevation group. However, patients were  
6 more satisfied with the cost of short implants ( $\leq 6$  mm), which was in accordance with  
7 previous studies<sup>13-15 70 71</sup>. Thus, in aspect of patient satisfaction, short implants ( $\leq 6$  mm)  
8 could serve as an alternative for longer implants with sinus floor elevation.  
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11 The present study has several strengths. Firstly, we conducted a comprehensive  
12 literature search, and all included studies were RCTs. Secondly, participant was used  
13 as the unit of analysis to ensure logical statistical syntheses and relevant interpretations.  
14 Thirdly, subgroup analysis by follow-up length and categories of complications was  
15 performed to reduce bias across studies. However, the evidence included in this  
16 systematic review was only of moderate or low quality. Serious risks of bias were found  
17 within and across studies. The number of participants and the follow-up period were  
18 limited. Due to limited data and methodological heterogeneity among studies, data  
19 synthesis for patient satisfaction was not performed. We suggest that researchers in this  
20 field carry out more well designed, long-term and large-scale RCTs to provide high  
21 quality evidence regarding the effects of short implants ( $\leq 6$  mm).  
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## 45 **5. Conclusions**

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47 Within its limitations, the present review suggests that the survival rate and patient  
48 satisfaction of maxillary short implants ( $\leq 6$  mm) was comparable to that of longer  
49 implants ( $\geq 10$  mm) with sinus floor elevation. However, short implants ( $\leq 6$  mm) show  
50 significantly less MBL and post-surgery reactions. Short implants ( $\leq 6$  mm) are  
51 therefore a promising alternative to sinus floor elevation for posterior maxilla with  
52 insufficient bone volume. Additional high-quality studies are needed to evaluate the  
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3 long-term effectiveness and safety of short implants ( $\leq 6$  mm).  
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10 **Author contributions** Conception and design of the review: FH and BS. Methodology:  
11  
12 FH. Drafting protocol, performing search strategies, literature searches, literature  
13 screening and data extraction: QY and XW. Original draft preparation: XW. Reviewing  
14 and editing draft: MS, QY, FH and BS. All authors critically reviewed and revised the  
15 manuscript and approved the final version for publication.  
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41 **Patient consent** Not required.  
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71 **Data sharing statement** No additional data are available.  
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**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

1 2 3 4 5 6 7 8 9 10 11 12	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
13 14 15 16 17 18 19 20	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
21 22 23 24 25 26 27 28	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
29 30 31 32 33 34 35 36	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 <sup>1</sup> (elevation group)	Corresponding risk (short implant group)				
survival rate follow up: range 1 years to 3 years	961 per 1,000	<b>970 per 1,000</b> (932 to 999)	<b>RR 1.01</b> (0.97 to 1.04)	321 (7 RCTs)	⊕⊕⊕○ MODERATE <sup>2</sup>	
survival rate follow up: range 3 years to longer years	982 per 1,000	<b>982 per 1,000</b> (953 to 1,000)	<b>RR 1.00</b> (0.97 to 1.04)	237 (5 RCTs)	⊕⊕⊕○ MODERATE <sup>2</sup>	
marginal bone loss follow up: range 1 years to 3 years	The mean marginal bone loss ranged from <b>0.1 to 1.15</b> 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 <sup>3</sup>	
marginal bone loss follow up: range 3 years to longer years	The mean marginal bone loss ranged from <b>1.08 to 1.5</b> 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 <sup>2</sup>	
post-surgery reaction	338 per 1,000	<b>37 per 1,000</b> (10 to 118)	<b>RR 0.11</b> (0.03 to 0.35)	157 (3 RCTs)	⊕⊕⊕○ MODERATE <sup>2</sup>	
biological complications: sinus perforation or infection	167 per 1,000	<b>23 per 1,000</b> (5 to 128)	<b>RR 0.14</b> (0.03 to 0.77)	120 (3 RCTs)	⊕⊕○○ LOW <sup>4</sup>	
biological complications: implant mobile	67 per 1,000	<b>23 per 1,000</b> (4 to 129)	<b>RR 0.34</b> (0.06 to 1.94)	117 (2 RCTs)	⊕⊕○○ LOW <sup>4</sup>	
biological complications: implant migrating into sinus	200 per 1,000	<b>100 per 1,000</b> (10 to 934)	<b>RR 0.50</b> (0.05 to 4.67)	20 (1 RCT)	⊕⊕○○ LOW <sup>4</sup>	
biological complications: peri-implant mucositis or peri-implantitis	29 per 1,000	<b>32 per 1,000</b> (3 to 326)	<b>RR 1.09</b> (0.11 to 11.10)	65 (2 RCTs)	⊕⊕○○ LOW <sup>4</sup>	
technical complications: screw loosening	92 per 1,000	<b>186 per 1,000</b> (79 to 439)	<b>RR 2.02</b> (0.86 to 4.77)	148 (3 RCTs)	⊕⊕○○ LOW <sup>4</sup>	
technical complications: crown loosening, decrementation and chipping	27 per 1,000	<b>35 per 1,000</b> (10 to 128)	<b>RR 1.27</b> (0.35 to 4.69)	216 (5 RCTs)	⊕⊕○○ LOW <sup>4</sup>	

\*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.

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3 **Figure Legends**  
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8 **Figure 1** Flow diagram for study selection  
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12 **Figure 2** Risk of bias in each included study  
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17 **Figure 3** Risk of bias across included studies  
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21 **Figure 4** Forest plot for implant survival rate  
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23 *footnote: SI, short implant group; SFE, sinus floor elevation group.*  
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28 **Figure 5** Forest plot for marginal bone loss  
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30 *footnote: SI, short implant group; SFE, sinus floor elevation group.*  
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35 **Figure 6** Forest plot for post-surgery reaction  
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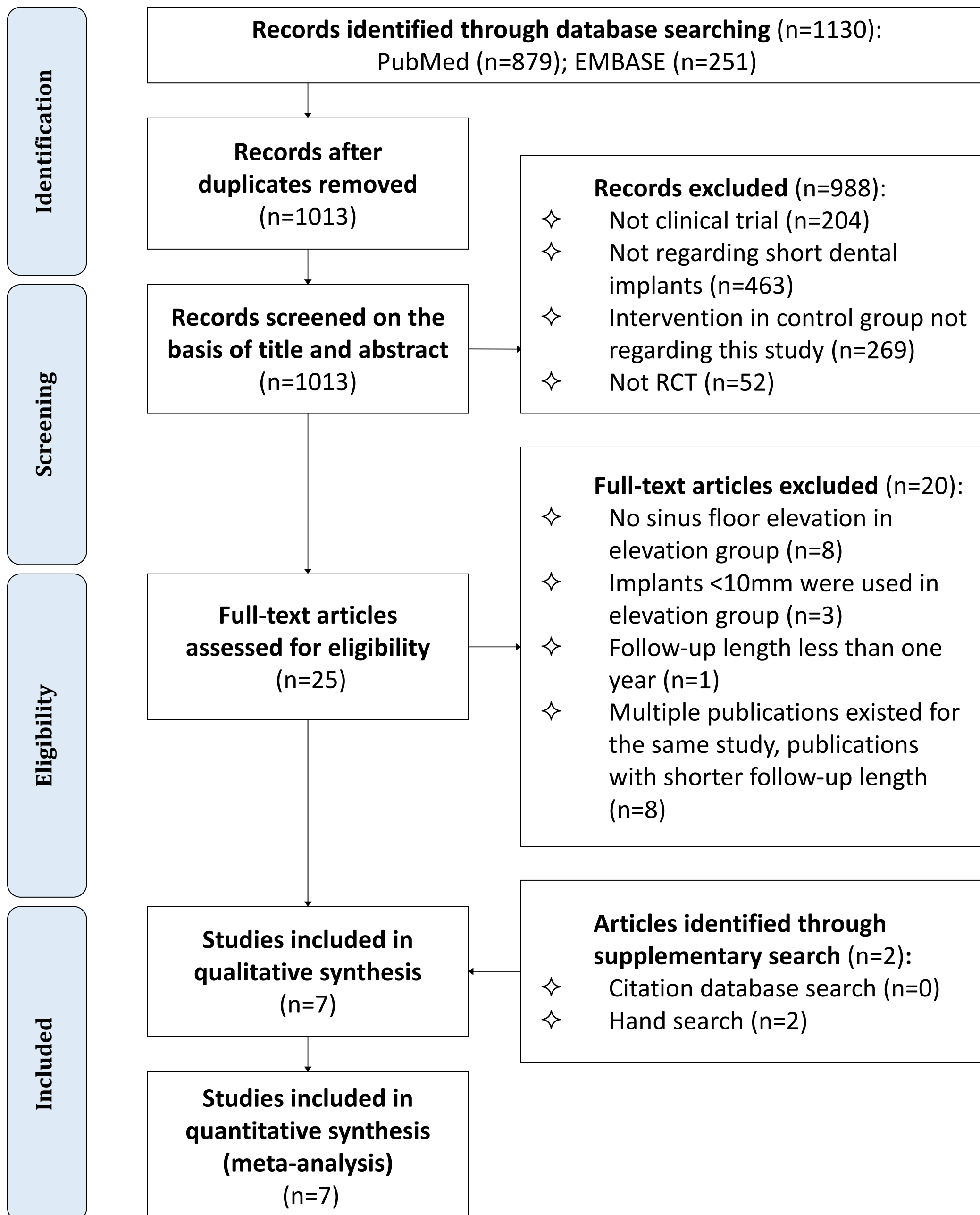
37 *footnote: SI, short implant group; SFE, sinus floor elevation group.*  
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42 **Figure 7** Forest plot for biological complications  
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44 *footnote: SI, short implant group; SFE, sinus floor elevation group.*  
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49 **Figure 8** Forest plot for technical complications  
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51 *footnote: SI, short implant group; SFE, sinus floor elevation group.*  
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Study	Random 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 reporting (reporting bias)	Other bias
Bechara 2017	?	+	?	?	+	+	+
Bolle 2018	+	+	+	+	+	+	+
Felice 2018	+	+	+	+	+	+	+
Gastraldi 2017	+	+	+	+	+	+	+
Gastraldi 2018	+	+	+	+	+	+	?
Guljic 2014	+	+	+	+	+	+	+
Pohl 2017	+	+	+	?	+	+	+

Figure 2 Risk of bias in each included study

269x146mm (300 x 300 DPI)

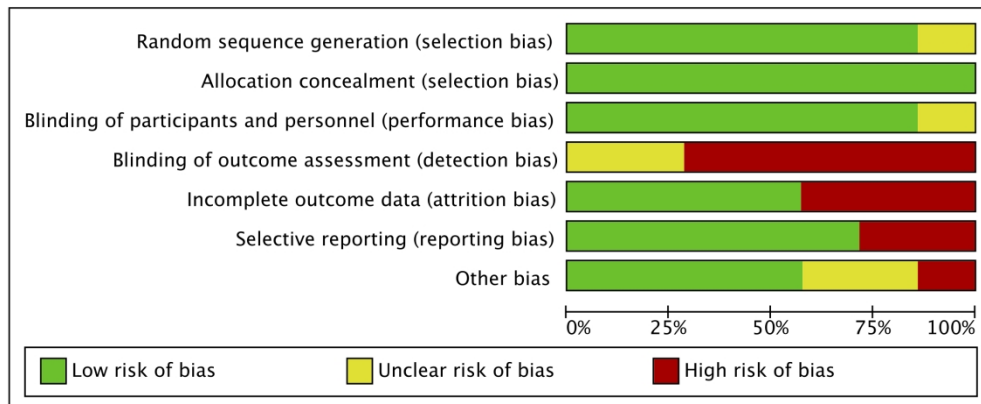


Figure 3 Risk of bias across included studies

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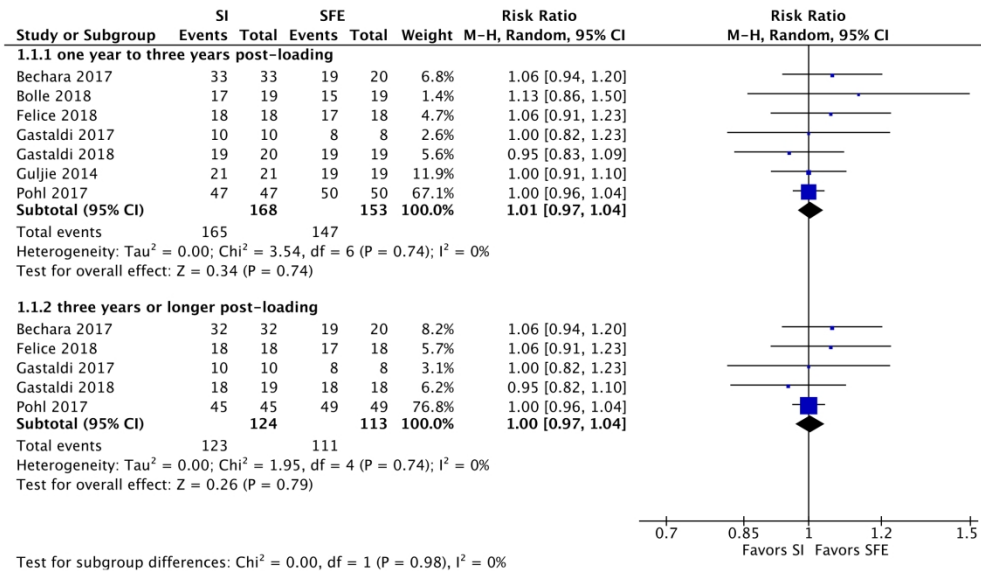


Figure 4 Forest plot for implant survival rate. footnote: SI, short implant group; SFE, sinus floor elevation group.

198x114mm (300 x 300 DPI)

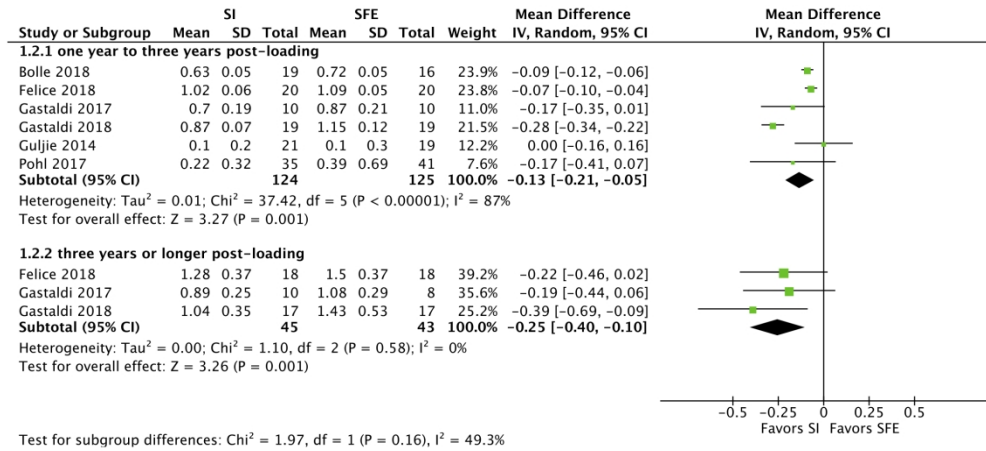


Figure 5 Forest plot for marginal bone loss. footnote: SI, short implant group; SFE, sinus floor elevation group.

197x90mm (300 x 300 DPI)

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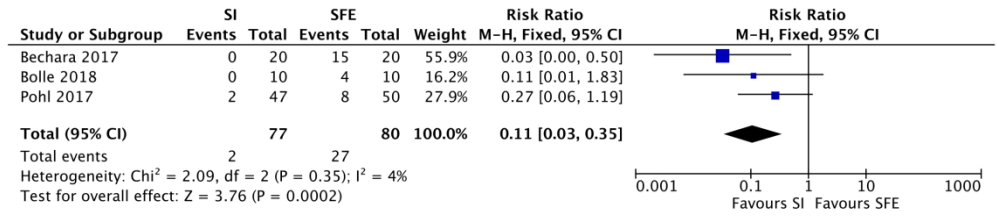


Figure 6 Forest plot for post-surgery reaction. footnote: SI, short implant group; SFE, sinus floor elevation group.

198x42mm (300 x 300 DPI)

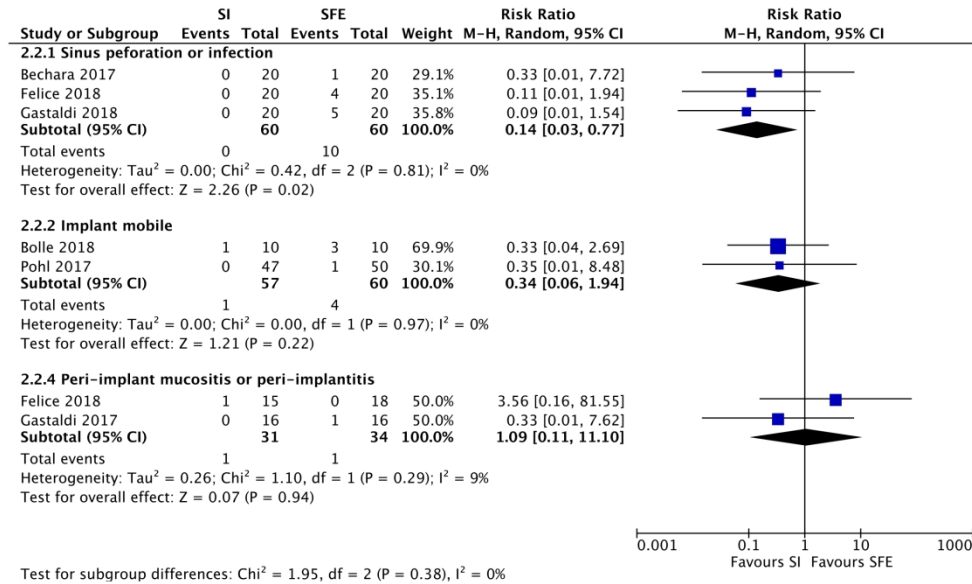


Figure 7 Forest plot for biological complications. footnote: SI, short implant group; SFE, sinus floor elevation group.

200x117mm (300 x 300 DPI)

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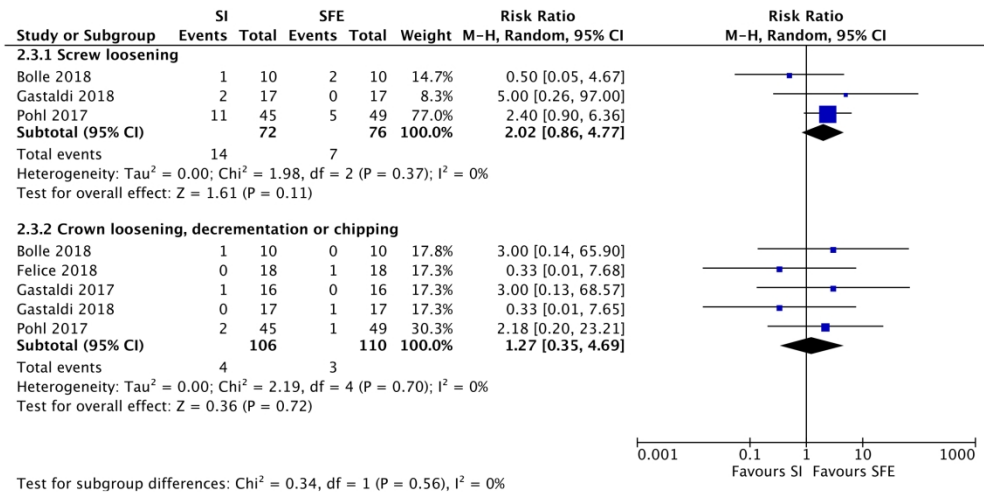


Figure 8 Forest plot for technical complications. footnote: SI, short implant group; SFE, sinus floor elevation group.

198x98mm (300 x 300 DPI)

## Short implants ( $\leq 6$ 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]

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- 5 28. sinus lift [Title/Abstract]
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- 7 29. sinus floor elevation [Title/Abstract]
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- 9 30. 23 OR 24 OR 25 OR 26 OR 27 OR 28 OR 29
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- 11 31. 22 OR 30
- 12 32. randomized controlled trial [Publication Type]
- 13
- 14 33. randomized [Title/Abstract]
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- 16 34. randomly [Title/Abstract]
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- 18 35. 32 OR 33 OR 34
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- 20 36. 16 AND 31 AND 35
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**The search strategy used for Embase (1980 to 31 May 2018):**

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- 26 1. 'alveolar bone loss'/exp/mj
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- 28 2. 'alveolar ridge augmentation'/exp/mj
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- 30 3. 'bone prosthesis'/exp/mj
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- 32 4. 1 OR 2 OR 3
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- 34 5. 'atrophic jaw': ab, ti
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- 36 6. 'atrophic maxilla': ab, ti
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- 38 7. 'atrophic mandible': ab, ti
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- 40 8. 'posterior maxilla': ab, ti
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- 42 9. 'posterior mandible': ab, ti
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- 44 10. 'augmented bone': ab, ti
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- 46 11. 'bone augmentation': ab, ti
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- 48 12. 'sinus lift': ab, ti
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- 50 13. 'sinus floor elevation': ab, ti
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- 52 14. 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13
- 53
- 54 15. 4 OR 14
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- 56 16. 'tooth implantation'/exp/mj
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- 58 17. 'tooth implant'/exp/mj
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- 60 18. 'tooth prosthesis'/exp/mj
19. 16 OR 17 OR 18
20. 'short implant': ab, ti

*Supplementary File*

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

	#	Checklist item	Reported on page #
<b>TITLE</b>			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
<b>ABSTRACT</b>			
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
<b>INTRODUCTION</b>			
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
<b>METHODS</b>			
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
<b>RESULTS</b>			
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

1			
2	within studies		(see item 12).
3			
4	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.
5			
6			
7			
8	Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.
9			
10			
11	Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).
12			
13			
14	Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).
15			
16			
17	<b>DISCUSSION</b>		
18			
19	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).
20			
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22	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).
23			
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25	Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.
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28	<b>FUNDING</b>		
29			
30	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.
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 34 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.  
 35 doi:10.1371/journal.pmed1000097

36 For more information, visit: [www.prisma-statement.org](http://www.prisma-statement.org).

# BMJ Open

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

Journal:	<i>BMJ Open</i>
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 Wu, Xinyu; School & Hospital of Stomatology, Wuhan University, Department of Oral Implantology Su, Meiyang; School & Hospital of Stomatology, Wuhan University, Department of Oral Implantology Hua, Fang; School & Hospital of Stomatology, Wuhan University, Centre for Evidence-Based Stomatology; Division of Dentistry, The University of Manchester, Cochrane Oral Health Shi, Bin; School & Hospital of Stomatology, Wuhan University, Department of Oral Implantology
<b>Primary Subject Heading</b>:	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

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

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## Abstract

**Objectives:** To compare the use of short implants ( $\leq 6$  mm) in atrophic posterior maxilla versus longer implants ( $\geq 10$  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 ( $\leq 6$  mm) and longer implants ( $\geq 10$  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 ( $\leq 6$  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 ( $\leq 6$  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 ( $\leq 6$  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 ( $\leq 6$  mm).

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

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For peer review only

**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.<sup>1-3</sup> 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.<sup>4,5</sup> These conditions are exacerbated if patients have a history of wearing removable dentures.<sup>6</sup>

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.<sup>7,8</sup> The lateral window approach is commonly used in dental implantation procedures.<sup>9</sup> 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.<sup>10-12</sup> 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.<sup>13-15</sup> 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.<sup>16-19</sup>

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<sup>20</sup>,  $\leq 8$  mm<sup>21</sup>,  $\leq 7$  mm<sup>22</sup>, and 6-8 mm<sup>23</sup> are reported to have survival rates comparable to those of longer implants. In addition, short implants  $\leq 6$  mm in length have been introduced as another alternative in atrophic posterior maxilla.<sup>6,24,25</sup> Short implants require a less complicated surgical approach and could be used in cases when sinus floor elevation surgery is not applicable,<sup>26,27</sup>

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3 especially in cases of maxillary sinusitis, maxillary cyst, large vessels and other cases  
4 involving abnormal sinus anatomy. Studies have explored the short- and long-term  
5 survival rates of short implants ( $\leq 6$  mm).<sup>27-31</sup> Unfortunately, the evidence supporting  
6 the use of short implants ( $\leq 6$  mm) in the posterior maxilla is weak, and no guideline  
7 statement is currently recommended.  
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14 The present systematic review aims to compare the effectiveness of short implants  
15 ( $\leq 6$  mm) and longer implants ( $\geq 10$  mm) with sinus floor elevation in atrophic posterior  
16 maxilla. Our null hypothesis was that the survival rate, patient satisfaction, MBL and  
17 surgery-related complications of short implants ( $\leq 6$  mm) were comparable to longer  
18 implants in combination with sinus floor elevation.  
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## 30 **2. Materials and methods**

### 31 *2.1 Protocol and registration*

32 This systematic review and meta-analysis was conducted in accordance with the  
33 PRISMA guidelines.<sup>32</sup> The protocol has been registered at PROSPERO  
34 (CRD42018103531).  
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### 43 *2.2 Eligible criteria*

44 Randomized controlled trials (RCTs) meeting the following pre-determined inclusion  
45 criteria (PICOS format) were included:  
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- 50 • Population: Partially edentulous patients in the premolar and molar regions of  
51 the maxilla, for whom the residual bone height in the atrophic posterior maxilla  
52 was sufficient for the insertion of a short implant ( $\leq 6$  mm) but insufficient for  
53 the insertion of longer implants;  
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- 59 • Intervention: One or more short implants ( $\leq 6$  mm) were placed in the posterior  
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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.

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3 Two review authors (QY and XW) extracted the data independently and in duplicate  
4 using specifically designed data extraction forms. The extracted data included citation  
5 details (year of publication, country of origin, setting and source of funding), details on  
6 the participants (demographic characteristics, residual bone height and inclusion  
7 criteria), details of intervention (implant length, diameter, brand, surface structure,  
8 surgical method, follow-up time, prosthesis type), outcome assessment, sample size  
9 calculation and trial registration. Corresponding authors were contacted for missing  
10 data or information.  
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### 23 24 *2.5 Risk of bias of included studies*

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26 Two authors (QY and XW) assessed the risk of bias of each included study  
27 independently and in duplicate using the Cochrane risk of bias assessment tool for  
28 RCTs.<sup>33</sup> Disagreements were resolved through discussion. A third review author (F.H.)  
29 was consulted when necessary. Seven domains were assessed, including sequence  
30 generation (selection bias), allocation concealment (selection bias), blinding of  
31 participants and personnel (performance bias), blinding of outcome assessment  
32 (detection bias), incomplete outcome data (attrition bias), selective outcome reporting  
33 (reporting bias) and other bias (factors that had potential influence on outcomes but  
34 were not evenly distributed across groups or not clearly reported, such as the  
35 manufacturer or diameter of implants). Individual studies were categorized as having  
36 low, high or unclear risk of bias. The risk of bias across studies was determined  
37 according to the risk of bias in each included study.  
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### 56 *2.6 Assessment of heterogeneity*

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58 Clinical heterogeneity among the included studies was assessed by comparing study  
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3 design, participant conditions (gender, age, residual bone height), intervention (implant  
4 length, diameter, surface structure, surgical method), and outcome measures. Statistical  
5 heterogeneity was evaluated using Cochrane's Q test and the  $I^2$  statistic. In the Q test,  
6 a P value < 0.1 was considered an indication of significant heterogeneity.  
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### 10 11 12 13 14 15 *2.7 Assessment of publication bias*

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17 If at least ten studies were included in a meta-analysis, We would have used a funnel  
18 plot and the Egger's test<sup>34</sup> asymmetry to assess the potential existence of publication  
19 bias if at least ten studies were included in a meta-analysis.  
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### 24 25 26 *2.8 Synthesis of results*

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28 The unit of analysis was set as participant rather than implant.<sup>35</sup> RevMan 5.3 software  
29 was used for data synthesis. Meta-analyses were undertaken only when at least two  
30 studies that made similar comparisons reported the same outcomes. The effect measures  
31 were risk ratio (RR) for dichotomous outcomes (implant survival and complications)  
32 and mean difference (MD) for continuous outcomes (MBL). RR was calculated through  
33 Mantel-Haenszel analysis and MD was calculated through inverse variance.  $P < 0.05$   
34 was considered statistically significant. The fixed effect model was used when fewer  
35 than four studies were included in a meta-analysis, and the random-effects model was  
36 used when four or more studies were included<sup>36-39</sup>.  
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### 50 51 *2.9 Additional analysis*

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53 Subgroup analysis by length of follow-up was performed to control for the possibility  
54 that function time might influence implant survival<sup>40</sup>. In addition, subgroup analysis  
55 by categories of complications was performed. Complications were categorized  
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3 according to into post-surgery reaction (bleeding, swelling and discomfort), biological  
4 complications (sinus perforation or infection, implant mobile, peri-implant mucositis  
5 and peri-implantitis) and technical complications (complications related to screws and  
6 crowns). If risks of bias in some studies were serious, we performed sensitivity analysis  
7 by excluding these studies. Considering only three studies were included in the MBL  
8 three years or longer follow-up but the meta-analysis for MBL included more than three  
9 studies, a sensitivity analysis was conducted for MBL by using fixed-effect model.  
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### 22 *2.10 Summary of findings (SoF)*

23 Grading of Recommendations Assessment, Development, and Evaluation (GRADE)  
24 approach<sup>41</sup> was adopted to evaluate quality of evidence in this systematic review. A  
25 SoF table was made with an online tool ([cebgrade.mcmaster.ca/gradepr.html](http://cebgrade.mcmaster.ca/gradepr.html)).  
26 Outcomes were evaluated including survival rate and MBL of one to three-year and  
27 three-year or longer follow-up, and complications. Five domains in quality of evidence  
28 were assessed: the overall risk of bias, directness of evidence, consistency of results,  
29 precision of estimates, as well as the risk of publication bias. The quality of the body  
30 of evidence was classified into four categories: high, moderate, low and very low.  
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### 45 *2.11 Patient and Public involvement*

46 No patient or public was involved in this systematic review.  
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## 51 **3. Results**

### 52 *3.1 Study selection*

53 Electronic searches identified a total of 879 titles and abstracts in PubMed and 251 in  
54 Embase. After removal of duplicates, the titles and abstracts of 1,013 unique items were  
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3 screened. We then retrieved the full texts of 25 potentially eligible articles, of which 20  
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5 were excluded for the reasons described in figure 1. Retrospective and prospective hand  
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7 searches yielded two more articles. Finally, seven studies<sup>30 42-47</sup> met our eligibility  
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9 criteria and were included in this review (figure 1).  
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### 14 3.2 Study characteristics

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16 The characteristics of the seven included studies are listed in table 1. One study was a  
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18 split-mouth trial, and the rest were two-arm parallel RCTs. The length of follow-up  
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20 ranged from one year to three years. For sinus floor elevation, either osteotomy-  
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22 mediated sinus floor elevation or the lateral window technique was adopted. In two  
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24 studies, single crowns were used as the rehabilitation method; in the remaining studies,  
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26 single crowns or splinted prosthetics were used. The outcome measures used in these  
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28 studies included implant failure, MBL, complications and patient satisfaction. Overall,  
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30 171 participants were included in the short implant groups, and 159 participants were  
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32 included in the elevation groups.  
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### 40 3.3 Risk of bias assessment

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42 The results of the risks of bias assessment are shown in figures 2 and 3. Selection bias  
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44 and performance bias were assessed as low in all but one study by Bachara et al<sup>47</sup> due  
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46 to inadequate description on random sequence generation and blinding of participants.  
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48 For detection bias, most studies showed high risks because assessors could recognize  
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50 sites that underwent sinus floor elevation. For attrition bias, three studies<sup>43 45 46</sup> was  
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52 assessed as high. Two studies<sup>45 47</sup> showed high risk of reporting bias. Other risks of bias  
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54 were considered high or unclear in three studies. Overall, all included studies were at  
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56 high risk of bias for at least one domain (table 2).  
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### 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 ( $\leq 6$  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, 321 participants) 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



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3 and technical complications (table 4). Short implant group was found with significantly  
4 less post-surgery reaction (RR=0.11, 95% CI: 0.14, 0.31, p<0.001, I<sup>2</sup> = 40%, three  
5 RCTs, 184 participants) and sinus perforation or infection (RR=0.11, 95% CI: 0.02,  
6 0.63, p=0.01, I<sup>2</sup> = 0%). Only one study<sup>30</sup> reported implant migrating into sinus in 5%  
7 patients (1/19) in short implant group while in 10.5% patients (2/19) in sinus floor  
8 elevation group. No statistically significant difference was found in other complications  
9 between short implants (≤6 mm) and longer implants.  
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#### 23 3.4.4 Patient satisfaction

24 Three studies <sup>43 44 47</sup> reported patient satisfaction. Meta-analysis was not conducted  
25 because methods of evaluating patient satisfaction were different. Gulje et al. <sup>44</sup> used a  
26 questionnaire to evaluate patient satisfaction before surgery and one year post-loading.  
27 Both groups showed improvement of satisfaction after crown placement. Gastaldi et  
28 al.<sup>43</sup> evaluated patient satisfaction in function and aesthetic aspects. All patients in the  
29 short implant group (10) were satisfied with both function and aesthetic aspects.  
30 However, three patients in elevation group (3/10) were partially satisfied with function.  
31 Bechara et al.<sup>47</sup> used a questionnaire evaluating patient satisfaction in function,  
32 aesthetic, cleaning of the implant-supported restorations, satisfaction, and cost.  
33 Significantly more patients in short implant group expressed satisfaction in cost. In the  
34 other four aspects, no significant difference was found between short implant group  
35 and sinus floor elevation group.  
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#### 52 3.5 Quality of evidence

53 For survival rate, the quality of evidence in both subgroups were downgraded by one  
54 level (moderate quality evidence) due to serious risks of bias. For short-term MBL (one  
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3 to three-year follow-up), quality of evidence was downgraded by two levels for serious  
4 risks of bias and inconsistency. For long-term MBL (three-year or longer follow-up),  
5 quality of evidence was downgraded by one level for serious risks of bias. For  
6 complications, the quality of evidence in post-surgery reaction was moderate,  
7 downgrading by one level for serious risks of bias. The quality of evidence in other  
8 complications was low, downgrading by two levels for serious risks of bias and  
9 imprecision. Details are listed in [table 5](#).

#### 21 **4. Discussion**

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

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33 The survival rate in this review was evaluated by participant unit as in a previous  
34 Cochrane review.<sup>35</sup> In this review, the overall survival rates for the short implant group  
35 and the elevation group were 98.21% and 96.08%, respectively, at one-year to three-  
36 year follow-up and 99.20% and 98.23%, respectively, at longer than three-year follow-  
37 up; no significant difference in survival rate was found. Other studies that assessed  
38 survival rate in implant unit had similar outcomes. A retrospective study<sup>48</sup> with a  
39 follow-up period of 17 to 48 months reported a 95.12% implant unit survival rate for  
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3 5-mm to 6-mm short implants. A two-year to three-year prospective study<sup>6</sup> reported  
4 that 6-mm short implants with micro rough surfaces achieved a 100% survival rate in  
5 posterior maxilla. Another five- to ten-year retrospective study<sup>49</sup> reported a 97%  
6 implant unit survival rate for 6-mm short implants supporting single crowns. All these  
7 results showed that short implants ( $\leq 6$  mm) represent a promising rehabilitation method  
8 with respect to their short-term and long-term survival rates.  
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17 In this review, all of the failed short implants were 4 mm or 5 mm. Although the  
18 use of short implants ( $\leq 6$  mm) could avoid complicated surgical procedures and related  
19 early failures, reduced implant length was still the major risk factor in survival rate. The  
20 authors of the included studies used wider implants (4 mm to 8 mm) to compensate for  
21 the short length of the implants. Finite element analyses showed that wider implants  
22 had increased functional surface area in cortical bone and decreased stress distribution  
23 on the implant neck; these qualities helped improve primary stability, produce a higher  
24 survival rate and reduce MBL.<sup>50-53</sup> However, it was not determined whether implant  
25 length or diameter contributed more to implant failure. Another factor was implant  
26 surface structure. Studies<sup>54-57</sup> have suggested that the implant surface influences bone-  
27 to-implant osseointegration, implant primary stability and MBL. In this review,  
28 implants 4 mm or 5 mm in length had novel surface structures, but they still presented  
29 a lower survival rate.  
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47 Significantly less MBL was found in the short implant group, and the difference was  
48 greater at the longer follow-up period. Additionally, in this review, 5-mm-diameter  
49 implants tended to induce less MBL than 4-mm-diameter implants. Implants  $\leq 10$  mm  
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54 <sup>20</sup> and  $\leq 8$  mm<sup>21</sup> were reported to induce MBL similar to that of longer implants, while  
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60 implants  $\leq 7$  mm<sup>58</sup> 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)<sup>59</sup> that

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3 induces more peri-implant bone loss and early implant failure.<sup>60 61</sup> According to finite  
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5 element analyses, inappropriate C/I results in adverse occlusal forces such as non-axial  
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7 forces and overloading.<sup>62</sup> Increased C/I was also correlated with more prosthesis  
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9 complications such as screw loosening, implant or abutment fracture, chipping of the  
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11 ceramic material, and prosthesis fracture.<sup>63-66</sup> However, the implants in the studies  
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13 included in this systematic review had wider diameters (4 mm to 8 mm) and different  
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15 surface structures. These two factors partially compensated for the complications of C/I  
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17 and contributed to less MBL. Differences in implant diameter and surface structure also  
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19 introduced heterogeneity among studies with respect to MBL. Short implants tolerated  
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21 less MBL because of the limited implant length. As a result, less MBL was not  
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23 necessarily correlated with better clinical outcome. MBL around short implants is still  
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25 a challenging issue, and much effort should be made to resolve it.  
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31 With respect to complications, the use of short implants ( $\leq 6$  mm) could decrease the  
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33 incidence of post-surgery reactions and sinus membrane perforation and infection.  
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35 Sinus membrane perforation was common in the elevation group.<sup>14</sup> This was in  
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37 accordance with a previous study<sup>67</sup> that reported more complications in cases involving  
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39 longer implants with sinus floor elevation and that the surgical procedure made a major  
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41 contribution to such complications. In this study, incidence of other biological and  
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43 technical complications was similar between the two groups. Implant migration into the  
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45 sinus, often with the co-occurrence of sinus infection, had a higher prevalence in the  
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47 elevation group. When implant migration occurs, implants may be removed, thus  
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49 leading to implant failure.<sup>68</sup> Technical complications, including screw loosening, crown  
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51 loosening and chipping, were mainly associated with inappropriate loading, which  
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53 could be resolved by improving supra rehabilitation structure. In addition, for short  
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55 implants ( $\leq 6$  mm), risks relating to reduced length could be partially alleviated by  
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3 improving the design of the implants<sup>69</sup> or increasing their diameter. With respect to the  
4 prevalence and severity of adverse events, the use of short implants ( $\leq 6$  mm) was  
5 acceptable and was a promising alternative to sinus floor elevation.  
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10 The present study has several strengths. Firstly, we conducted a comprehensive  
11 literature search, and all included studies were RCTs. Secondly, participant was used  
12 as the unit of analysis to ensure logical statistical syntheses and relevant interpretations.  
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14 Thirdly, subgroup analysis by follow-up length and categories of complications was  
15 performed to reduce bias across studies. However, the evidence included in this  
16 systematic review was only of moderate or low quality. Serious risks of bias were found  
17 within and across studies. The number of participants and the follow-up period were  
18 limited. Due to limited data and methodological heterogeneity among studies, data  
19 synthesis for patient satisfaction was not performed. We suggest that researchers in this  
20 field carry out more well designed, long-term and large-scale RCTs to provide high  
21 quality evidence regarding the effects of short implants ( $\leq 6$  mm).  
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## 38 **5. Conclusions**

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40 Within its limitations, the present review suggests that the survival rate of maxillary  
41 short implants ( $\leq 6$  mm) was comparable to that of longer implants ( $\geq 10$  mm) with sinus  
42 floor elevation. However, short implants ( $\leq 6$  mm) show significantly less MBL and  
43 post-surgery reactions. Short implants ( $\leq 6$  mm) are therefore a promising alternative to  
44 sinus floor elevation for posterior maxilla with insufficient bone volume. Additional  
45 high-quality studies are needed to evaluate the long-term effectiveness and safety of  
46 short implants ( $\leq 6$  mm).  
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3 **Author contributions** Conception and design of the review: FH and BS. Methodology:  
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5 FH. Drafting protocol, performing search strategies, literature searches, literature  
6  
7 screening and data extraction: QY and XW. Original draft preparation: XW. Reviewing  
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9 and editing draft: MS, QY, FH and BS. All authors critically reviewed and revised the  
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11 manuscript and approved the final version for publication.  
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**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

1 2 3 4 5 6 7 8 9 10 11 12	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
13 14 15 16 17 18 19 20	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
21 22 23 24 25 26 27 28	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
29 30 31 32 33 34 35 36	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.

For peer review only



Table 5 Summary of findings

**Short implant ( $\leq 6$  mm) compared to longer implant ( $\geq 10$  mm) with sinus floor elevation in atrophic posterior maxilla**

**Patient or population:** atrophic posterior maxilla

**Intervention:** short implant ( $\leq 6$  mm)

**Comparison:** longer implant ( $\geq 10$  mm) 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 <sup>1</sup> (elevation group)	Corresponding risk (short implant group)				
survival rate follow up: range 1 years to 3 years	961 per 1,000	<b>970 per 1,000</b> (932 to 999)	<b>RR 1.01</b> (0.97 to 1.04)	321 (7 RCTs)	⊕⊕⊕○ MODERATE <sup>2</sup>	
survival rate follow up: range 3 years to longer years	982 per 1,000	<b>982 per 1,000</b> (953 to 1,000)	<b>RR 1.00</b> (0.97 to 1.04)	237 (5 RCTs)	⊕⊕⊕○ MODERATE <sup>2</sup>	
marginal bone loss follow up: range 1 years to 3 years	The mean marginal bone loss ranged from <b>0.1 to 1.15</b> 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 <sup>3</sup>	
marginal bone loss follow up: range 3 years to longer years	The mean marginal bone loss ranged from <b>1.08 to 1.5</b> 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 <sup>2</sup>	
post-surgery reaction	307 per 1,000	<b>34 per 1,000</b> (12 to 59)	<b>RR 0.11</b> (0.04 to 0.31)	184 (3 RCTs)	⊕⊕⊕○ MODERATE <sup>2</sup>	
biological complications: sinus perforation or infection	197 per 1,000	<b>20 per 1,000</b> (4 to 113)	<b>RR 0.11</b> (0.02 to 0.63)	125 (3 RCTs)	⊕⊕○○ LOW <sup>4</sup>	
biological complications: implant mobile	59 per 1,000	<b>20 per 1,000</b> (4 to 121)	<b>RR 0.34</b> (0.06 to 2.06)	132 (2 RCTs)	⊕⊕○○ LOW <sup>4</sup>	
biological complications: peri-implant mucositis or peri-implantitis	200 per 1,000	<b>100 per 1,000</b> (10 to 934)	<b>RR 0.91</b> (0.14 to 5.79)	54 (2 RCTs)	⊕⊕○○ LOW <sup>4</sup>	
technical complications: screw loosening	81 per 1,000	<b>217 per 1,000</b> (76 to 916)	<b>RR 2.66</b> (0.93 to 7.60)	169 (3 RCTs)	⊕⊕○○ LOW <sup>4</sup>	
technical complications: crown loosening, decementation and chipping	27 per 1,000	<b>33 per 1,000</b> (9 to 120)	<b>RR 1.22</b> (0.33 to 4.49)	223 (5 RCTs)	⊕⊕○○ LOW <sup>4</sup>	

\***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.

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3 **Figure Legends**  
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8 **Figure 1** Flow diagram for study selection  
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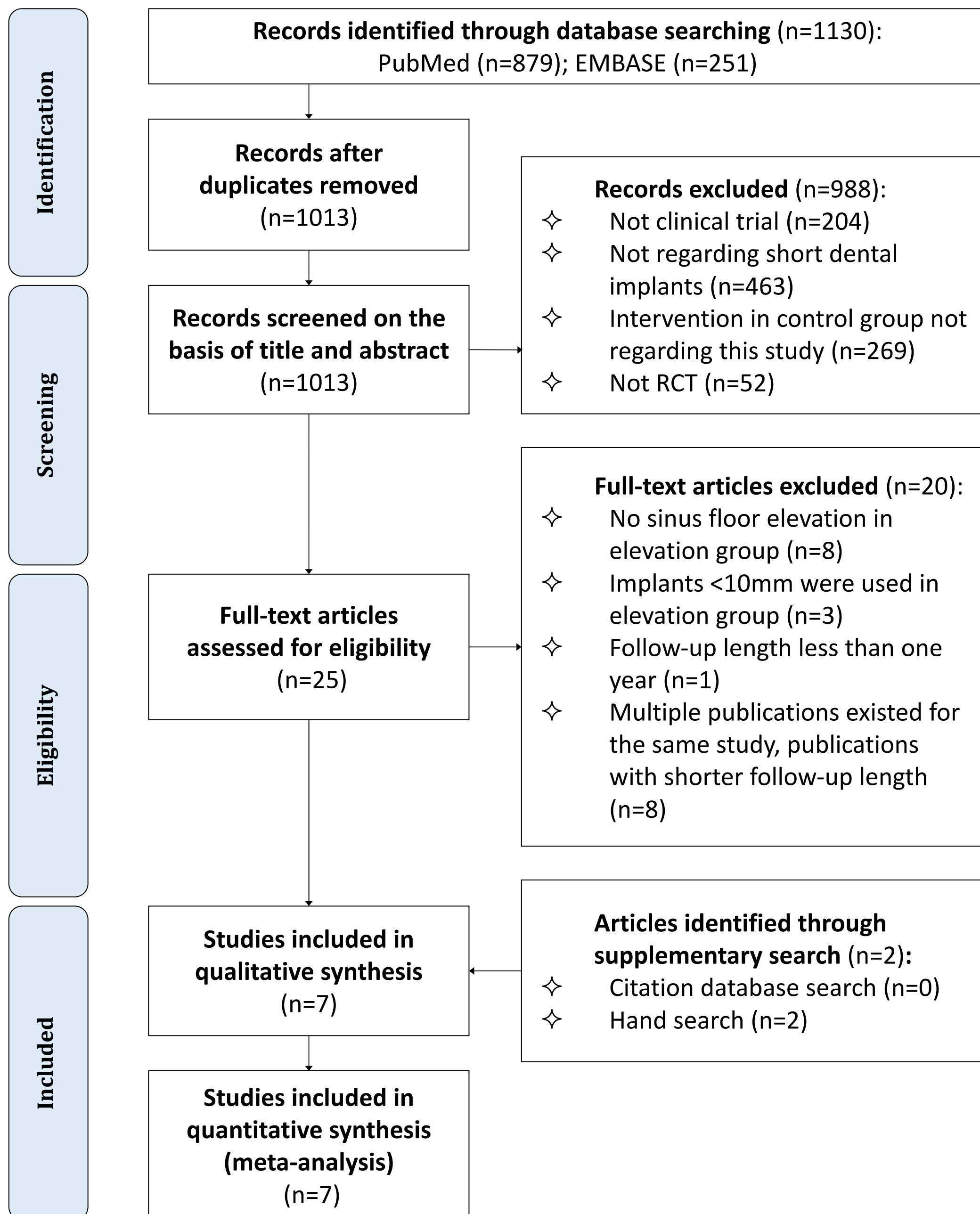
12 **Figure 2** Risk of bias in each included study  
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17 **Figure 3** Risk of bias across included studies  
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22 **Figure 4** Forest plot for implant survival rate  
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24 *footnote: SI, short implant group; SFE, sinus floor elevation group.*  
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28 **Figure 5** Forest plot for marginal bone loss  
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31 *footnote: SI, short implant group; SFE, sinus floor elevation group.*  
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Study	Random 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 reporting (reporting bias)	Other bias
Bechara 2017	?	+	?	?	+	+	+
Bolle 2018	+	+	+	+	+	+	+
Felice 2018	+	+	+	+	+	+	+
Gastraldi 2017	+	+	+	+	+	+	+
Gastraldi 2018	+	+	+	+	+	+	?
Guljic 2014	+	+	+	+	+	+	+
Pohl 2017	+	+	+	?	+	+	+

Figure 2 Risk of bias in each included study

269x146mm (300 x 300 DPI)

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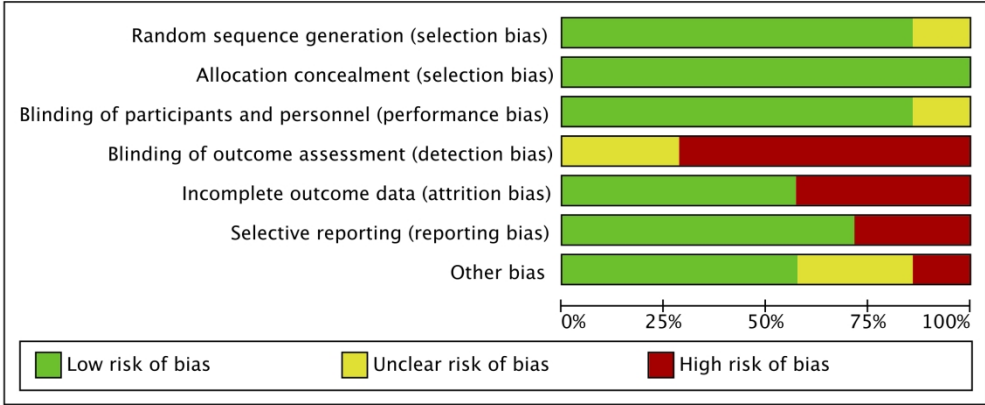


Figure 3 Risk of bias across included studies

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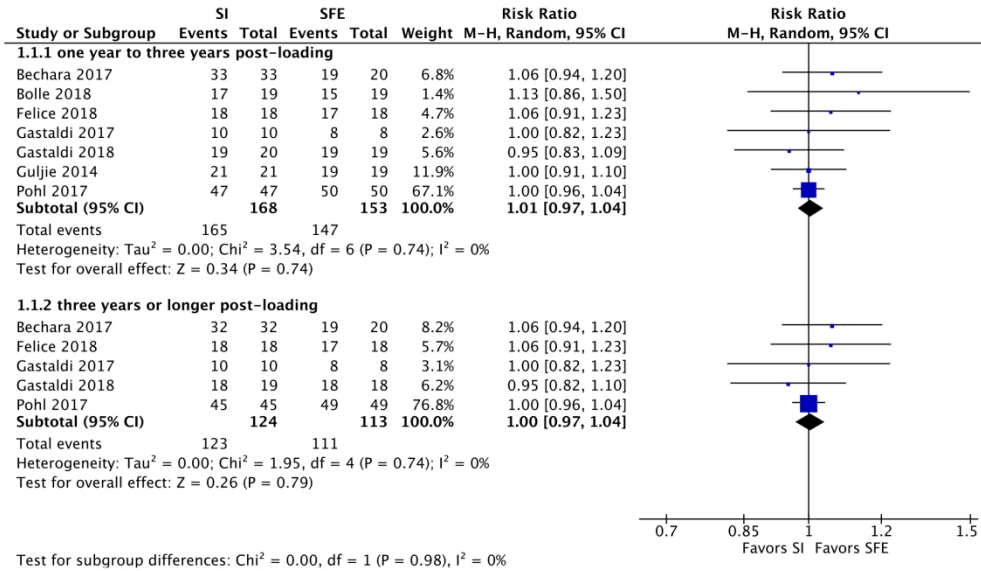


Figure 4 Forest plot for implant survival rate. footnote: SI, short implant group; SFE, sinus floor elevation group.

198x114mm (300 x 300 DPI)

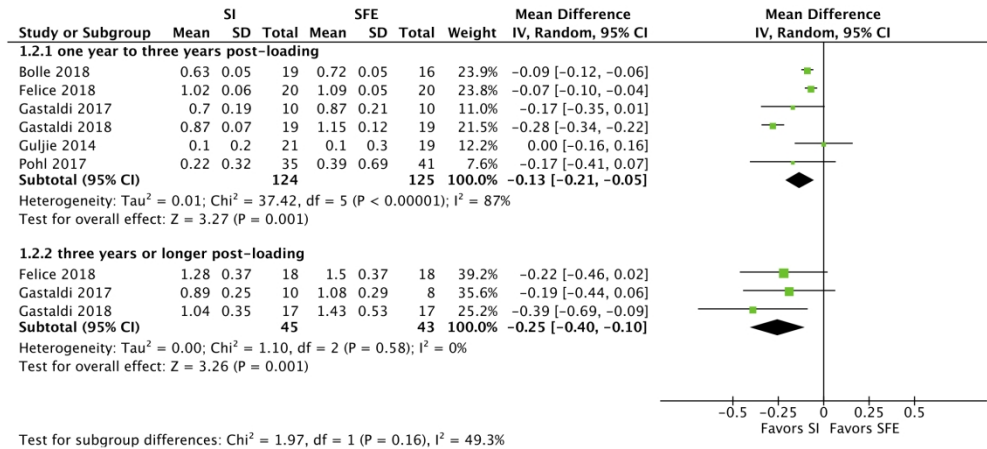


Figure 5 Forest plot for marginal bone loss. footnote: SI, short implant group; SFE, sinus floor elevation group.

197x90mm (300 x 300 DPI)

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**Short implants ( $\leq 6$  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]



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- 5 28. sinus lift [Title/Abstract]
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- 7 29. sinus floor elevation [Title/Abstract]
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- 9 30. 23 OR 24 OR 25 OR 26 OR 27 OR 28 OR 29
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- 11 31. 22 OR 30
- 12 32. randomized controlled trial [Publication Type]
- 13
- 14 33. randomized [Title/Abstract]
- 15
- 16 34. randomly [Title/Abstract]
- 17
- 18 35. 32 OR 33 OR 34
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- 20 36. 16 AND 31 AND 35
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**The search strategy used for Embase (1980 to 31 May 2018):**

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- 26 1. 'alveolar bone loss'/exp/mj
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- 28 2. 'alveolar ridge augmentation'/exp/mj
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- 30 3. 'bone prosthesis'/exp/mj
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- 32 4. 1 OR 2 OR 3
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- 34 5. 'atrophic jaw': ab, ti
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- 36 6. 'atrophic maxilla': ab, ti
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- 38 7. 'atrophic mandible': ab, ti
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- 40 8. 'posterior maxilla': ab, ti
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- 42 9. 'posterior mandible': ab, ti
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- 44 10. 'augmented bone': ab, ti
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- 46 11. 'bone augmentation': ab, ti
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- 48 12. 'sinus lift': ab, ti
- 49
- 50 13. 'sinus floor elevation': ab, ti
- 51
- 52 14. 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13
- 53
- 54 15. 4 OR 14
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- 56 16. 'tooth implantation'/exp/mj
- 57
- 58 17. 'tooth implant'/exp/mj
- 59
- 60 18. 'tooth prosthesis'/exp/mj
19. 16 OR 17 OR 18
20. 'short implant': ab, ti

*Supplementary File*

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

	#	Checklist item	Reported on page #
<b>TITLE</b>			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
<b>ABSTRACT</b>			
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
<b>INTRODUCTION</b>			
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
<b>METHODS</b>			
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
<b>RESULTS</b>			
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*

1			
2	within studies		(see item 12).
3			
4	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.
5			
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8	Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.
9			
10			
11	Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).
12			
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14	Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).
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17	<b>DISCUSSION</b>		
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19	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).
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22	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).
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25	Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.
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28	<b>FUNDING</b>		
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30	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.
31			
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33  
 34 *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.  
 35 doi:10.1371/journal.pmed1000097

36 For more information, visit: [www.prisma-statement.org](http://www.prisma-statement.org).