Short Implants (5 to 8 mm) Versus Longer Implants (>8 mm) with Sinus Lifting in Atrophic Posterior Maxilla: A Meta-Analysis of RCTs

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ABSTRACT
Objective: The specific purposes of this study were (1) to undertake a thorough systematic review and meta-analysis based only on randomized clinical trials (RCTs) to compare the rates of survival and complications of short implants to those of long implants; (2) to compare the surgical time and cost of short implants to those of long implants.

Methods: RCTs were identified from the major electronic databases (MEDLINE, Embase and Cochrane Library) using the keywords “dental implant,” “short implant” and “atrophic maxilla,” and a quantitative meta-analysis was conducted. The survival rate of implants and complications were the primary outcome measures, and other parameters assessed included costs and surgical time.

Results: Seven RCTs that met the inclusion criteria included 554 implants (265 implants in the short implant group). There was no significant difference in survival rate between two groups (RR: 1.00; 95% CI: [0.97, 1.03]; \(p = .96\); seven trials, 554 participants). Compared with long implant group, the short implant group had a lower complications and the effect measure was significant (RR: 0.58; 95% CI: [0.37, 0.90]; \(p = .02\); seven trials, 554 participants).

Conclusion: This systematic review showed that no difference between the survival rates of short implants (5–8 mm) and long implants (>8 mm); complications in short implants are lower than that in long implants. However, further studies are required to substantiate our findings.

KEY WORDS: atrophic maxilla, dental implant, meta-analysis, short implant

INTRODUCTION
In many clinical situations, it is impossible to place dental implants since there is not enough residual vertical bone height. That is to say, not every patient has adequate bone volumes to receive dental implants. This condition is common especially below the maxillary sinuses. Due to a limited ridge height following the expansion of the sinus maxillaries and vertical bone loss of the ridge after tooth extraction in the posterior region of the maxilla, primary implant placement is often difficult to achieve. Bone augmentation is the most common method to solve this problem. Generally, there are two options existing to increase the ridge height in the posterior maxilla (1) a sinus floor elevation procedure in acranial direction, using a transalveolar or a lateral window approach;1,2 (2) vertical bone regeneration in a caudal direction.3 The first option is worth to recommend in case of a severely reduced ridge height.4 However, there are three main problems associated with bone augmentation procedures in general: the cost and duration of the treatment, the higher patient morbidity, and not necessarily ideal success rates.5,6 The results of systematic reviews showed that the lateral window approach and simultaneous implant

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DOI 10.1111/cid.12432
placement demonstrated complications to occur in up to 38% of the patients and implants to fail in up to 17% within 3 years. Therefore, current clinical researches are focusing on evaluating the performance of short implants (5–8 mm) or tilted implants, in conjunction or not with less invasive bone augmentation procedures. Most recently, a lot of systematic reviews evaluated the survival rate of short implants, overall concluding that the survival rates are similar to long implants. In summary, the above researches suggested that both sinus floor elevation procedures with long implants and short dental implants might have their own limitations and advantages. In addition, costs, surgical time, and morbidity associated with the procedures also play a key role. Even so, there is a lack of high quality researches of comparing short implants and long implants placed in the posterior maxilla. Scholars still debate over which is better between short implants and long implants with sinus lifting in the posterior maxilla.

The specific purposes of this study were (1) to undertake a thorough systematic review and meta-analysis based only on randomized clinical trials (RCTs) to compare the rates of survival and complications of short implants to those of long implants with sinus lifting in the posterior maxilla. (2) to compare the surgical time and cost of short implants to those of long implants with sinus lifting.

**MATERIALS AND METHODS**

This systematic review was conducted by following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) principles. The focused question was, are the survival rate and other clinical outcomes different between short and long implants with sinus lifting in the posterior maxilla in RCTs?

The survival rates and complications of short and control implant groups were the primary outcomes to be extracted and analyzed by meta-analysis. The surgical time and cost were the secondary outcomes.

**Inclusion Criteria**

Studies were included if they fulfilled all the following inclusion criteria: (a) randomized controlled trials; (b) studies that included the survival rate of implants, complications, and other detailed data regarding implant lengths, diameters, locations, and surgical techniques; and (c) evaluations with a mean follow-up period of at least 1 year; (d) something about summary data being available for the outcomes of interest.

**Exclusion Criteria**

Nonenglish language articles were excluded. Articles that did not provide sufficient information on prognosis were excluded.

**Literature Search**

A computerized, systematic literature search was performed using MEDLINE (Until November 2015), EMBASE (Until November 2015), and the Cochrane Library databases (Until November 2015). The MEDLINE database was searched with the following search terms as keywords (or MeSH): (a) “randomized controlled trial” and (b) “dental implant” and (c) “short implant” and (d) “atrophic maxilla.” The EMBASE and Cochrane databases were searched by using a) “randomized controlled trial” and (b) “dental implant” and (c) “short implant” and (d) “atrophic maxilla” as key words. Reference listed within the retrieved articles were used as secondary reference sources (hand-searching).

**QUALITY ASSESSMENT AND DATA ANALYSIS**

The quality and risk of bias of all the included trials were independently assessed by Tengfei Fan and Yicun Li, based on the recommendations from the Cochrane Handbook of Systematic Review of Interventions (www.cochrane-handbook.org). The criteria included allocation concealment, random sequence generation, blinding for participants and personnel, selective outcome reporting, blinding of outcome assessments, incomplete outcome data, and other biases. An assessment of the risk of bias was categorized as “Low risk of bias,” “High risk of bias,” or “Unclear risk of bias” in each domain, based on the guidelines from the Cochrane Handbook, with notes explaining the specific reasons for each categorization in the risk of bias table (Cochrane Handbook for Systematic Reviews of Interventions). Any conflicts in opinion were resolved by discussion.

We extracted data on trial characteristics, including trial site, year, trial methods, participants, interventions, outcomes (survival rate of implants,
complications, surgical time and costs, etc.) and entered this data into Review Manager 5.3. The number of participants randomized and the number analyzed in the experimental and control arms were extracted in each group for each outcome. We attempted to contact the study authors for any relevant missing or unclear data. We also asked the authors to confirm whether the study was duplicated and whether there was any doubt if the studies shared the same patients. We excluded the studies that did not meet the inclusion criteria in terms of study design. Tengfei Fan extracted the data, which was checked by Yicun Li. If multiple publications from a particular research group reported data from overlapping samples, we will include the study reporting the largest or latest dataset. Differences in opinion were resolved by discussion.

**Statistical Analysis**

All the individual outcomes were pooled using RevMan5.3 (Cochrane Collaborative, Oxford, England). We used the risk ratio (RR) to summarize dichotomous outcomes. We presented all measures of effect with 95% confidence intervals (CI). The outcomes were aggregated and analyzed using a random-effect model or fixed-effect model. If there is big heterogeneity, we use random-effect model. If not, we use fixed-effect model. Statistical heterogeneity was assessed by using the chi-squared distributed Q statistic and $I^2$. Subgroup analyses were needed when the statistical heterogeneity was significant ($I^2 \geq 50\%$). Sensitivity analyses and subgroup analyses were performed to assess whether there was a difference in primary outcomes.

**Trial sequential Analysis**

According to Cochrane Handbook for systematic reviews of interventions, if all eligible trials are included, the systematic reviews or meta-analyses are considered to be the best available evidence. However, “the best available evidence” might not be equal to “sufficient evidence” or “strong evidence.” To resolve this question, we applied the trial sequential Analysis (TSA) to estimate the robustness of the current conclusions. In this study, we calculated the required power to collect adequate information and assessed how many subjects would be enough to make these robust conclusions. The required information power was based on the assumption of a plausible relative risk of 10% with low risk bias, and we adopted the risks for a type I error (a) of 5%, a type II error (b) of 20%.15 Based on the required power and risk for type I and type II errors, TSA monitoring boundaries were built. If a TSA monitoring boundary is crossed with Z-curve before the required power is reached, robust verdict might have been confirmed and further researches are unnecessary. Otherwise, it is necessary to continue performing more researches.

**RESULTS**

**Search Findings**

Two thousand one hundred and twenty-eight records identified through database searching and 35 additional records identified through the reference lists of articles were obtained. After deleting the duplications, 1,765 papers were left. Then we estimated the rest records and 1,624 papers were excluded according to the abstracts. The remaining 141 articles were further assessed for eligibility and another 134 articles were eventually excluded because of the lack of relevant data. Figure 1 shows the flowchart of studies retrieved and excluded and the reasons for their exclusion are listed. Seven studies16–22 comprising a total of 554 implants were included in this meta-analysis, including 265 implants in the short implant group and 289
implants in the control group. (The information of these seven RCTs is in Table 1.)

**Methodological Quality of the Included Studies**

The studies by Esposito et al.\(^ {17,18}\) were identified as being of a higher design quality. Other studies were identified as being of a lower design quality because of providing inadequate information in performance bias (blinding of participants and personnel) (Figure 2). In addition, the agreement between the two assessors (Tengfei Fan and Yicun Li) about the quality of this five included studies was high, although there was still a slice of controversy. A third assessor (Wei Wei Deng) was asked to review the study, when there was controversy in the assessment of the quality of the studies.

### TABLE 1 The Characteristics of the Studies

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Country</th>
<th>Size of Study (No of implants in maxillae)</th>
<th>Length of Implants</th>
<th>Healing Time</th>
<th>Provisional to Definitive Loading</th>
<th>Presurgical Prophylaxis</th>
<th>Definitive Restoration</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cannizzaro</td>
<td>2013</td>
<td>Italy</td>
<td>82</td>
<td>Short: 8 mm Long: 11.35 mm (mean)</td>
<td>6 wk</td>
<td>6 wk</td>
<td>Amoxicillin 2 g, 1 hour prior to surgery</td>
<td>Splinted for multiple short and control implants</td>
<td>5 years</td>
</tr>
<tr>
<td>Esposito</td>
<td>2011</td>
<td>Sweden</td>
<td>72</td>
<td>Short: 5 mm Long: 12.4 mm (mean)</td>
<td>3 mo</td>
<td>4 mo</td>
<td>Amoxicillin 2 g, 1 hour prior to surgery</td>
<td>Splinted for multiple short and control implants</td>
<td>1 year</td>
</tr>
<tr>
<td>Esposito</td>
<td>2014</td>
<td>Sweden</td>
<td>72</td>
<td>Short: 5 mm Long: 12.4 mm (mean)</td>
<td>3 mo</td>
<td>4 mo</td>
<td>Amoxicillin 2 g, 1 hour prior to surgery</td>
<td>Splinted for multiple short and control implants</td>
<td>3 years</td>
</tr>
<tr>
<td>Gulje</td>
<td>2014</td>
<td>Netherlands</td>
<td>40</td>
<td>Short: 6 mm Long: 11 mm</td>
<td>12 wk</td>
<td>14 wk</td>
<td>Amoxicillin 3 g, 1 hour prior to surgery</td>
<td>Not splinted</td>
<td>1 year</td>
</tr>
<tr>
<td>Pistilli</td>
<td>2013</td>
<td>Italy</td>
<td>73</td>
<td>Short: 5 mm Long: 11.9 mm (mean)</td>
<td>3 mo</td>
<td>4 mo</td>
<td>Amoxicillin 2 g, 1 hour prior to surgery</td>
<td>Splinted for multiple short and control implants</td>
<td>1 year</td>
</tr>
<tr>
<td>Pistilli</td>
<td>2013</td>
<td>Italy</td>
<td>83</td>
<td>Short: 6 mm Long: 11.8 mm (mean)</td>
<td>3 mo</td>
<td>4 mo</td>
<td>Amoxicillin 2 g, 1 hour prior to surgery</td>
<td>Splinted for multiple short and control implants</td>
<td>1 year</td>
</tr>
<tr>
<td>Thoma</td>
<td>2014</td>
<td>Switzerland Austria Poland Spain USA</td>
<td>132</td>
<td>Short: 6 mm Long: 11–15 mm</td>
<td>6 mo</td>
<td>NA</td>
<td>NA</td>
<td>single non-splinted crown</td>
<td>1 year</td>
</tr>
</tbody>
</table>

NA: Data not available.
Meta-Analysis

As shown in Table 1, six out of the seven RCTs included in the meta-analysis were single-center studies conducted in Italy, Sweden and Netherlands. The study by Thoma et al.\textsuperscript{22} was a multicenter trial conducted in Switzerland, Austria, Poland, Spain, and USA. All these seven RCTs were published in the last 5 years. Although the data used in this meta-analysis were from different parts of the world, inter-study heterogeneity of the relative risk of survival rate of implants and complications in the trials were tested, and no statistically significant heterogeneity was observed ($I^2=0\%$, $ p = .65$ in survival rate; $I^2=43\%$, $p = .12$ in complications).

Survival Rate of Implants

In this meta-analysis, all these seven studies reported the survival rate of implants. Therefore, we directly utilized the data of survival rate. There was not significant heterogeneity between each study ($I^2=0\%$, $p = .65$). Owing to the relatively low statistical heterogeneity in these studies, a fixed-effect model was employed. There was not significant difference between the survival rate of short and long implants (RR:1.00; 95% CI: [0.97,1.03]; $p = .96$; seven trials, 554 participants) (Figure 3).

Complications

In this meta-analysis, all these seven studies reported the complications. Therefore, we directly utilized the data of complications (Figure 4). The heterogeneity between each study were acceptable ($I^2=43\%$, $p = .12$). So a fixed-effect model was employed. The effect measure was significant (RR: 0.58; 95% CI: [0.37, 0.90]; $p = .02$; seven trials, 554 participants). That is to say, the short implant group had less complication than long implant group.
Other Outcomes

Thoma et al.\textsuperscript{22} reported that the difference in surgical time between the two groups was statistically significantly different ($p < .05$). In group short (34 patients), the mean time needed to place one single implant amounted to 52.6 minutes (range 15–165 minutes). In group long (36 patients), the additional sinus floor elevation procedures increased the surgery time by roughly 50%, rendering a mean of 74.6 minutes (range 20–210 minutes). In addition, Thoma et al. also described the price of one single implant limited to the surgery (without prosthetic treatment). The mean price for group short amounted to 941 EUR (range 626–1313 EUR), while in group graft, the mean price was 1946 EUR (range 1,455–2,691 EUR).

Trial Sequential Analysis

Data from all seven RCTs were used to investigate whether there is difference in survival rate of implants or complications between short (5–8 mm) and long (>8 mm) implant groups. Using the TSA (e.g., taking the data of complications), the required information size for adequate power was 2,043 implants. The cumulative $Z$-curve crossed the traditional significant line but did not cross the TSA monitoring boundary (Figure 5). Similar results were obtained with survival rate of implants. The cumulative $Z$-curve neither crossed the traditional significant line nor crossed the TSA monitoring boundary (Figure 6). In other words, further studies are required to substantiate this result.

Figure 4 Forest plot for complications: The complications of long implants is more than that of short implants, and the effect measure was significant (RR: 0.58; 95% CI: [0.37, 0.90]; $p = .02$; seven trials, 554 participants). The heterogeneity between each study were acceptable ($I^2 = 43\%$, $p = .22$).

Figure 5 TSA of this meta-analysis, data on the survival rate: The solid blue line represents the cumulative $Z$-curve. The dashed red line represents the trial sequential monitoring boundary. TSA indicates that further trials are required.
DISCUSSION

This is the first systematic review and meta-analysis of short and long implants in atrophic posterior maxilla based on RCTs. In addition to these seven included RCTs, there are lots of studies that primarily compared the clinical outcomes of short and long implant groups in maxilla or mandible. Short implants were expected to have more failures than control implants after loading because of their mechanical disadvantage.23 Some studies reported the failure rate of short implants was higher than that of long implants.24–26 Other researchers hold opposite views, their findings showed that the failure rate of short implants was not higher than control group, and the complications of control group were more.21,27 However, most studies have failed to reach statistically significant differences in disease-free survival or overall survival between the two groups. What’s worse, most of these studies have small sample sizes and their study design was not rigorous. Our meta-analysis of RCTs could help answer these questions. To minimize any possibility of bias, detailed criteria for study selection was developed prior to conducting the literature search. Further, the procedure and criteria for literature search, data extraction and analysis were explicitly laid down.

Although only seven RCTs were included in this meta-analysis, all seven were judged to be of a high quality. The fact that only seven trials have been successfully performed and published to date is perhaps indicative of the inherent challenges in conducting methodologically robust RCTs in general, and, in particular, those involving dental implant patients. Adherence to the study protocol including the follow-up schedule, and completeness of reporting on outcomes are some of the key determinants of the quality of evidence. Thoma et al.22 reported that the mean time needed to place one single short implant amounted to 52.6 minutes (range 15–165 minutes.), the additional sinus floor elevation procedure increased the surgery time by roughly 50%, rendering a mean of 74.6 minutes (range 20–210 minutes) in long implants with sinus lifting. Although only this one study reported that two groups of operation time directly, the operation time in short implant group is shorter than that in long implants with sinus lifting group. The size of cases in these included studies was not large, and the set of conditions of each study was different. The types of complications reported by the included studies were various. So, we could only statistic the total number of various complications. We learned from the data of these included studies, most complications happened after loading. The most common type of complications is inflammation, including sinusitis, peri-implant bone loss, peri-implant mucositis, and peri-implantitis.

The results of this meta-analysis supported that there were not significant difference between short and long implants in survival rate of implants. In addition, the results manifested an absolute complications benefit of 10%–63% with the short implant strategy. Moreover, both the costs and surgical time in short implant group were significantly lower than that of long implant group. The result of TSA further
confirmed the findings of this meta-analysis. The result of TSA showed that both the cumulative Z-curve of survival rate and complications were not crossed the TSA monitoring boundary. That is to say, further studies are required to substantiate the findings of this meta-analysis.

Every systematic review, including this one, has its limitations.\textsuperscript{28} First and foremost, the number of included studies was low at only seven, and the number of cases was also small. More studies are required to further confirm our findings. Second, several studies provided only limited methodology-related information on aspects like blinding of participants and personnel. All the above cited factors could have had an impact on their respective outcomes, and thereby might have had a bearing on the results of the present study.

In conclusion, the results of our systematic review and meta-analysis suggest that no difference between the survival rates of short implants (5–8 mm) and long implants (>8 mm); complications in short implants are lower than that in long implants; surgical time and costs in short implants are lower than that in long implants. However, some limitations weakened the power of this meta-analysis. That is to say, further studies are required to substantiate our findings.

ACKNOWLEDGMENTS

The authors thank Dr. Zhi-jun SUN for statistical analyses. This work was supported by National Natural Science Foundation of China, 81272964, 81472529 (W.F.Z) and Fundamental Research Funds for the Central Universities (No. 2042015kf0075). The authors declare no potential conflicts of interest with respect to the authorship and/or publication of this article.

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