Outcomes of implants placed after osteotome sinus floor elevation without bone grafts: a systematic review and meta-analysis of single-arm studies

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Abstract
Background: The aim of this study is to evaluate the implant survival/success rate, gain in alveolar bone height, crestal bone loss, and complications associated with implants placed in the posterior maxilla after osteotome sinus floor elevation without bone substitutes.

Methods: The electronic databases, such as MEDLINE, EMBASE, CENTRAL, and SCOPUS were systematically and manually searched for publications in peer-reviewed journals. The included articles were subjected to qualitative and quantitative analyses, and the meta-analysis was carried out for single-arm studies. Methodological quality assessment was made for all the included studies.

Results: The included studies were of moderate quality, with the overall implant success and survival rates of 98.3% and 97.9% respectively. The most frequent intra-surgical complication was sinus membrane perforation, accounting for 3.08% of the total implants with reported perforations. The overall crestal bone loss in patients with immediate implants placed with OSFE after a 5-year follow-up was 0.957 mm 95%CI (0.538, 1.377).

Conclusion: Within the limitations of this review, it can be concluded that the survival and success rates of implants placed immediately along with OSFE without any bone substitutes are acceptable and show adequate implant stability with less crestal bone loss over 5 years.

Introduction
Dental implants provide a strong foundation for fixed (permanent) or removable replacement teeth that are essential for the improvement of appearance, speech, eating, comfort, self-esteem, and oral health of the patients [1]. A loss of the natural dentition leads to a reduction of occlusal forces that activate a series of bone remodeling processes in the alveolar bone, causing pressure-threshold-regulated bone atrophy [1]. However, there is still not enough scientific evidence to determine whether osteoclastic bone resorption is pressure-threshold-regulated or proportionally pressure-dependent. Moreover, after tooth extraction, there is an increase in the osteoclastic activity of the peristomeum of the maxillary sinus floor, leading to sinus maxillary sinus pneumatization and expansion into the alveolar bone crest [2]. Maxillary sinus pneumatization is a serious obstacle to oral implantology [2]. Therefore, there is a great need for specific surgical procedures to partially or totally reduce the expanded volume of this cavity. Several grafting techniques based on using autogenous bone (either alone, mixed with a bone-substituting biomaterial, or biomaterial only) are now available. Insufficient alveolar bone height, width, and density, as well as quality and quantity of posterior edentulous maxillary bone, are common limiting factors for placement...
of dental implants in the posterior maxillary region. These factors can increase incidences of implant failure and complications and worsen overall clinical outcomes of dental implant treatments [3]. Surgical sinus floor elevation (SFE) can significantly increase the height of bone available for implant placement. For dental implant placement, two main sinus floor elevation approaches can be used—direct and indirect. Direct SFE is a lateral window sinus grafting approach that is used for treating cases with a residual bone height of less than 5.0 mm. This approach allows to increase bone height to > 5.0 mm but usually requires a 6–9-month delay in subsequent implant placement. Indirect SFE is a transalveolar approach that condenses bone grafting materials under the Schneiderian membrane in the presence of at least 5 mm of residual bone. This approach allows gaining approximately 3–5.0 mm of bone height within the sinus with a simultaneous implant placement [4].

The use of bone grafts for sinus augmentation, irrespective of the technique used, has been associated with a high success rate despite certain shortcomings, such as a need for a second surgical site for autogenous bone harvesting, increased rate of complications, higher cost, and increased surgical time. Lundgren et al. described spontaneous bone formation below the sinus floor after cyst enucleation, suggesting that proliferative and regenerative proprieties of the sinus membrane may have a potential for bone formation [5]. This concept led to a number of studies in which successful implant placement and rehabilitation were carried out without using bone grafts. These studies have demonstrated a guided tissue regeneration process, where bone deposition and new bone formation are induced by the blood clot in the void that is created after sinus augmentation [6].

In 2019, Rawat et al. conducted a prospective controlled clinical trial of 21 patients with 26 implants by indirect sinus lift with simultaneous implant placement without bone graft. This study demonstrated a predictable successful osseointegration with osteotome sinus floor elevation without bone graft, and spontaneous new bone formation [4]. A prospective study by Merheb et al. [7] compared the 5-year progression of implant stability in grafted and non-grafted sites in 12 patients with ≤ 4-mm initial bone height in the posterior maxilla. The implants were positioned using osteotome sinus floor elevation. This study showed that the stability of implants positioned with osteotome sinus floor elevation in non-grafted sites is similar to that of implants placed in grafted sites. A randomized controlled trial by Qian et al. [8] evaluated long-term clinical and radiographic outcomes of implants placed using osteotome sinus floor elevation (OSFE) with or without bone grafting in 45 patients with 4.58 ± 1.28 mm of average residual bone height. The study concluded that OSFE with or without grafting gives similar clinical outcomes with comparable alveolar bone gain. Since then several new studies have been published. The aim of the current study is to provide updated pooled evidence and meta-analysis by systematically searching the literature for all single-arm studies that evaluate the outcomes of implants placed in posterior maxillae after osteotome sinus floor elevation without bone substitutes.

Methods

Review methodology

This systematic review and meta-analysis of single-arm studies was carried out in strict accordance with Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines [9]. The protocol for smooth conduction of the systematic review was prepared a priori.

Review question

What is the survival/success rate of the implants placed in the posterior maxilla after osteotome sinus floor elevation without any bone substitutes?

What is the gain in alveolar bone height, crestal bone loss?

What intra-surgical and post-surgical complications were reported with the implants placed in the posterior maxilla after osteotome sinus floor elevation without any bone substitutes?

Designing PICO

The description of PICO is as follows:

| Population/type of participants | The patients indicated for immediate dental implant placement in posterior maxillae with insufficient residual bone height requiring sinus elevation |
| Type of intervention | Immediate dental implant placement following osteotome sinus floor elevation without any additional bone substitutes |
| Comparison | Not applicable (single-arm studies) |
| Outcomes | Survival rate, success rate, gain in alveolar bone height, crestal bone loss around implants, intra-surgical and post-surgical complications |

Search strategy

A comprehensive search was carried out in 4 electronic databases, MEDLINE, EMBASE, CENTRAL, and SCOPUS, using a series of relevant keywords: Maxillary sinus, Dental Implant, Sinus augmentation, Sinus elevation, Crestal sinus elevation, Summer's osteotome, Osteotome sinus floor elevation, OSFE, Indirect sinus lift, Immediate Implant, Survival rate. We searched each database from 1979 up to 10th February 2021. A manual search was also carried out in peer-reviewed international indexed journals, such as Clinical Implant Dentistry and
Related Research, Clinical Oral Implant Research, Implant Dentistry, International Journal of Oral and Maxillofacial Implants, Journal of Clinical Periodontology, Journal of Periodontal and Implant Science, Journal of Periodontology, and Quintessence International, from inception till January 2021. The bibliographies of previously conducted relevant systematic reviews or randomized clinical trials were additionally screened for any potentially eligible articles. The search was limited to the studies published in the English language only.

Articles retrieved from the digitalized and manual sources were imported into a citation manager software to remove the duplicates, and the final set of retrieved studies was screened by looking at titles and abstracts on the basis of relevancy. The potentially eligible articles were then subjected to full text analysis.

Selection of studies
The study selection was carried out by two independent reviewers.

The inclusion criteria were as follows:

- Articles published in the English language
- Single-arm clinical studies with human subjects
- Articles employing OSFE alone without any bone substitute along with simultaneous placement of dental implant
- Articles with RBH measurements
- Articles with a minimum sample size of 10 and a minimum follow-up of 6 months–1 year
- Articles reporting implant survival/success rate, alveolar bone gain, crestal bone loss, or post-surgical adverse events

The articles not reporting the outcomes, or multiple publications with the same cohort, or employing ridge split or any additional augmentation procedures, were excluded.

Data selection and extraction
Data from the included articles were collected by two independent reviewers, and the information was entered into the excel sheet under the following domains: study design, sample size, gender, age range; smokers; number and location of implants placed; make, diameter, and length of implants placed; osteotome technique; follow-up months; etc. The primary outcomes assessed were implant survival, implant success, gain in alveolar bone height, and mean crestal bone loss around the implants placed. Secondary outcomes included the intra-surgical and post-surgical complications observed across the included studies. The authors were contacted through email for clarification and in case of any missing relevant information.

Data synthesis
The retrieved data was subjected to both qualitative and quantitative synthesis. Demographic and interventional characteristics were included in the table and summarized. In the case of two or more studies assessing similar outcomes, the quantitative items were subjected to single-arm pooled meta-analysis using the Open Meta-analyst 2.0 software. The pooled estimate of gain in alveolar bone height and mean crestal bone loss was expressed as mean and standard deviation with 95% confidence interval (CI). The dichotomous data pertaining to implant success/survival was expressed as pooled odd’s ratio (OR) with 95% CI. The heterogeneity among the included studies was assessed using $i^2$ statistics. The $i^2$ value greater than 70% was considered high heterogeneity, and less than 40% was considered low heterogeneity.

Quality assessment
The quality assessment of the included studies was carried out using the methodology assessment criteria adopted by Clementini et al., by judging the following domains: appropriateness in statistical analysis, validated measurements, reports of loss to follow-up, defined inclusion and exclusion criteria, and proper sample selection.

Results
A pool of 324 articles were retrieved from digitalized and manual searches and screened based on titles and abstracts. A total of 41 potentially eligible articles were selected for full text assessment. After evaluating inclusion and exclusion criteria, 35 articles [4, 7, 8, 10–41] were included, and 6 manuscripts [42–47] were excluded. The detailed study selection process is summarized in Fig. 1.

Seven clinical trials [4, 8, 10, 16, 18, 24, 33], fifteen prospective clinical studies [7, 13–15, 17, 21, 22, 26–29, 31, 32, 37, 39], twelve retrospective cohort studies [11, 12, 19, 20, 23, 25, 30, 34–36, 40, 41], and 1 case series [27] were included in this systematic review. The age of the patients included in the studies ranged from 17 to 90 years. Eight studies [8, 10, 18, 26, 29, 34, 36, 39] reported the inclusion of smokers, and two studies reported exclusion of smokers [13, 15]. The rest of the studies did not report the smoking status of the patients. The follow-up period ranged between 6 months and 16 years. Overall, data on 2267 patients with a total of 3390 dental implants were reported in the 35 selected studies. The pre-operative residual bone height (RBH) ranged from 2 to 13.5 mm. The diameters of the implants varied between 3.3 and 7.0 mm, and the length of the implants ranged from 6 to 15 mm. The highest reported success rate was 100%, and the lowest was 95%. Demographic
and interventional characteristics of the included studies are summarized in Table 1 and Table 2, respectively.

Intraoperative membrane perforation was the most frequently observed intraoperative complication and was reported by 22 studies [7, 10–17, 22, 24, 26–31, 33–35, 37, 39]. Out of 22 studies, 11 studies [7, 17, 22, 24, 26–29, 34, 35, 37] did not report any tear or perforation in the sinus membrane. Membrane perforation occurred in 88 cases out of 2858 implants placed, accounting for 3.08% of the total implants with reported perforations. Postoperative nosebleed, paroxysmal vertigo, and infections were observed in few studies, however, they were less frequent. The details regarding the intra-surgical and post-surgical complications are provided in Table 3.

Meta-analysis

Fourteen different brands of implants were used; 5 articles [10, 12, 25, 28, 41] did not report any information on the dental implant brands; 4 studies [10, 13, 17, 31] did not provide any information on the dental implant diameters. The quantitative data retrieved from the parameters assessed in five included studies [10, 14, 18, 22, 32] were pooled and the overall estimate with 95% CI was obtained. Most of the studies used success criteria described by Buser et al. [48] and Albrektsson et al. [49].

The overall implant success rate was 98.3 (96.6–100) % (Fig. 2) with low heterogeneity (39.13%). Pooled survival rate of the twenty-two included studies [7, 8, 11–13, 15, 17, 19, 20, 23–26, 28–31, 33–36, 39] was 97.9% (97.3, 98.5) with 0% heterogeneity (Fig. 3).

The overall gain in the alveolar bone height was 2.459 mm 95%CI (2.232, 2.867) when the included studies describing < 6-mm RBH were pooled (Fig. 4). For studies with > 6-mm RBH, the overall gain was 2.218 mm, 95% CI (1.882, 2.554) (Fig. 5). The heterogeneity between the studies was high (94.71%), possibly due to the variation in length of implants that ranged from 6 to 15 mm and the variability in the pre-operative RBH. The overall crestal bone loss in immediate implants placed
Table 1 Demographic characteristics of included studies

| S.L.no. | Author | Year | Country | Centers | Surgeons | Study design | Sample size | Gender | Age range | Smokers |
|---------|--------|------|---------|---------|----------|--------------|-------------|--------|-----------|---------|
| 1       | Leblebicioglu et al. [10] | 2005 | Turkey  | 1       | NR       | Randomized controlled clinical trial | 40          | 2F, 19M | 46-7 years | Yes     |
| 2       | Jurisic et al. [11] | 2008 | Serbia  | 1       | 2        | Retrospective cohort                  | 33          | 26F, 35M | 38-64 years | NR      |
| 3       | Schmidlin et al. [12] | 2008 | Switzerland | 1   | 2        | Retrospective cohort                  | 24          | 15F, 9M | 61.9 ± 103 years | NR      |
| 4       | Gabbert et al. [13] | 2009 | Germany | 1       | 2        | Prospective clinical study            | 36          | 20F, 16F | 20-76 years | No      |
| 5       | Nedir et al. [14] | 2009 | Switzerland | 1   | 2        | Prospective clinical study            | 32          | NR     | 39-82 years | NR      |
| 6       | Pjetursson et al. [15] | 2009 | Switzerland | 1   | NR       | Prospective clinical study            | 181         | NR     | 17-90 years | No      |
| 7       | Lai et al. [16] | 2010 | Switzerland | 1   | NR       | Clinical trial                        | 202         | NR     | 20-68 years | NR      |
| 8       | Nedir et al. [17] | 2010 | Switzerland | 1   | NR       | Prospective clinical study            | 17          | 14F, 3M | 38-69 years | NR      |
| 9       | Fornell et al. [21] | 2011 | Sweden   | 1       | NR       | Prospective clinical study            | 14          | 7F, 7F | 34-75 years | NR      |
| 10      | He et al. [23] | 2011 | China    | NR      | NR       | Retrospective cohort                  | 22          | 10F, 12M | 19-70 years | NR      |
| 11      | Senylmaz et al. [18] | 2011 | Turkey   | NR      | NR       | Pilot study                           | 17          | 9F, 8M  | 55 years    | Yes     |
| 12      | Volpe et al. [25] | 2011 | Sweden   | NR      | NR       | Retrospective cohort                  | 20          | 15F, 5M | 48 years    | NR      |
| 13      | Zahran et al. [22] | 2011 | Egypt    | NR      | NR       | Prospective clinical study            | 64          | 34F, 30M | 35-72 years | NR      |
| 14      | Bruschi et al. [19] | 2012 | Italy    | 1       | 1        | Retrospective cohort                  | 46          | 29F, 17M | 26-83 years | NR      |
| 15      | Fermegard et al. [20] | 2012 | Sweden   | NR      | NR       | Retrospective cohort                  | 36          | NR     | 64 ± 12 years | NR      |
| 16      | Si et al. [24] | 2013 | China    | 1       | NR       | Randomized controlled clinical trial  | 20          | NR     | ≥ 18 years | NR      |
| 17      | Brizuela et al. [26] | 2014 | Spain    | 1       | 1        | Prospective clinical trial            | 37          | 22F, 15M | 31-68 years | Yes     |
| 18      | Gu et al. [31] | 2016 | China    | 1       | NR       | Prospective clinical study            | 28          | 13F, 15M | 19-78 years | NR      |
| 19      | Nedir et al. [27] | 2014 | Switzerland | 1   | NR       | Case series                           | 7           | NR     | 475 ± 184 years | NR     |
| 20      | Bassi et al. [28] | 2015 | Sweden   | 1       | NR       | Prospective clinical study            | 17          | NR     | NR         | NR      |
| 21      | Markovic et al. [32] | 2015 | Serbia   | 2       | NR       | Prospective clinical trial            | 45          | NR     | 18-56.7 years | NR      |
| 22      | Nedir et al. [33] | 2016 | Switzerland | 1   | NR       | Prospective clinical study            | 17          | 14F, 3M | 38-69 years | NR      |
| 23      | Spinelli et al. [29] | 2015 | Switzerland | 1   | NR       | Prospective clinical study            | 39          | 17F, 12M | 33-76 years | Yes     |
| 24      | French et al. [30] | 2016 | Canada   | NR      | NR       | Retrospective cohort                  | 541         | 279F, 262M | 18-88 years | NR      |
| 25      | Nedir et al. [38] | 2017 | Switzerland | 1   | NR       | Randomized controlled clinical trial  | 9           | NR     | 576 ± 47 years | NR      |
| 26      | Si et al. [34] | 2016 | China    | 1       | NR       | Retrospective cohort                  | 80          | 37F, 43M | 25-70 years | Yes     |
| 27      | Zill et al. [35] | 2016 | Germany  | 1       | NR       | Retrospective cohort study            | 113         | NR     | 31-84 years | NR      |
| 28      | Caban et al. [36] | 2017 | Sweden   | 1       | 1        | Retrospective cohort                  | 25          | 11F, 14M | 44-84 years | Yes     |
| 29      | Cheng et al. [37] | 2017 | China    | NR      | NR       | Prospective clinical study            | 29          | 13F, 35M | 43-71 years | NR      |
| 30      | Abi Najm et al. [39] | 2018 | Switzerland | NR   | NR       | Prospective clinical study            | 17          | 14M, 3F | 38-69 years | Yes     |
| 31      | Yang J et al. [40] | 2018 | China    | 1       | 1        | Retrospective cohort                  | 40          | 19F, 21M | 22-70 years | NR      |
| S.L. no. | Author            | Year | Country   | Centers | Surgeons | Study design                     | Sample size | Gender     | Age range     | Smokers |
|---------|-------------------|------|-----------|---------|----------|----------------------------------|-------------|------------|---------------|---------|
| 32      | Merheb et al. [7] | 2019 | Switzerland | 1       | NR       | Prospective clinical study      | 12          | 9F, 3M     | 57.6 ± 4.7 years | NR      |
| 33      | Qian et al. [8]   | 2020 | China     | 1       | NR       | Randomized controlled clinical trial | 22          | NR         | ≥ 18 years     | Yes     |
| 34      | Rawat et al. [4]  | 2019 | India     | NR      | NR       | Randomized controlled clinical trial | 21          | NR         | NR            | NR      |
| 35      | Nahlieli et al. [41] | 2019 | Turkey    | NR      | NR       | Retrospective study              | 331         | NR         | NR            | NR      |

NR: not reported, M male, F female
| S.L. no. | Author | Year | Location | No. implants | Make of implant | Diameter of implant placed | Length of implant placed | Healing time | Bone quality | Follow-up |
|----------|--------|------|----------|--------------|-----------------|---------------------------|-------------------------|--------------|-------------|-----------|
| 1        | Leblebicoglu et al. [10] | 2005 | First premolar (16%), second premolar (26%), first molar (52%), second molar (6%) | 75 | NR | NR | 8 mm | 6 months | D3, D4 | 25 months |
| 2        | Jurisic et al. [11] | 2008 | Premolar (NR), molar (NR) | 40 | Straumann with SLA | 4.03 ± 0.13 | 10.72 ± 0.76 | NR | NR | 3 years |
| 3        | Schmidlin et al. [12] | 2008 | Premolar (10), molar (14) | 24 | NR | 4.4 ± 0.4 | 8.6 ± 1.3 | NR | NR | 17.4 ± 18.4 months |
| 4        | Gabbert et al. [13] | 2009 | Premolar (41), molar (51) | 92 | ITI solid screw and Nobel Biocare | NR | 8 mm, 10 mm, 11.5 mm, 12 mm | NR | 1.2 ± 0.69 years |
| 5        | Nedir et al. [14] | 2009 | Premolar (17), molar (37) | 54 | Straumann | 4.8 mm, 6.5 mm | 8 mm, 10 mm | 42 ± 26 months | D1, D2, D3, D4 | 1 year |
| 6        | Pjetursson et al. [15] | 2009 | Second premolar (46%), first molar (35%), first premolar (14%), second molar and canine (5%) | 252 | Straumann | 4.1 mm, 4.8 mm, 3.3 mm | 6 mm, 8 mm, 10 mm, 12 mm | 4-6 months | D4 | 3.2 years |
| 7        | Lai et al. [16] | 2010 | NR | 191 | Straumann | 4.1 mm, 4.8 mm | 6 mm, 8 mm, 10 mm, 12 mm | NR | NR | 3 & 6 months |
| 8        | Nedir et al. [17] | 2010 | Premolar (9), molar (16) | 25 | Straumann | NR | 6 mm, 8 mm, 10 mm | 3-4 months | D3, D4 | 3 & 5 years |
| 9        | Fornell et al. [21] | 2011 | NR | 21 | SLActive | 4.1 mm, 4.8 mm | 10 mm | NR | NR | 1 year |
| 10       | He et al. [23] | 2011 | Premolar (3), molar (24) | 27 | BEGO | 4.7 ± 0.4 mm | 10 ± 1.0 mm | NR | D1, D2, D3, D4 | 2 years |
| 11       | Senyilmaz et al. [18] | 2011 | Premolar (4), molar (23) | 27 | Straumann | 4.1 mm | 8 mm, 10 mm | 8-12 weeks | NR | 2 years |
| 12       | Volpe et al. [25] | 2011 | Premolar (19), molar (10) | 29 | NR | 4 mm | NR | 6 months | NR | 16.4 months |
| 13       | Zahran et al. [22] | 2011 | NR | 108 | OsteoCare™ Maxi-Z Flat-End | 3.75 mm, 4.5 mm | 8 mm, 10 mm, 12 mm | 6 months | D4 | 1 year |
| 14       | Bruschi et al. [19] | 2012 | NR | 66 | Frialit, PILOT | 4.5 mm, 5.5 mm, 65 mm, 4.7 mm, 5.7 mm, 6.7 mm | 13 mm, 15 mm | NR | NR | 1, 5, 10, & 16 years |
| 15       | Fermergard et al. [20] | 2012 | NR | 53 | Astra Tech | 4.5 mm | 9 mm, 11 mm, 13 mm | NR | NR | 1 & 3 years |
| 16       | Si et al. [34] | 2016 | Premolar (9), molar (11) | 20 | SLA | 4.1 mm, 4.8 mm | 6 mm, 8 mm, 10 mm | NR | NR | 6, 12, 24, 36 months |
| 17       | Brizuela et al. [26] | 2014 | Premolar (13), molar (23) | 36 | Klockner | 3 mm, 4.1 mm, 5 mm | 8 mm, 10 mm | NR | NR | 2 years |
| 18       | Gu et al. [31] | 2016 | NR | 41 | SLA | NR | NR | 1, 3, & 5 years |
| 19       | Nedir et al. [27] | 2014 | First molar | 7 | SLA | 4.1 mm, 4.8 mm | 8 mm, 10 mm | 12 weeks | NR | 1, 3, 5, & 10 years |
| 20       | Bassi et al. [28] | 2015 | NR | 25 | NR | 4.3 mm | 13 mm | NR | NR | 3 & 51 months |
| 21       | Markovic et al. [29] | 2015 | NR | 21 | SLActive-BL | 4.1 mm | 10 mm | 6 months | NR | 1 & 2 years |
| S.L. no. | Author          | Year | Location         | No. implants | Make of implant                        | Diameter of implant placed | Length of implant placed | Healing time | Bone quality | Follow-up               |
|--------|-----------------|------|------------------|--------------|----------------------------------------|---------------------------|--------------------------|--------------|--------------|-------------------------|
| 22     | Nedir et al.    | 2016 | Premolar (9), molar (16) | 25           | SLA                                    | 4.8 mm                    | 6 mm, 8 mm, 10 mm       | 3.1 ± 04 mm | NR           | 1, 3, 5, & 10 years   |
| 23     | Spinelli et al. | 2015 | Premolar (NR), molar (NR) | 66           | NobelSpeedy Groovy and NobelActive Internal, Nobel Biocare AB | 4 mm, 4.8 mm               | 10 mm, 11.5 mm, 13 mm   | 5 months    | NR           | 3 years                |
| 24     | French et al.   | 2016 | NR               | 926          | Straumann, Nobel Biocare               | 4.1 mm, 4.3 mm, 4.8 mm, 5mm | 6 mm, 8 mm, 10 mm, 12 mm, 13 mm | NR          | NR           | 10 years               |
| 25     | Nedir et al.    | 2017 | Premolar (NR), molar (NR) | 17           | TE SLActive                            | 4.1 mm, 4.8 mm             | 8 mm                     | 2.6 ± 0.9 mm | NR           | 1, 3, & 5 years       |
| 26     | Si et al.       | 2016 | Premolar (15), molar (81) | 96           | Straumann                              | 4.1 mm, 4.8 mm             | 8 mm, 10 mm, 12 mm      | NR          | NR           | 4, 5, 6, 7, 8, & 9 years |
| 27     | Zill et al.     | 2016 | Premolar (66), Molar (167) | 233          | Straumann solid screw transmucosal implants | 3.3 mm, 4.1 mm, 4.8 mm     | 6 mm, 8 mm, 10 mm, 12 mm | 3 months    | NR           | 5 years                |
| 28     | Caban et al.    | 2017 | First premolar (1), second premolar (18), First molar (4) | 34           | Astra Tech                             | 4.5 mm                    | 9 mm, 11 mm, 13 mm      | 35 months   | NR           | 10 years               |
| 29     | Cheng et al.    | 2017 | Second premolar (6), first molar (28), second molar (14) | 48           | Bicon, Nobel Replace                   | 4.9 mm                    | 68 mm                    | 3–6 months   | NR           | 6 months               |
| 30     | Abi Najm et al. | 2018 | First premolar (2), second premolar (8), first molar (10), second molar (1) | 21           | Straumann                              | NR                        | 6 mm, 8 mm, 10 mm       | NR          | NR           | 10 years               |
| 31     | Yang J et al.   | 2018 | NR               | 27           | Bicon                                  | 4.5 mm, 5 mm               | 6 mm, 8 mm               | 6 months    | NR           | 18 months              |
| 32     | Merheb et al.   | 2020 | NR               | 20           | TE SLActive                            | 4.1 mm, 4.8 mm             | 8 mm                     | 8 weeks     | D2, D3, D4 | 5 years                |
| 33     | Qian et al.     | 2020 | NR               | 22           | Straumann with SLA                     | 4.1 mm, 4.8 mm             | 6 mm, 8 mm, 10 mm       | NR          | NR           | 1, 3, 5, & 10 years   |
| 34     | Rawat et al.    | 2019 | Second premolar (26%), first molar (40%), second molar (33%) | 26           | Pitt Easy Puretex                      | 3.25 mm, 4 mm, 4.9 mm     | 10 mm, 12 mm            | 6 months    | NR           | 3 & 6 months           |
| 35     | Nahlieli et al. | 2019 | NR               | 722          | NR                                     | 3.75 mm, 4.20 mm           | 11.5 mm, 13 mm          | 6 months    | NR           | 6 months–7 years       |

NR not reported
Table 3  Adverse events reported among the included studies

| S.L. no. | Author                          | Year | Sample size | No. of implants | No. (%) of membrane perforations | Postoperative nosebleed | Postoperative paroxysmal vertigo | Postoperative infection |
|----------|--------------------------------|------|-------------|-----------------|----------------------------------|------------------------|---------------------------------|------------------------|
| 1        | Leblebicioglu et al. [10]      | 2005 | 40          | 75              | 2 (3.70)                         | 0                      | N/A                             | 0                      |
| 2        | Jurisic et al. [11]            | 2008 | 33          | 40              | 7                                | N/A                    | N/A                             | 3                      |
| 3        | Schmidlin et al. [12]          | 2008 | 24          | 24              | 2 (8.33)                         | 1                      | 0                               | N/A                    |
| 4        | Gabbert et al. [13]            | 2009 | 36          | 92              | 24 (26)                          | N/A                    | N/A                             | 0                      |
| 5        | Nedir et al. [14]              | 2009 | 32          | 54              | 5 (9.25)                         | 0                      | N/A                             | 0                      |
| 6        | Pjetursson et al. [15]         | 2009 | 181         | 252             | 26 (10.40)                       | N/A                    | 9                               | 0                      |
| 7        | Lai et al. [16]                | 2010 | 202         | 280             | 12 (4.29)                        | 3                      | 0                               | 2                      |
| 8        | Nedir et al. [17]              | 2010 | 17          | 25              | 0                                | N/A                    | N/A                             | N/A                    |
| 9        | Fornell et al. [21]            | 2012 | 14          | 21              | N/A                             | N/A                    | N/A                             | N/A                    |
| 10       | He et al. [23]                 | 2013 | 22          | 27              | N/A                             | N/A                    | N/A                             | N/A                    |
| 11       | Senyilmaz et al. [18]          | 2011 | 17          | 27              | N/A                             | N/A                    | N/A                             | N/A                    |
| 12       | Volpe et al. [25]              | 2013 | 20          | 29              | N/A                             | N/A                    | N/A                             | N/A                    |
| 13       | Zahran et al. [22]             | 2012 | 64          | 108             | 0                                | 0                      | N/A                             | 0                      |
| 14       | Bruschi et al. [19]            | 2012 | 46          | 66              | N/A                             | 4                      | N/A                             | N/A                    |
| 15       | Fermergard et al. [20]         | 2012 | 36          | 53              | N/A                             | N/A                    | N/A                             | N/A                    |
| 16       | Si et al. [24]                 | 2013 | 20          | 20              | 0                                | 0                      | N/A                             | 0                      |
| 17       | Brizuela et al. [26]           | 2014 | 37          | 36              | 0                                | 0                      | N/A                             | 0                      |
| 18       | Gu et al. [31]                 | 2016 | 28          | 41              | 2                                | 0                      | N/A                             | 0                      |
| 19       | Nedir et al. [27]              | 2014 | 7           | 7               | 0                                | N/A                    | N/A                             | N/A                    |
| 20       | Bassi et al. [28]              | 2015 | 17          | 25              | 0                                | 0                      | N/A                             | 0                      |
| 21       | Nedir et al. [33]              | 2016 | 17          | 25              | 4 (16)                          | 1                      | N/A                             | 0                      |
| 22       | Spinelli et al. [29]           | 2015 | 39          | 66              | 0                                | 0                      | 0                               | 0                      |
| 23       | French et al. [30]             | 2016 | 541         | 926             | 1                                | N/A                    | 0                               | 1 (0.1%)               |
| 24       | Nedir et al. [38]              | 2017 | 9           | 17              | N/A                             | N/A                    | 0                               | 1                      |
| 25       | Si et al. [34]                 | 2016 | 80          | 96              | 0                                | 0                      | N/A                             | 0                      |
| 26       | Zill et al. [35]               | 2016 | 113         | 233             | 0                                | N/A                    | N/A                             | N/A                    |
| 27       | Caban et al. [36]              | 2017 | 25          | 34              | N/A                             | N/A                    | N/A                             | 0                      |
| 28       | Cheng et al. [37]              | 2017 | 29          | 48              | 0                                | 0                      | N/A                             | 0                      |
| 29       | Abi Najm et al. [39]           | 2018 | 17          | 21              | 3                                | N/A                    | N/A                             | 1                      |
| 30       | Yang J et al. [40]             | 2018 | 40          | 27              | N/A                             | N/A                    | N/A                             | N/A                    |
| 31       | Merheb et al. [7]              | 2020 | 12          | 20              | 0                                | N/A                    | N/A                             | 0                      |
| 32       | Qian et al. [8]                | 2020 | 22          | 22              | N/A                             | N/A                    | N/A                             | 0                      |
| 33       | Rawat et al. [4]               | 2019 | 21          | 26              | N/A                             | N/A                    | N/A                             | N/A                    |

N/A data not available

Fig. 2  Pooled estimate of the implant success rate among the included studies
with OSFE after a 5-year follow-up was 0.957 mm, 95%CI (0.538, 1.377) (Fig. 6).

The quality of the included studies was moderate. One of the included studies [27] was a case series study, with a high risk in sample selection. However, most of the studies were ranked at low to moderate risk for appropriateness in statistical analysis, validated measurements, report of loss to follow-up, defined inclusion and exclusion criteria, and proper sample selection. The methodological quality assessment summary of included studies is provided in Fig. 7.

Discussion

This systematic review and meta-analysis included 35 studies with a total of 3390 dental implants in 2267 patients.

The included studies reported both implant success and implant survival rates. The implant success rate is determined according to predefined success criteria [50]. The included studies reporting success rates employed one of the two success criteria described by Alberktson et al. [49], and Buser et al. [48], respectively. One included study [15] used different success criteria based on the clinical and radiological parameters such as distance between implant shoulder and mucosal margin, probing pocket depth, attachment level, and marginal bone level. The study was therefore not included in the pooled estimation of implant success rate. The overall implant success was estimated in only five out of 35 studies, showing a rate of 98.3%. The implant survival rate refers to the number of implants remaining in the patient’s mouth until the end of the follow-up period. The overall estimate of implant survival in our study was 97.9%.

The implant success/survival can be influenced by numerous factors, implant dimension, surface characteristics,
host factors, surgical technique, or any postoperative complications or infections [51]. The implant length reported in the included articles ranged from 6, 8, 10, 11.5, 13, and 15 mm. Majority of included studies reported length between 8 and 13 mm. Only 9 studies [8, 15–17, 30, 33–35, 39] used 6-mm length implants. One of the included articles [15] assessed the success rate relative to the length of the implant placed. According to Pjetursson et al. [15], the success rate of 6-mm trans-alveolar short implants placed with OSFE was 47.6%, while 8, 10, and 12-mm implants had success rates of 88.7%, 88.8%, and 100% respectively. The use of short implants resulted in reduced success/survival rate over a period of time. However, at the same time, it could reduce the chances of membrane tears.

The most common and frequent diameter of implants among the included studies ranged between 4 and 5 mm. However, only one study assessed implant survival in relation to the different implant diameters [16]. Lai et al. [16] showed that 161 implants with a diameter of 4.1 mm had a 95.15% survival rate, while 115 implants with a diameter of 4.8 mm had a survival rate of 96.62% [16].

Implant type as well as its surface characterization could also affect the implant success/survival rate. Sand-blasted, large-grit, acid-etched threaded implants were one of the most common types of implants used in the included articles. The SLA-treated surface results in increased bone-to-implant contact due to the elevated level of osteoblast proliferation and cellular adhesion at the surface of the dental implant [52]. These factors play a significant role in the process of osseointegration and aid in improving the wettability of the implant which is essential for better osseointegration in closed spaces like sinuses filled with blood clots.

The most frequent intra-surgical complication reported in the included studies was sinus membrane perforation, which occurred in 88 cases out of 2858 implants placed, 3.08% of the total implants with reported perforations. These results are in agreement with a previous systematic review by Tan et al. [53] that reported a total of 3.8% of perforations among 1776 implants assessed. A study by Del Fabbro et al. [54] also revealed 4.2% perforations out of a total of 3131 implants.

The endo-sinus bone gain is relative to the length of the implant [55]. Our analysis showed that the overall gain in the alveolar bone height was relatively higher in studies with < 6-mm RBH than in studies with > 6-mm RBH (2.459 mm 95%CI (2.232, 2.867) as compared to 2.218 mm 95% CI (1.882, 2.554)). The heterogeneity

![Fig. 5 Pooled estimate of gain in alveolar bone height with RBH more than 6mm](image)

![Fig. 6 Pooled estimate of crestal bone loss in immediate implants placed with OSFE after a 5-year follow-up](image)
among the included studies was high, probably due to possible confounding factors, such as the different lengths of the dental implants, RBH ranging from 2.1 to 6 mm, and inclusion of smokers among the participants. Smoking could be a detrimental factor leading to implant failure. A study by Barone et al. [56] concluded that the postoperative infection rate was higher in smokers compared to non-smokers. This was further supported by the observation by Cha et al. [57] that smoking could be a possible factor of implant failure in immediate implants placed after OSFE. In the present systematic review, the included studies were heterogeneous, and the effect of smoking on any of the parameters could not be assessed.

A prospective randomized controlled trial by Nedir et al. 2017 [38] showed that the mean crestal bone loss at the end of 5 years was 0.6 + 1.1 mm. The overall crestal bone loss in immediate implants placed with OSFE after a 5-year follow-up was 0.957 mm 95%CI (0.538, 1.377). The crestal bone loss around implants is observed at a higher rate in the first year of functional loading. After that, the marginal bone remains relatively stable in well-placed, properly osseo-integrated implants.

**Conclusion**

Within the limitations of this review, it can be concluded that the survival and success rates of implants placed immediately along with OSFE without any bone substitutes are 97.9 and 98.3 %, respectively. The most common complication observed with this technique was membrane perforation (up to 3.07% of the cases) that did not affect the survival of implants. OSFE showed improved alveolar bone height in the posterior maxilla with RBH < 6 mm and relatively stable crestal bone loss at the end of a 5-year follow-up.

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**Authors’ contributions**

MY designed the project; WL, SC, and LY were involved in data collection and data analysis; MY prepared and edited the manuscript; all authors read and approved the final manuscript.

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**Availability of data and materials**

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Declarations**

**Ethics approval and consent to participate**

Not applicable.

**Consent for publication**

Not applicable.

**Competing interests**

Mingfu Ye, Wenjun Liu, Shaolong Cheng, and Lihui Yan declare that they have no competing interests.

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