Implant Survival Rates after Osteotome-Mediated Maxillary Sinus Augmentation: A Systematic Review

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ABSTRACT

Purpose: The aim of the present study was to systematically evaluate the implant survival rate after osteotome-mediated maxillary sinus augmentation with or without using grafting materials.

Materials and Methods: MEDLINE database was searched using a combination of specific search terms. Furthermore, a hand searching of the relevant journals and of the bibliographies of reviews was performed. Prospective and retrospective clinical studies with at least 20 patients treated by osteotome-mediated sinus floor elevation were included.

Results: Nineteen studies were selected for data analysis. A total of 1,822 patients, accounting for 3,131 implants were considered. Mean weighted cumulative implant survival at 1, 2, 3, and 5 years was estimated as 98.12%, 97.40%, 96.75%, and 95.81%, respectively. No significant difference was found in relation to the use of grafting material nor in relation to implant length. Overall implant survival was 92.7% for 331 implants placed in <5 mm ridge height and 96.9% for 2,525 implants inserted in ≥5 mm ridge height. The difference was significant ($p = .0003$).

Conclusions: The transalveolar sinus augmentation technique could be a viable treatment in case of localized atrophy in the posterior maxilla even in case of minimal residual bone height. The prognosis can be more favorable when the residual ridge is at least 5 mm high.

KEY WORDS: atrophic maxilla, dental implants, maxillary sinus, osteotome, sinus lift

INTRODUCTION

Implant placement in the posterior maxilla is a challenging procedure when the available bone is reduced because of atrophy of the bone crest. Different materials and techniques have been proposed to augment bone volume in the posterior maxilla in order to allow for implant placement. Maxillary sinus augmentation technique is a common surgical procedure for creating adequate bone volume before implant placement.

While a lateral approach in sinus lifting is generally indicated in case of less than 4 to 5 mm of residual bone height,[1–3] a crestal approach was described as a viable treatment in the presence of greater bone height.[3–5] Tatum described the first technique for transalveolar maxillary sinus lift and subsequent placement of implants in 1986.[6] In the original technique, after fracturing sinus floor, an implant was placed and submerged during healing phase. A modification of this protocol was then proposed by Summers in 1994.[7] In this technique, implant site is prepared using a set of osteotomes that also allow increasing bone density through a lateral compression. The osteotome-mediated technique allows preservation of bone because drilling is avoided.

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Such transalveolar approach is more conservative than the lateral approach because only a small osteotomy is performed at crestal level.[4] Though, the main drawback is that both the sinus floor lifting and the bone grafting procedure is conducted blindly.[4]

In both procedures, after lifting of the Schneiderian membrane, various types of bone grafting material can fill the resulting space. However, several studies showed that even without using bone grafting material, the stabilization of blood clot after elevation of the sinus floor can be sufficient to obtain new bone formation.[8–10]

The aim of this systematic review was to evaluate implant survival rate (SR) after osteotome-mediated sinus lift procedure and evaluate factors potentially affecting the clinical outcome.

MATERIALS AND METHODS

Search Strategy

An electronic search was conducted via MEDLINE (Pubmed) in the dental literature to select only human clinical trials published from 1986 to December 2010. The search terms used were "sinus lift," "sinus augmentation," "sinus grafting," "sinus elevation," "osteotome AND implants," "osteotome AND sinus lift," "osteotome AND sinus augmentation," "osteotome AND sinus grafting," "osteotome AND sinus elevation," "crestal AND sinus lift," "crestal AND sinus augmentation," "crestal AND sinus grafting," and "crestal AND sinus elevation" and were chosen accordingly with previously published reviews.[1,3–5] No language restriction was placed.

A manual search was performed of the bibliographies of the selected articles and of the reviews resulting from the electronic search. In addition, a hand search of issues from 1995 to December 2010 was undertaken on the following journals: *British Journal of Oral and Maxillofacial Surgery*, *Clinical Implant Dentistry and Related Research*, *Clinical Oral Implants Research*, *Dental Clinics of North America*, *European Journal of Oral Implantology*, *International Journal of Oral and Maxillofacial Implants*, *International Journal of Oral and Maxillofacial Surgery*, *International Journal of Periodontics and Restorative Dentistry*, *Journal of Cranio-Maxillofacial Surgery*, *Journal of Oral and Maxillofacial Surgery*, *Journal of Periodontology*, *Journal of Prosthetic Dentistry*, *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontology*, and *Journal of Oral Surgery*.

Inclusion Criteria

This systematic review included prospective and retrospective cohort studies according to the following inclusion criteria:

- publications concerning transcrestal sinus lift in combination with implant placement;
- follow-up time of at least 1 year after prosthetic rehabilitation;
- studies with at least 20 patients treated; and
- studies presenting data on implant SR.

When papers from the same group of authors were identified, with very similar databases of patients, materials, methods, and outcomes, the authors were contacted to clarify whether the pool of patients was indeed the same. In case of multiple publications relative to consecutive phases of the same study, only the most recent data (those with the longer follow-up) were considered.

Selection of the Studies

Two reviewers (SC and ST) independently screened abstracts and full-text of the eligible articles for possible inclusion. In case of disagreement, a joint decision was taken by discussion.

Data Extraction

Two reviewers (SC and MDF) independently recorded data from the selected studies on a previously designed data extraction form.

Data regarding population (sample size, mean age) and the characteristics of the sinus lifting technique were extracted. Implant length was categorized into subclasses (less than 8.5 mm, 8.5 to 10 mm, >10 mm). Mean weighted SRs at 1 year, 2 years, 3 years, and 5 years of follow-up from implant placement were estimated, taking into account the sample size, the follow-up duration, and the timing of failures of each study. Data concerning surgical complications (like nose bleeding and membrane perforation) were also recorded.

Residual bone height was classified according to a threshold value (less than 5 mm and more than or equal to 5 mm). For studies that provided only the mean residual bone height value, it was assumed that all implants had been placed in crest with residual bone height equal to the mean value. One-year SRs were estimated for implants placed in <5 mm or

≥5 mm residual bone height by aggregating data from different studies.

Data Analysis

All comparisons between subgroups for any variable (follow-up duration, use of bone graft, implant length, residual bone height) were made by using Pearson's chi-square test. A probability level of $p = .05$ was considered as the threshold for significance. Odd ratios (ORs) and 95% confidence intervals (CIs) were also estimated.

RESULTS

Figure 1 summarizes the article selection process. The initial electronic search provided 420 items. After screening of the titles and abstracts, 351 articles were excluded because of not strictly pertinent to the aims of this review. A total of 69 full-text articles were eligible and underwent full-text evaluation. Of these, 50 articles were excluded because of not fulfilling the inclusion criteria. The most frequent reasons for exclusion were inadequate sample size, too short follow-up, and inadequate data reporting. A total of 19 studies were finally included for data analysis.[11–29]

The characteristics of the included studies are summarized in Table 1. A total of 1,822 patients and 3,131 implants were considered in this review. In one study,[13] the number of patients was not reported, and the reviewers assumed it was equivalent to the reported number of interventions.

The included studies were published between 1998 and 2010. Nine studies described the use of graft materials in combination with sinus membrane elevation,[11,12,15,17,19,20,24,26,27] while in 11 studies, no graft was used.[13,14,16,18,21–25,28,29] In one of the included studies, 35% of the implants were inserted in combination with bone grafting procedure, and for 65% of the implants, no graft was used.[24]

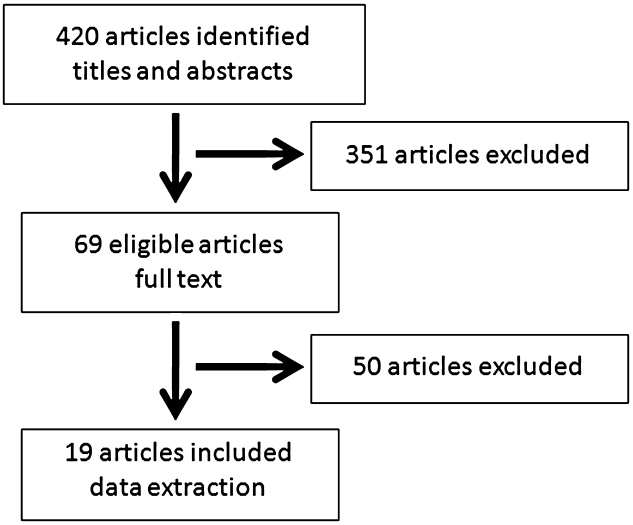

Figure 1 Flow of articles during the selection process.

Implant SR and Failures

Cumulative implant SRs were estimated for each study at the 1-, 2-, 3-, and 5-year follow-up (Table 2). Overall weighted mean SR was estimated to 98.12% at 1-year, 97.40% at 2-year, 96.75% at 3-year, and 95.81% at 5-year follow-up.

The pattern of implant failure in studies with at least 3-year follow-up is presented in Figure 2. A total of 2,884 implants in 14 studies[12–15,17,18,20,22–24,26–29] were considered in this analysis with a total of 92 failures over the years.

Effect of Bone Graft

Considering separately studies using[11,12,15,17,19,20,24,26,27] and not using[13,14,16,18,21–25,28,29] bone graft materials, the SR at 1 year was respectively 97.37% for 1,367 implants and 97.90% for 1,764 implants. No statistically significant difference was found between the outcomes of the two groups using Pearson's test ($p = .32$; OR = 0.79; 95% CI 0.50, 1.26).

Effect of Implant Length

Table 3 shows the distribution of implants according to implant length and residual ridge height. The mean values of these variables are also reported for each study, when available. A total of 1,791 implants in 15 studies[11,13–15,17,19–27,29] were considered: 387 implants shorter than 8.5 mm, 769 from 8.5 mm to 10 mm long, and 635 longer than 10 mm. Overall implant survival was, respectively, 97.16%, 97.66%, and 98.11% for the subgroups. No significant difference was found between subgroups, suggesting that implant length had no consistent relation with implant survival.

Effect of Residual Ridge Height

Residual ridge height was analyzed dichotomously and pooled according to the use of bone graft. Two studies did not provide sufficient data to be included in this subanalysis.[14,19] The mean residual bone height varied from 6.5 ± 1.7 mm[19] to 8.8 ± 2.5 mm[11] for implants placed in combination with bone graft and from

TABLE 1 General Characteristics of the Included Studies

Author	Year	Study Type	Total (*n*) Patients	Total (*n*) Implants	Total (*n*) Failures	Follow-Up Months, Mean (Range)	Type of Intervention	Grafting Material
Zitzmann and Scharer[11]	1998	Pro	20	59	3	23	Osteotome	ABB
Rosen and colleagues[12]	1999	Retro	101	174	8	(6–66)	Osteotome	ABB; ABG; FDBA; OgN
Cavicchia and colleagues[13]	2001	Pro	43*	97	11	35 (6–90)	Osteotome modified	None
Fugazzotto[14]	2002	Pro	103	116	2	(1–73)	Trephine/Osteotome	None
Toffler[15]	2004	Retro	167	276	18	27.9 (1–84)	Osteotome	ABB + ABG
Leblebicioglu and colleagues[16]	2005	Pro	40	75	2	24.6 ± 7	Osteotome	None
Ferrigno and colleagues[17]	2006	Pro	323	588	18	59.7 (12–144)	Osteotome	ABB; ABG
Jurisic and colleagues[18]	2008	Retro	33	40	0	36	Osteotome	None
Diss and colleagues[19]	2008	Pro	20	35	1	12	Osteotome	PRF
Kermalli and colleagues[20]	2008	Retro	45	57	2	5–84	Osteotome	ABB; ABG
Schmidlin and colleagues[21]	2008	Retro	24	24	0	17.6 ± 8.4	Osteotome	None
Gabbert and colleagues[22]	2009	Pro	36	92	4	14 (9–43)	Osteotome	None
Fermergard and Astrand[23]	2009	Retro	36	53	3	36	Osteotome	None
Pjetursson and colleagues[24]	2009	Pro	181	252	6	38 (12–84)	Osteotome	ABB
Nedir and colleagues[25]	2009	Pro	32	54	0	12	Osteotome	None
Calvo-Guirado and colleagues[26]	2010	Pro	30	60	2	36	Threaded bone dilators	PB
Crespi and colleagues[27]	2010	Pro	20	30	0	36	Osteotome	MgHA
Tetsch and colleagues[28]	2010	Retro	522	983	27	55 (12–180)	Osteotome	None
Bruschi and colleagues[29]	2010	Retro	46	66	3	125 (60–192)	Osteotome	None

*A minimum number of 43 patients.

ABB = anorganic bovine bone; ABG = autogenous bone graft; DFDBA = demineralized freeze-dried bone allograft; FDBA = freeze-dried bone allograft; MgHA = magnesium-enriched hydroxyapatite; OgN = Osteograf-N (Ceramed, Lakewood, CO, USA); PB = porcine bone; PRF = platelet-rich fibrin; Pro = prospective study; Retro = retrospective study.

TABLE 2 Implant Survival Rates Over Time

Study	*N*	CSR % 1 Year	*N*	CSR % 2 Years	*N*	CSR % 3 Years	*N*	CSR % 5 Years
Zitzmann and Scharer[11]	59	94.92	56	94.92	—	—	—	—
Rosen and colleagues[12]	174	98.28	79	97.03	43	97.03	—	—
Cavicchia and colleagues[13]	97	89.69	87	89.69	87	89.69	86	88.65
Fugazzotto[14]	116	98.28	83	98.28	40	98.28	—	—
Toffler[15]	276	96.38	266	95.29	263	93.48	258	93.48
Leblebicioglu and colleagues[16]	75	97.33	73	97.33	—	—	—	—
Ferrigno and colleagues[17]	588	99.83	431	99.60	359	99.32	230	98.46
Jurisic and colleagues[18]	40	100.00	40	100.00	40	100.00	—	—
Diss and colleagues[19]	35	97.14	—	—	—	—	—	—
Kermalli and colleagues[20]	57	96.49	55	96.49	55	96.49	55	96.49
Schmidlin and colleagues[21]	24	100.00	24	100.00	—	—	—	—
Gabbert and colleagues[22]	92	95.65	83	95.65	83	95.65	—	—
Fermergard and Astrand[23]	53	96.23	—	—	50	94.30	—	—
Pjetursson and colleagues[24]	252	98.81	200	97.82	144	97.14	38	97.14
Nedir and colleagues[25]	54	100.00	—	—	—	—	—	—
Calvo-Guirado and colleagues[26]	60	96.67	58	96.67	58	96.67	—	—
Crespi and colleagues[27]	30	100.00	30	100.00	30	100.00	—	—
Tetsch and colleagues[28]	983	98.88	887	97.88	805	97.39	529	96.84
Bruschi and colleagues[29]	66	95.45	63	95.45	63	95.45	63	95.45
	3,131	98.12*	2,515	97.40*	2,120	96.75*	1,259	95.81*

*Weighted mean cumulative implant survival.
CSR = cumulative survival rate; N = number of implants at the beginning of the interval.

2.5 ± 1.7[25] to 9.1 ± 0.3 mm[16] for implants placed without the use of bone graft. Overall implant survival was 92.7% for 331 implants placed in <5 mm ridge height and 96.9% for 2525 implants inserted in ≥5 mm ridge height. The difference was significant ($p = .0003$; OR = 0.43; 95% CI = 0.27, 0.69), suggesting that the prognosis can be more favorable when the residual ridge height is greater than 5 mm.

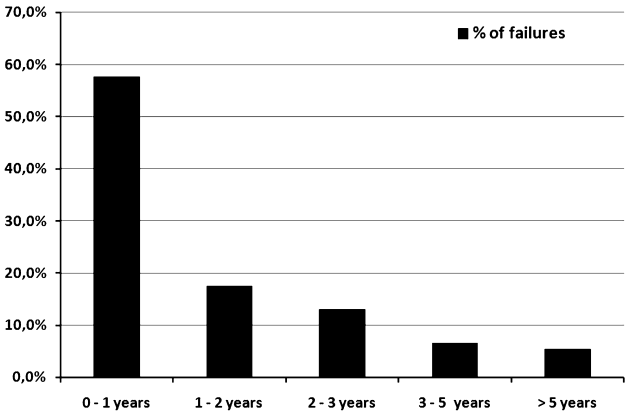

Figure 2 Pattern of implant failure over time in studies with at least 3-year follow-up.

Combined Effect of Grafting and Ridge Height

The data were further split by combining the analysis on grafting and that on ridge height. When a grafting procedure was performed, overall implant survival was 87.0% and 96.2% for residual ridge height of <5 mm ($n = 46$) and ≥5 mm ($n = 1198$), respectively. The difference was significant ($p = .002$; OR = 0.26; 95% CI = 0.10, 0.64). For implants placed without a grafting procedure, implant survival was 94.2% and 97.2% for residual ridge height of <5 mm ($n = 241$) and ≥5 mm ($n = 1151$), respectively ($p = .016$; OR = 0.46; 95% CI = 0.24, 0.88). This analysis confirmed that, independent of using a grafting procedure, better implant survival may be achieved when residual ridge height is at least 5 mm. In such a case, no significant difference was found between the outcomes of implants placed in combination or not with a grafting procedure ($p = .18$; OR = 0.73; 95% CI = 0.46, 1.16). Also for lower residual

TABLE 3 Implant Distribution According to Residual Ridge Height, Implant Length, and Use of Graft Material

		Residual Ridge Height			Implant Length				
Study	Total *n* Implants	Average, mm	<5 mm	≥5 mm	Average, mm	<8.5 mm	8.5–10 mm	>10 mm	Bone Graft
Zitzmann and Scharer[11]	59 (3)	8.8	0	59 (3)	n.r.	0	37 (2)	22 (1)	Yes
Rosen and colleagues[12]	174 (8)	n.r.	14 (2)	160 (6)	n.r.	n.r.	n.r.	n.r.	Yes
Cavicchia and colleagues[13]	97 (11)	2.9	97 (11)	0	12.3	6	28	63	No
Fugazzotto[14]	116 (2)	n.r.	n.r.	n.r.	9.1	20 (1)	87 (1)	9	No
Toffler[15]	276 (18)	7.1	15 (4)	261 (14)	11.1	0	78	198	Yes
Leblebicioglu and colleagues[16]	75 (2)	9.1	0	75 (2)	12.9	n.r.	n.r.	n.r.	No
Ferrigno and colleagues[17]	588 (18)	n.r.	0	588 (18)	10.1	103 (4)	342 (10)	143 (4)	Yes
Jurisic and colleagues[18]	40 (0)	n.r.	0	40	10.72	0	n.r.	n.r.	No
Diss and colleagues[19]	35 (1)	6.5	4	31	10.5	5	6	24	Yes
Kermalli and colleagues[20]	57 (2)	7.2	17	40 (2)	8.8	28 (1)	21	8 (1)	Yes
Schmidlin and colleagues[21]	24 (0)	3.6	24	0	8.6	15	9	0	No
Gabbert and colleagues[22]	92 (4)	n.r.	28	64	10.3	2	74	16	No
Fermergard and Astrand[23]	53 (3)	6.3	0	53 (3)	10.9	0	11 (1)	42 (1)	No
Pjetursson and colleagues[24]	252 88 (1) 164 (5)	7.5	44 (4)	176 (2)	8.7	164 (5)	77 (1)	9 (0)	Yes 35% No 65%
Nedir and colleagues[25]	54 (0)	2.5	54	0	8.4	44	10	0	No
Calvo-Guirado and colleagues[26]	60 (2)	n.r.	0	60 (2)	11.3	0	10 (1)	50 (1)	Yes
Crespi and colleagues[27]	30 (0)	6.62	0	30	12.3	0	7	23	Yes
Tetsch and colleagues[28]	983 (27)	8.2	0	983 (27)	11.5	n.r.	n.r.	n.r.	No
Bruschi and colleagues[29]	66 (3)	≤3	66 (3)	0	13.6	0	0	66 (3)	No

The number of failed implants is indicated within parentheses. Details on failed implants as residual ridge height and implant length were not always available.
n.r. = not reported.

ridges, no significant difference was found ($p = .08$; OR = 0.41; 95% CI = 0.15, 1.13), although the higher variation suggests that implant survival might be less predictable. The article by Pjetursson and colleagues, in which the transalveolar technique was performed either with or without grafting, had to be excluded from the latter analysis as it did not provide sufficient details for splitting the data as required.[24]

Intrasurgical Complications

Nose bleeding was reported in 0.3% of cases in which a grafting procedure was adopted ($n = 1367$) and in 1.6% of cases performed without grafting ($n = 1764$). The difference was significant ($p = .0003$; OR = 5.50; 95% CI = 1.92, 15.71). Sinus membrane perforation was reported in 2.5% and 1.7% of cases performed with or without grafting, respectively. Such difference was not significant ($p = .12$; OR = 0.68; 95% CI = 0.41, 1.11).

DISCUSSION

Previous systematic reviews suggested that the cumulative SRs for implants placed with transalveolar technique are comparable with those relative to implants placed in native maxillary bone.[4,5] However, the advantage of using bone grafting material in the osteotome technique was not clearly demonstrated and discussed in the above-mentioned reviews.[4,5]

In the present study, the SR for implants placed in combination with osteotome-mediated sinus floor elevation was around 95% at 3-year follow-up demonstrating the high standard of performance of this treatment option. Implant failures occurred mainly during the first year after prosthetic loading, while only about one-third of the total failures occurred subsequently.

Several studies showed that neo-osteogenesis may occur even when the sinus membrane is lifted and the underneath space filled by blood clot.[9,30–34] It was hypothesized that blood clot can induce neo-osteogenesis through the stimulation of osteoprogenitor cells from the periosteum.[35] Other authors observed the spontaneous bone formation under the Schneiderian membrane after tooth extraction or cyst removal in the posterior maxilla.[9,36] It was also postulated that the membrane itself has osteogenic potential that may support bone neoformation.[32]

These considerations provided the biological background to perform the transalveolar sinus lifting procedure without the use of any graft material. As evidenced in the present review, studies in which the sinus membrane is lifted without using bone grafts are relatively recent in comparison with those using grafting material. Moreover no statistically significant difference was observed as regard to implant SR at 1-year follow-up ($p = .32$) between studies using or not using a grafting material. Thus, it could be postulated that the use of grafting material should not be considered fundamental for achieving successful outcomes in the transalveolar technique.

Some of the included studies emphasized the finding that implant failures occur more frequently when using short implants,[17,24] suggesting an inverse relation between implant failure rate and implant length. Such relation, however, could not be confirmed by the present review. Implants less than 8.5 mm long displayed an SR comparable with longer ones, as also reported in previous studies.[37–39] If the implant length is appropriately chosen in function of the available bone, and the prosthetic design is correct, the use of short or extra-short implants is not contraindicated and may as well lead to successful outcomes as shown by recent literature.[40–42]

Analysis of residual ridge height was limited by incomplete reported data. It was observed that, generally, the use of bone grafting procedure was not correlated with initial bone height, although no significant correlation could be obtained. Otherwise, also in studies where reported mean initial bone height was less than 3 mm, the sinus lifting procedure without grafting was successful and without severe adverse sequelae.[13,25,29]

While residual ridge height is considered a fundamental factor to achieve implant primary stability immediately after placement, which is critical to successful osseointegration, residual ridge height analysis lead to other relevant considerations. It could be postulated that bone neoformation in the transalveolar technique may not depend only on residual bone height because all anatomical local components (including Schneiderian membrane and periosteum) together may contribute. This concept implies that, in order to obtain neo-osteogenesis without the use of bone grafting material, the integrity of these structures should be preserved as much as possible during surgical procedure. The analysis concerning intrasurgical complications showed substantial equivalence in membrane perforation rate between cases treated using and not

using grafting procedure, the incidence being rather low as compared with perforation rates reported for the lateral approach.[43–45] It should be noted, however, that a number of unnoticed perforations of the membrane should be reasonably taken into account, due to the blindness of the procedure regarding this aspect. Therefore, the results of such analysis should be interpreted cautiously.

Thus, similar to the scientific literature pertinent to sinus lifting with lateral approach,[6,46,47] successful implant rehabilitation could be achieved with transalveolar technique also in cases with scarce residual bone height.

The low implant SR found when grafting procedure is used in the presence of a ridge less than 5 mm high (87%), even though not significantly different from the outcome of procedures without grafting in similar ridge height, could be misleading. Indeed, such a value was estimated using a very low sample size ($n = 46$) respect to the other subgroups, and most failures derive from a single study.[15] Clearly, a higher sample size is needed to get more insight in this issue.

Some limitations could be identified in the present paper. First, the absence of randomized controlled trials prevents the estimation of the true efficacy of the use of bone grafting material in the transalveolar maxillary sinus augmentation procedure. Incomplete data reporting in most of the included studies precluded the possibility to perform a consistent meta-analysis. Only weighted mean implant SRs could be estimated and used for comparisons. Furthermore, the absence of individual patients' data for most variables, such as the residual bone height, could be a confounding factor in all comparative analyses. Finally, the use of the implant instead of the patient as the analysis unit was due as most of the included studies did not provide information at patient level about the failures.

Within the limitations of the study, we can assume that the transalveolar sinus augmentation technique could be a viable treatment in case of localized atrophy in the posterior maxilla even in case of minimal residual bone height. The authors could find no differences in terms of SRs in relation with the use of bone grafting material or not.

Further RCT studies with larger sample size and precise description of anatomical features of the bone crest could be useful for gaining more insight on this treatment option.

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