Long-Term Outcomes for the Treatment of Atrophic Posterior Maxilla: A Systematic Review of Literature

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ABSTRACT

Purpose: The aim of the present systematic review was to estimate the implant survival rate in different types of techniques for the rehabilitation of posterior atrophic maxilla, after at least 3 years of follow-up.

Materials and Methods: MEDLINE database was searched using a combination of specific terms. A hand searching of the relevant journals and of the reference lists of systematic reviews was also performed. All retrospective and prospective studies evaluating short implants in posterior maxilla, osteotome sinus floor elevation and lateral approach sinus floor elevation, and having a follow-up of at least 3 years, were included.

Results: Forty-four articles were included in the review. In four studies reporting on a total of 901 short implants, the implant survival rate varied from 86.5% to 98.2% with up to 5 years follow-up. For the osteotome technique, 1,208 implants in eight studies were considered, showing a survival rate varying from 95.4% to 100% after 3-year follow-up. Twenty-nine studies, accounting for 6,940 implants placed in 2,707 sinuses augmented through lateral technique were considered. Implant survival rate varied from 75.57% to 100%. Only three comparative studies were found that showed no significant difference in clinical outcomes between lateral approach and osteotome technique.

Conclusions: Sinus floor elevation with the lateral approach and with the osteotome technique is an effective and well-documented therapeutic option for the rehabilitation of atrophic posterior maxilla. The use of short implants is promising but needs further investigation to be considered as effective as the other techniques in the long term. However, the indication for the three different techniques is not perfectly equivalent and the treatment choice should be based on a careful evaluation of the individual case, in particular on the available residual bone.

KEY WORDS: lateral approach, osteotome, posterior maxilla, short implant, sinus floor elevation, sinus lift

INTRODUCTION

An inadequate bone volume in the posterior maxilla is a frequent anatomical restriction for implant placement. The loss of bone can strongly influence the choice of the most appropriate rehabilitation in edentulous patients.

Even though the application of removable prosthesis to treat posterior edentulism can be considered as a treatment alternative, it was demonstrated that such treatment can cause an impairment in mastication function and may compromise the prognosis of adjacent teeth in comparison with implant-supported rehabilitations.[1,2]

Moreover, placement of dental implants in the atrophic posterior maxilla is a challenging procedure due to

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risk of violation of the maxillary sinuses during surgical procedures.[3,4]

Various techniques have been proposed in order to achieve the necessary bone dimension for the insertion of implants.[5,6] In the last years, due to the improvement of surgical techniques and the progress of research in the field of biomaterials, excellent outcomes have been reported for implant-supported rehabilitations.[7–9]

Recent systematic reviews of the literature have demonstrated that sinus floor augmentation procedure is well documented with an overall implant survival rate well beyond 90%.[10–14] In some cases, the presence of a sinus pathology as sinus inflammation, nasal/sinus obstruction, and oroantral fistulation, requires a presinus lift referral to ear, nose, and throat specialist.[3,15,16] Moreover, several types of complications may occur during and after the sinus elevation procedure with lateral approach. In fact, relatively frequent Schneiderian membrane perforations, nose bleeding, postoperative pain, and swelling could be considered as major drawbacks for this treatment alternative.[11,17,18]

More recently, short implants (SIs) (less than 10 mm long) were proposed as an alternative to sinus augmentation in order to rehabilitate posterior maxilla, allowing to reduce the occurrence of surgical complications and the impact on patients' quality of life.[19–22]

The main objective of this systematic review was to compare the medium- to long-term outcomes of the three alternative techniques for the rehabilitation of the atrophic posterior maxilla with fixed prosthesis, based on clinical reports from 1970 to 2012.

MATERIALS AND METHODS

Search Strategy

The electronic search was performed on MEDLINE (through PubMed interface), EMBASE, and the Cochrane Library. A search string was created ad hoc combining keywords with the use of boolean operators "AND" and "OR". The search string was ((("sinus" OR "maxillary sinus") AND ("floor elevation" OR "lift" OR "augmentation" OR "elevation" OR "lateral approach" OR "crestal approach" OR "transcrestal approach" OR "BAOSFE" OR "OSFE" OR "Summers technique" OR "osteotome-mediated" OR "osteotome")) OR ("short implant*" OR "reduced length implant*" OR "extra-short implant*")) AND ("maxilla" OR "posterior maxilla" OR "atrophic posterior maxilla"). Results were limited by year of publication (from 1970) and the last search was performed in January 2013. In addition, a manual research was performed in the reference lists of selected articles and in all issues since 1990 of 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*, *Journal of Oral Surgery*. The language of the studies in the search was restricted to English and French.

Study Selection Criteria

The following inclusion criteria had to be met to be included in the review:

1 study on humans;
2 randomized or nonrandomized controlled clinical trials (RCT or CCT) with at least 3 years of mean follow-up for all implants (20% dropouts allowed) comparing at least two of the treatment options (lateral approach sinus floor elevation (LASFE), osteotome sinus floor elevation [OSFE], or SIs) for the treatment of edentulous posterior maxilla and reporting on at least 10 patients for each treatment group;
3 noncomparative prospective or retrospective studies with at least 3 years of mean follow-up (20% dropouts allowed) regarding one of the treatment options (LASFE, OSFE, or SIs) for the treatment of edentulous posterior maxilla and at least 20 implants placed;
4 clearly reported data about implant survival, implant failures, and implant success, describing success and survival criteria and causes of implant failure; in cases of inadequate data, reporting authors were contacted through e-mail asking for missing information;
5 clear presentation of patients' demographics;
6 clear definition of selection criteria and success criteria.

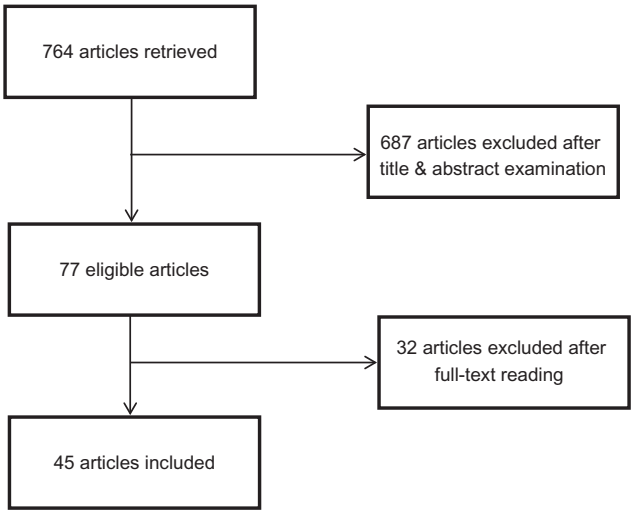

Figure 1 Flowchart of article selection process.

Data Extraction and Analysis

The primary outcomes evaluated were:

1 implant survival rate defined as the percentage of implants still in function;
2 implant success rate defined as the percentage of implants in function without any sign or symptoms of complications (peri-implant radiolucency, signs of inflammation and pain, excessive marginal bone loss);
3 implant failure rate defined as the percentage of implants removed for any reason;
4 occurrence of complications as peri-implant diseases and infections, maxillary sinus pathologies following grafting procedure, prosthesis failure, and any other biomechanical complications.

For comparative studies, the meta-analysis was made using Review Manager 5.1 (Cochrane Library, http://www.ims.cochrane.org/revman). LASFE technique was compared with OSFE technique in terms of risk of implant failure.

TABLE 1 Excluded Studies and Reasons for Exclusion

Reason for Exclusion	*N*	Studies
Inadequate data reporting	9	84–92
Inadequate follow-up	19	88, 93–110
Small sample size	2	111, 112
Other reasons	2	113, 114
Data regarding other rehabilitations		
Older data		

In case of impossibility of performing a meta-analysis, a narrative data analysis would be presented.

RESULTS

Article selection process is summarized in the flowchart shown in Figure 1. The first electronic search yielded 764 articles. After title and abstract screening, 76 articles were selected for full-text reading. A total of 44 articles were finally included in the review: four studies dealing with SIs,[23–26] eight studies regarding OSFE,[27–34] 29 studies regarding LASFE,[35–63] and three comparative studies.[64–66] The reasons for study exclusion after full-text evaluation are listed in Table 1.

Due to the characteristics of the data from the included studies, a narrative presentation of the outcomes was presented. For comparative studies, a meta-analysis was performed.

SIs

Data extracted from studies concerning SIs are summarized in Table 2. Nine hundred one implants were inserted in the posterior maxilla. The mean reported implant length varied from 6.56[26] to 8.2 mm,[24] while no study reported data on the residual bone height. Implant

TABLE 2 Summary of Data of Short Implants Studies

Author	Year	Study Type	No. of Patients	No. of Implants	Mean Implant Length (mm)	Mean Follow-Up Duration (Years)	Results
Feldman and colleagues[23]	2004	Pros	NE	568	8.12	Up to 5	96.60% 5 years (rough); 86.50% 5 years (machined)
Maló and colleagues[24]	2007	Retro	NE	113	8.2	1–9-year	Survival rate: 94.69%
Lai and colleagues[25]	2012	Retro	71	110	7.71	5–10-year	Survival rate: 98.20%
Perelli and colleagues[26]	2012	Pros	87	110	6.56	5 years	Survival rate: 90%

NE, not estimable; Pros, prospective study; Retro, retrospective study.

TABLE 3 Summary of Data of Osteotome Sinus Lift Studies

Authors	Year	Study Type	Treatment	No. of Patients	No. of Implants	Mean Implant Length (mm)	Mean Residual Bone Height (mm)	Mean Follow-Up (Months)	ISR%
Ferrigno and colleagues[27]	2006	Pros	BAOSFE (ABG)	323	588	10.1	7.7	59.7	98.46
Pjetursson and colleagues[28]	2009	Pros	BAOSFE (ABG/None)	181	252	8.7	7.5 ± 2.2	38	97.14
Fermegard & Astrand[29]	2012	Retro	OSFE	36	53	10.9	6.3	36	94.30
Nedir and colleagues[30]	2010	Pros	OSFE	17	25	8.4	5.4 ± 2.3	59	100.00
Bruschi and colleagues[31]	2012	Retro	OSFE	46	66	13.6	≤3	125	95.45
Crespi and colleagues[32]	2010	Pros	OSFE	20	30	12.3	6.62	36	100.00
Calvo-Guirado and colleagues[33]	2011	Pros	BAOSFE (PB)	30	60	11.3	NR	36	96.67
Bernardello and colleagues[34]	2011	Retro	BAOSFE (ABG)	117	134	12.9	3.42	48.2	95.52

ABG, autogenous bone graft; BAOSFE, bone added osteotome sinus floor elevation; ISR, implant survival rate; NR, not reported; OSFE, osteotome sinus floor elevation; PB, porcine bone.

survival rate varied from 86.5[23] to 98.2%[25] with up to 5-year follow-up.

OSFE

Data about studies adopting the osteotome technique are summarized in Table 3. A total of 1,208 implants placed in 770 patients were considered in the review. The mean follow-up varied from 36 months[29] to 125 months,[31] while the survival rate after 3 years varied from 95.4%[31] to 100%.[30,32]

LASFE

Data from studies about LASFE are summarized in Table 4. A total of 6,940 implants, placed in 2,707 augmented sinuses in 2,301 patients, were considered. A total of 446 failures were recorded. In a single study, the number of failures of implants placed in lifted sinuses was not estimable.[46] The mean follow-up varied from 36 months[40,41,45,53] to 84 months.[51] Implant survival rate varied from 75.6%[40] to 100%.[39,56,62,63]

Comparative Studies

A summary of data of studies comparing different techniques is presented in Table 5. Three studies compared LASFE and osteotome technique.[64–66] A total of 1,287 implants placed in sinuses augmented using the LASFE technique in 526 patients were compared with 1,063 implants placed in 569 patients treated with the OSFE technique. The survival rates varied from 97.3%[66] to 100%[64,65] for LASFE group and from 97.7%[66] to 100%[64,65] for OSFE group, without any significant difference between the two treatments. The follow-up varied from 36 months[65] to 176 months.[66] The meta-analysis confirmed the absence of a significant difference in outcomes between the two treatment alternatives (Figure 2).

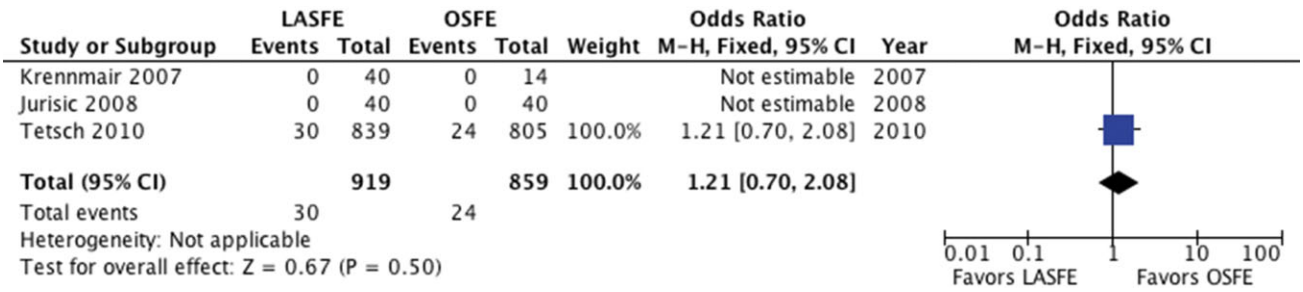

Figure 2 Meta-analysis of studies comparing LASFE and OSFE (implant failures at 3-year follow-up). LASFE, lateral approach sinus floor elevation; OSFE, osteotome sinus floor elevation.

TABLE 4 Summary of Data of Lateral Sinus Lift Studies

Authors	Year	Study Type	Graft	No. of Patients	No. of Sinuses	No. of Implants	Mean Residual Bone Height	Mean Follow-Up (Months)	ISR%
Hurzeler and colleagues[35]	1996	Pros	Other	113	113*	340	NR	38.5	98.80
Block & Kent[36]	1997	Retro	ABG	33	53	173	NR	70	88.44
Block and colleagues[37]	1998	Retro	ABG + Mixed	16	27	73	5.1 ± 2.2	75	95.89
Kaptein and colleagues[38]	1998	Retro	Mixed	88	132	388	NE	55	88.14
Buchmann and colleagues[39]	1999	Pros	ABG	50	75	167	<5 mm	60	100.00
Johansson and colleagues[40]	1999	Retro	ABG	39	39	131	<5 mm	36	75.57
Lekholm and colleagues[41]	1999	Retro	ABG	55	82	280	NR	36	81.07
Becktor and colleagues[42]	2002	Retro	ABG	81	120	329	NR	64.2	79.64
Valentini and colleagues[43]	2003	Retro	Other	59	78	187	<5 mm	78	94.65
Hallman and colleagues[44]	2004	CS	Mixed	20	30	108	1.6–3.8 mm	60	86.11
Boyne and colleagues[45]	2005	RCT	ABG/Other	44	88	219	<6 mm	36	83.11
Ellegaard and colleagues[46]	2006	Retro	None	68	71	131	>3 mm	64.2/57.5	91.00/88.70 (5 years)
Peleg and colleagues[47]	2006	CT	ABG/Mixed/Other	731	731	2132	NE	69	98.45
Becktor and colleagues[48]	2007	Retro	ABG (Block)	17	17	69	NR	53.1	91.30
Huynh-Ba and colleagues[49]	2008	Retro	NR	71	71*	116	NR	36.9	92.20
Bornstein and colleagues[50]	2008	Pros	Mixed/Other	56	59	111	<4 mm	NR	98.00
Yamamichi and colleagues[51]	2008	Retro	ABG/Mixed/Other	188	188	466	NE	84	96.35
Blus and colleagues[52]	2008	Retro	ABG + Mixed/+ PRP	34	53	117	<6 mm	44.2	96.60
Sbordone and colleagues[53]	2009	Retro	ABG	28	39	70	NE	36	92.45
Manso and colleagues[54]	2010	Pros	Mixed	45	57	160	<4 mm	61.7	98.05
Scarano and colleagues[55]	2010	Retro	Porcine Bone	113	153	264	2–3 mm	60	94.70
Garlini and colleagues.[56]	2010	Retro	Resorb HA	26	27	47	7.4 mm	72	100.00
Zijderveld and colleagues[57]	2009	CT	ABG/Beta-TCP	20	24	60	5.4–7 mm	60	98.33
Cho-Lee and colleagues[58]	2010	Retro	ABG/Mixed	119	177	272	6.59 mm	60.7	93.01
Lambert and colleagues[59]	2010	Retro	Other	40	50	102	NE	44.4	97.50
Barone and colleagues[60]	2011	CS	Mixed	41	41*	201	NR	69.9	86.00
Caubet and colleagues[61]	2011	Retro	Mixed	34	40	63	<4 mm	60	96.90
Lin and colleagues[62]	2011	Pros	None	44	44*	80	5.06 ± 1.51	>60	100.00
Ozkan and colleagues[63]	2011	Pros	Other	28	28*	84	5.2 mm	60	100.00

*Estimated on the basis of the number of patients as the minimum number of sinuses treated.
ABG, autogenous bone graft; CS, cohort study; CT, controlled trial; NE, not estimable; NR, not reported; RCT, randomized controlled trial.

TABLE 5 Summary of Data of Comparative Studies

Authors	Year	Study Type	Treatment	No. of Patients	No. of Implants	Mean Implant Length (mm)	Mean Residual Bone Height (mm)	Mean Follow-Up (Months)	ISR%
Osteotome sinus lift versus lateral sinus lift									
Krennmair and colleagues[64]	2007	Retro	Sinus Lateral (BioOss)	37	40	11.6 ± 1.3; 12 ± 1	7.8 ± 0.8; 3.5 ± 0.8	44.5 ± 22.7	100
			Osteotome (BAOSFE – BioOss)	14	14	11.6 ± 1.1	9.6 ± 0.9		100
Jurisic and colleagues[65]	2008	Pros	Sinus Lateral (BioOss)	28	40	11.10 ± 0.69; 11.02 ± 0.71	NE	36	100
			Osteotome (BAOSFE – BioOss)	33	40	10.72 ± 0.76	NE		100
Tetsch and colleagues[66]	2010	Retro	Sinus Lateral (Various)	461	1207	8–16	Mean deficit: 6.5	176	97.30
			Osteotome (OSFE)	522	983		Mean deficit: 3.3		97.70

BAOSFE, bone added osteotome sinus floor elevation; NE, not estimable; OSFE, osteotome sinus floor elevation.

DISCUSSION

The present systematic review sought at evaluating the medium- and long-term outcomes of different treatment alternatives for the rehabilitation of atrophic posterior maxilla. In spite of the strict inclusion criteria, the selected articles presented heterogeneity regarding study design, sample size, graft materials and techniques, implant type, shape and surface, baseline features of the patient populations. Therefore, the present results have to be interpreted cautiously.

SIs

The analysis of the performance of SIs in the posterior maxilla was restricted only to a few studies. This was mainly due to the exclusion of many studies which have a follow-up shorter than 3 years. Though the number of included articles is limited in comparison with the other two techniques, the results of this review are coherent with those presented in previously published systematic reviews which also included short-term studies.[19,22,67,68]

Similar outcomes were reported by retrospective and prospective studies. In one study, the authors showed that the survival rate of short machined implants was significantly lower than that of textured ones,[20] as also confirmed by the results of two systematic reviews.[19,68] However, this consideration appeared to have a scarce clinical relevance in modern implant dentistry, as currently the majority of implants have a textured surface.

The residual bone height at the region intended for implant placement was not systematically reported, preventing a precise analysis of its effects on clinical outcomes.

OSFE

The OSFE (or BAOSFE) technique was originally described as a viable treatment in patients with more than 5 mm of residual bone height in the posterior edentulous maxilla.[69–71] Such approach is considered less invasive than the lateral one; however, the major drawback is that the lifting procedure has to be performed blindly by the operator, who can be unaware of a membrane injury during the surgical procedure.[70]

Recently, a systematic review of the literature showed that crestal sinus lift can be an effective treatment option, reporting a mean weighted survival rate of 95% after 5 years of function.[13] That review also showed that the majority of failures occurred during the first

year after treatment. Finally, no significant difference in outcomes was observed between studies that used a bone substitute during the lifting procedure and those in which no grafting was adopted.[13]

In the present review, excellent implant survival rates were showed for the OSFE (or BAOSFE) technique in studies with at least 36 months of mean follow-up. Moreover, the mean residual bone height appeared not to influence implant survival rate; in fact, even in studies reporting less than 5 mm of residual ridge height a high survival rate was observed.[31,34]

Similarly to what was stated in the previously cited review,[13] no specific benefit of grafting with autogenous bone or a bone substitute could be observed; rather, the key factor appeared to be the clot formation and the stabilization of the lifted floor.[46,72–76]

Besides, retrospective and prospective studies displayed similar outcomes (94.3%[29] to 95.52%[34] in retrospective studies and 96.67%[33] to 100%[30,32] in prospective ones), showing that the study design appeared not to affect clinical results in the included articles.

Lateral Technique

The LASFE technique is widely described in the literature and it is recommended in cases of residual bone height lower than 4 to 5 mm.[10,47,71]

A high survival rate was reported in the great majority of the included studies, demonstrating that LASFE could be considered a viable treatment alternative both in the medium and long term. Moreover, as a general consideration, the lowest survival rates were reported in older studies.[36,38,40,48,77] This is in agreement with the results of another recent systematic review[77] and can probably be related to different implant morphologies and surface textures used in older studies.

A great heterogeneity of study design was found even if apparently this did not influence the reported outcomes, confirming what was observed for the other treatment alternatives.

Different bone grafting materials were used in the included studies: autogenous bone, xenografts, allografts, synthetic bone substitutes, and several combinations of these graft materials. As described in the literature, such heterogeneity had no relevant effect on the clinical outcomes.[78,79] It is noticeable that two studies in which no bone substitute was used after sinus floor elevation reported survival rates comparable with those from studies describing the use of bone substitute material.[46,62]

Comparative Studies

Comparative randomized studies were generally considered as the primary studies with the highest level of evidence. In the present systematic review, three comparative studies were included,[64–66] but none of them was an RCT. In the meta-analysis of such studies (Figure 2), two out of three studies reported no failure in each group, thereby noncontributing to the effect estimation. However, data from these two studies may further support the absence of difference between the outcomes of the two techniques.

Considering the 3-year results, no difference among treatments could be evaluated in terms of clinical outcomes. If we consider the single arms of each controlled study, the clinical outcomes were quite comparable with those presented in cohort studies evaluating only a single treatment. Even though the authors agree that comparative studies provide more information than single-cohort studies or retrospective ones, the validity of the outcomes in terms of treatment prognosis could be considered similar.

Several limitations emerged in this study. First, the consideration of mean follow-up of 3 years caused the exclusion of good studies with shorter follow-up duration. Then, the lack of some data concerning demographics in studies evaluating SIs could have limited the power of the analysis of this treatment alternative.

Finally, although the clinical outcomes of the three techniques in terms of implant survival were similar, some considerations have to be done regarding the true interchangeability of these different surgical approaches from the practical point of view. The LASFE indeed represents the most invasive approach but it is the only one that allows the treatment of severe ridge atrophy and difficult cases because of its wider field of view and more comfortable management of the sinus region as compared with other techniques. A systematic review by Chao and colleagues evaluated the effect of initial bone height on implant survival rate using a quadratic-curve fitting meta-regression analysis.[80] They found for the lateral approach a very predictable outcome for bone height 4 mm or greater, near to 100% implant survival rate, while there was a decreasing trend as the residual ridge height decreased, with the lowest implant survival rate of 86% in correspondence with a mean ridge height of 1.5 mm. For the crestal approach, no study was found with a ridge height lower than 4 mm, whereas for higher ridges the outcome ranged between 93% and 100%.

Though a few more recent studies reported a successful crestal approach to the maxillary sinus floor elevation even when the residual ridge height is lower than 4 mm,[32,35] the sinus management through a "blind" technique such as the BAOSFE in the presence of a very reduced bone height should be reserved only to very experienced surgeons.

Regarding the complications associated with sinus augmentation, Schneiderian membrane perforation was found to occur more frequently with a reduced ridge height mainly due to technical difficulties.[81,82] It has also been suggested that a wider portion of the sinus membrane may have to be elevated when dealing with a smaller initial ridge height, which might produce an increased risk of sinus membrane perforation.[83]

Therefore, it seems reasonable and safer to recommend the LASFE technique when the residual ridge height is 4 mm or less and let the clinician decide, based on careful clinical and radiographic assessment, whether to adopt the crestal approach in the presence of at least 5 mm.

Regarding the adoption of SIs, again a careful evaluation of the residual bone height and width is mandatory. The rationale of using SIs is to avoid augmentation procedures, reducing patient's discomfort; however, there must be sufficient residual volume to accommodate the implants ensuring primary stability. The fact that SIs with wide diameter can have a contact surface available for osseointegration which is comparable with longer ones with narrow diameter should be considered in the presence of wide bone crest. Moreover, SIs should be indicated in case of systemic conditions contraindicating more invasive surgeries. Finally, in the presence of pathology as chronic sinusitis, the involvement of sinus should be avoided and SIs could represent a valid treatment alternative to ear-nose-throat treatment and maxillary sinus augmentation.

CONCLUSIONS

The analyzed data suggested that SIs, OSFE (or BAOSFE), and LASFE had similar clinical outcomes. A larger volume of literature was available for LASFE while the long-term evidence for SIs is still scarce and more well-designed studies with a better description of implant demographics are needed for such treatment option.

Taking into account the current available evidence, the clinical indication for each of the three techniques is not strictly equivalent. LASFE should be considered the standard of care in cases of atrophic posterior maxilla even though OSFE can be considered a viable alternative when the need for bone volume increase is limited. In spite of the limited long-term evidence, SIs represent an appealing and successful alternative in the presence of a sufficient residual bone volume. They should be considered especially in those patients seeking for an alternative to more demanding bone augmentation techniques. In fact, patients' wills and expectations, as well as the clinician's confidence in specific techniques, should be taken into account in the treatment choice. Reduced invasiveness and shorter treatment times for prosthetic rehabilitations are important issues in favor of SIs together with the impossibility of performing LASFE or OSFE in cases of presence of sinus pathosis.

More data from high evidence-based and well-reported studies are needed to clarify the specific indications for each treatment.

DISCLOSURE

The authors declare that they are free from any conflict of interest.

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None.

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