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REVIEW ARTICLE

Minimal invasiveness in the transcrestal elevation of the maxillary sinus floor: A systematic review

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1 | INTRODUCTION

Transcrestal sinus floor elevation of the maxillary sinus floor is a surgical option to restore adequate ridge dimensions for implant placement at atrophic maxillary posterior sites. Technically, transcrestal sinus floor elevation consists of two consecutive steps. First, access to the maxillary sinus membrane is obtained through the implant site. Then, the sinus membrane, submucosa, and periosteum are detached from the maxillary sinus floor and displaced cranially to place one or more implants (and, eventually, a space-making material) without perforating the endosinusal soft tissues. Transcrestal sinus floor elevation was presented in 1977 and published in 1986 by Dr Hilt Tatum,[1,2] and was later modified by Summers, who suggested the use of a specific set of osteotomes.[3,4] Since Summers' publications,[3,4] many surgical techniques, differing for one or both steps, have been proposed for transcrestal sinus floor elevation.[5] The methods investigated most to create a sinus access include the use of osteotomes,[3,4,6–8] rotating instruments,[9–14] a combination of osteotomes and trephine burs,[15] and ultrasonic piezoelectric instruments;[16] the mechanical (hydraulic) pressure for the detachment of the endosinusal soft tissues from the sinus floor can be generated by different methods, including osteotomes alone,[12] a combination of osteotome and graft biomaterials,[4] a combination of osteotomes, trephined pristine bone core, plus graft biomaterials,[17–20] piezoelectric inserts with internal irrigation,[16] injection of liquids through a channel internal to the implant body,[21] and inflatable devices.[22]

Data from several systematic reviews indicate that transcrestal sinus floor elevation represents a valid option in terms of extent of subantral bone augmentation and implant survival rates.[23–29] Based on moderate-quality evidence, a network meta-analysis showed that transcrestal sinus floor elevation is superior to lateral sinus floor elevation at sites with a residual bone height of 4-8 mm.[30] A recent randomized trial conducted a comparative evaluation of transcrestal sinus floor elevation (performed according to a standardized sequence of manual and rotating instruments used with stop devices) and lateral sinus floor elevation at sites with a residual bone height of 3-6 mm, generating data on morbidity,[31,32] radiographic outcomes,[32,33] chair time,[31] costs,[34] and specific aspects of oral health–related quality of life.[34] Several results favored transcrestal sinus floor elevation (Table 1). When considered collectively, the meta-analysis by Al-Moraissi et al[30] and the clinical trial by Farina and coworkers[31–34] clearly indicate that one of the aspects supporting the use of transcrestal sinus floor elevation resides in its limited invasiveness. Within the context of sinus floor elevation procedures, "invasiveness" is a broad term that includes need/number of invasive preoperative diagnostic examinations; intra- and postoperative morbidity, complications, and adverse events with respect to the surgical protocol; number of surgical sessions and chair time needed for each session; need for autologous tissue harvesting and/or reconstructive devices; and costs related to the surgery (eg, anesthetic, graft material) and postsurgery phases (eg, management of complications). As for other surgical interventions in dental implantology, invasiveness is a key factor that may orient clinical decision-making when approaching a maxillary sinus floor elevation procedure, in general, and transcrestal sinus floor elevation, in particular.[35,36]

Over the last three decades, technical and technological advancements have allowed for progressively reducing transcrestal sinus floor elevation invasiveness.[5,35] Consistently, it has been demonstrated that the invasiveness of transcrestal sinus floor elevation may approach that of implant placement entirely in native bone,

TABLE 1 Synopsis of the main results stemming from the comparative evaluation of transcrestal sinus floor elevation and lateral sinus floor elevation in the randomized trial performed by Farina and coworkers[31–34]

Outcome		Reference study	Main results		
			In favor of transcrestal sinus floor elevation	Indicating comparable performance of transcrestal sinus floor elevation and lateral sinus floor elevation	In favor of lateral sinus floor elevation
Chair time		Farina et al (2018)[31]	• Significantly shorter duration of either sinus floor elevation procedure (32.0 min vs 54.5 min) or entire surgery (54.0 min vs 86.0 min)		
Morbidity	Intra-operative complications	Farina et al (2018)[31]		• No significant difference in the incidence of sinus membrane perforation	
	Postoperative complications	Farina et al (2018, 2022)[31,32]		• Similarly high implant survival rate up to 3 y postsurgery • Similarly low incidence of postoperative complications • Similar incidence of peri-implant mucositis	
	Patient-reported outcomes	Farina et al (2018)[31]	• Significantly lower incidence of swelling, bruising, and nasal discharge/bleeding • Significantly less severe limitation in swallowing, continuing daily activities, eating, speaking, opening the mouth, and going to school/work • Significantly different patient distribution according to the level of postoperative discomfort, with high or very high discomfort occurring only for lateral sinus floor elevation at 2 d postsurgery	• No significant difference in patient willingness to undergo the same type of surgery if needed	• Significantly lower pain on the day of surgery
	Dose of rescue analgesics	Farina et al (2018)[31]		• No significant difference in the median dose of rescue analgesics during the first two postoperative weeks (transcrestal sinus floor elevation: 2 tablets; interquartile range 1.0-4.0; lateral sinus floor elevation: 3.5 tablets; interquartile range 1.0-6.3)	
Radiographic outcomes		Farina et al (2019, 2022)[32,33]		• Similarly high (100%) median proportion of implant surface embedded in a radiopaque area up to 3 y postsurgery • Similarly low (0 mm) median marginal bone loss up to 3 y postsurgery	

TABLE 1 (Continued)

Outcome	Reference study	Main results		
		In favor of transcrestal sinus floor elevation	Indicating comparable performance of transcrestal sinus floor elevation and lateral sinus floor elevation	In favor of lateral sinus floor elevation
Costs	Farina et al (2021)[34]	• Significantly lower median dose of anesthetic (transcrestal sinus floor elevation: 2.0 vials; interquartile range 2.0-2.5; lateral sinus floor elevation: 3.0 vials; interquartile range 2.0-4.0) • Significantly lower median amount of xenograft (transcrestal sinus floor elevation: 420 mg; interquartile range 350-500; lateral sinus floor elevation: 1975 mg; interquartile range 1450-2500)	• Similarly low number of days of abstention from study/work • No significant differences in the number of additional surgical sessions, examinations, specialist consultations, and drug consumption	
Specific aspects of oral health–related quality of life	Farina et al (2021)[34]		• Impact of the implant-supported rehabilitation on specific aspects of oral health–related quality of life	

with similarly low (less than 12 on a 100 mm visual analog scale) postoperative pain levels (Figure 1), discomfort, and dose of analgesics.[37] Despite the relevance of invasiveness in clinical decision-making and the availability of several procedures that have been proposed and validated for transcrestal sinus floor elevation, the invasiveness of transcrestal sinus floor elevation has never been comprehensively evaluated in a systematic review in relation to the technical and technological aspects of the procedure. In this scenario, this systematic review aims at summarizing the evidence from controlled studies that contributed identifying aspects of the transcrestal sinus floor elevation intervention that may reduce the invasiveness of the latter.

2 | REVIEW

This systematic review is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses 2020 guidelines.[38,39] The review was not registered.

2.1 | Eligibility criteria

Only prospective controlled studies comparing two or more transcrestal sinus floor elevation procedures (differing for at least one technical or technological element; eg, grafting protocol) for one or more aspects related to invasiveness were considered for this systematic review.

The eligibility criteria were structured according to the following Population, Intervention, Comparison, Outcomes, and Study design:

- Participants. Adult (over 18 years) subjects needing one or more dental implants.
- Intervention. Transcrestal sinus floor elevation, irrespective of (a) the technique and technology used and (b) the timing with respect to implant placement and loading.
- Comparison. Any of the aforementioned transcrestal sinus floor elevation interventions.
- Outcome measures. At least one of the following primary outcomes related to transcrestal sinus floor elevation invasiveness: (a) number of invasive preoperative diagnostic examinations (eg, bi- and tridimensional radiographic examinations, otolaryngologist consultation); (b) patient perception of the extent of surgical trauma; (c) intra-operative complications; (d) postoperative morbidity; (e) number of surgical sessions and chair time. Where available, data on treatment effectiveness (eg, extent of subantral ridge augmentation) was extracted only from included studies evaluating one or more of the primary outcomes, and was considered as a secondary outcome of the review.
- Studies. Prospective, parallel-arm, or split-mouth controlled trials (either randomized or not). No restriction was applied in terms of treatment group size.

2.2 | Literature search strategy

A systematic literature search was performed in duplicate by two authors (RF, CF) in Medline (PubMed, CENTRAL) and Scopus databases between 1 and 15 December 2021. Owing to the variety of different outcome measures falling under the term "invasiveness," no search terms related to the primary outcomes were used, intentionally keeping the literature search broad. On Medline, the following combination of Medical Subject Headings (MeSH) terms, free terms, and Boolean operators was used: "(maxillary sinus OR sinus floor augmentation OR dental implants) AND (transcrestal OR osteotome OR transalveolar OR crestal)." Filters "randomized clinical trial" and "controlled clinical trial" were activated. On Scopus, the search strategy was structured as follows: ((ALL (transcrestal) OR ALL (osteotome) OR ALL (transalveolar) OR ALL (crestal)) AND (ALL (dental AND implants) OR ALL (maxillary AND sinus) OR ALL (sinus AND floor AND augmentation))). The same two authors performed a manual search in the articles published between 2011 and 2021 in *Clinical Oral Implants Research*, *Clinical Implant Dentistry and Related Research*, *European Journal of Oral Implantology*, *Journal of Dental Research*, *Journal of Clinical Periodontology*, *Journal of Periodontology*, and *International Journal of Periodontics and Restorative Dentistry*. Also, manual searching was extended to the bibliography of the most recent, pertinent, and influential systematic reviews on the topic. Only publications in English were considered. No attempt was made to retrieve pertinent gray literature.

2.3 | Article selection

The titles and abstracts were screened independently by two reviewers (RF, CF), and all publications identified by at least one author entered the selection phase. The inter-reviewer agreement in the screening phase was 94.5%. Disagreements regarding article eligibility for full text screening were resolved by discussion with a third reviewer (LT). The full-text versions of eligible articles were then retrieved and evaluated independently by two reviewers (RF, CF) and, whenever needed, by a third reviewer (LT), to make a final decision on inclusion/exclusion. All studies meeting the Population, Intervention, Comparison, Outcomes, and Study design criteria were included for data extraction and assessment of risk of bias.

2.4 | Search results and description of the studies included

The flow chart of article screening and selection is shown in Figure 2.

The following 19 articles (corresponding to 15 studies) were included (Table 2), and contributed to the review as follows:

- Seven articles (six studies) included a comparative evaluation of intra- and postoperative morbidity and/or patient preference for two transcrestal sinus floor elevation procedures differing for at least one technical aspect (Table 3).
- Four articles (four studies) included a comparative evaluation of the number of surgical sessions and/or chair time for two transcrestal sinus floor elevation procedures differing for at least one technical aspect (Table 4).
- Eleven articles (eight studies) included a comparative evaluation of one or more aspects of invasiveness for two different grafting protocols (including graftless protocol) within the same transcrestal sinus floor elevation procedure (Tables 5 and 6).

No controlled studies were retrieved that included a comparative evaluation of the number and type of preoperative examinations for two or more different transcrestal sinus floor elevation procedures.

2.5 | Methodology used for data description

Owing to differences in experimental design, outcome measures, and observation interval that were found among the studies

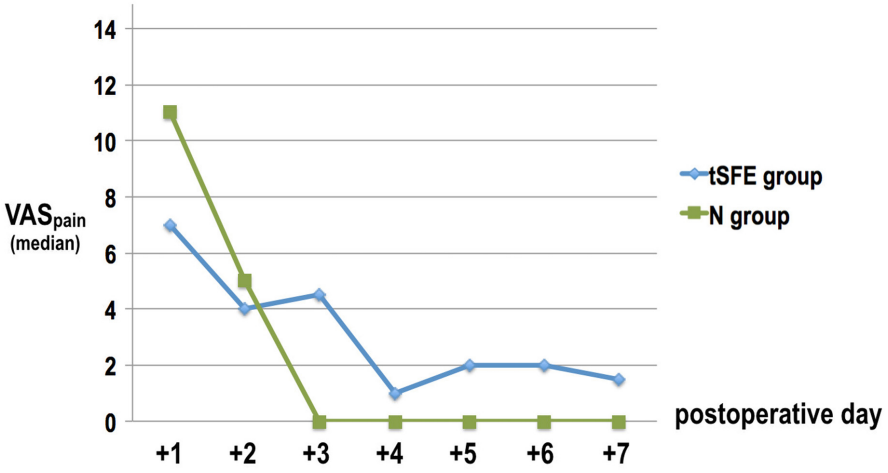

FIGURE 1 Median level of pain as self-reported on a 100-mm visual analog scale by patients undergoing implant placement entirely in native bone (group N) or concomitantly with transcrestal sinus floor elevation (group tSFE). The area under the curve (AUC) was 11.5 (interquartile range: 4.5-18.5) and 18.0 (interquartile range: 8.5-85.0) in the N group and tSFE group, respectively, with no significant intergroup differences ($P = 0.084$). Reprinted from Franceschetti et al[37]

included, no meta-analysis could be performed. Therefore, data were summarized according to a narrative style.

2.6 | Assessment of risk of bias in the studies included

For the randomized controlled trials included, a methodological quality assessment was performed according to the revised Cochrane risk-of-bias tool for randomized trials.[40] Five main domains for risk of bias were assessed: randomization process, deviations from the intended interventions, missing outcomes data, measurement of the outcomes, and selection of the reported results. A risk-of-bias judgment (among "low risk of bias," "some concerns," or "high risk of bias") was assigned to each domain (depending on the descriptions given for each field) or to the entire study.

For the nonrandomized studies included, a methodological quality assessment was performed according to the Risk of Bias in Non-randomized Studies of Interventions.[41] Seven main domains for risk of bias were assessed: bias due to confounding, bias in selection of participants into the study, bias in classification of interventions, bias due to deviations from intended interventions, bias due to missing data, bias in measurement of outcomes, bias in selection of the reported result. A risk-of-bias judgment (among "low risk of bias," "moderate risk of bias," "serious risk of bias," "critical risk of bias," or "no information") was assigned to each domain (depending on the descriptions given for each field) or to the entire study.

2.7 | Descriptive results

2.7.1 | Does the technique used to perform transcrestal sinus floor elevation influence the morbidity of the intervention?

The list of studies contributing to this section and their main findings are reported in Table 3.

Though some studies offered the opportunity to derive information on the impact of specific operative steps of the transcrestal sinus floor elevation intervention (eg, implant site preparation or fracture of the sinus floor) on intra- and postoperative morbidity,[42,43] for the majority of the studies the data on morbidity remained referred generically to transcrestal sinus floor elevation as a whole intervention.[44–48] When considered comprehensively, the available data showed that the incidence of complications was low in all treatment groups. Interestingly, complications were almost entirely related to transcrestal sinus floor elevation procedures based on the use of manual instruments, such as osteotomes and hand mallet. The only intra-operative complication that was reported (with an incidence ranging from a minimum of one to a maximum of three cases per treatment arm) consisted of the perforation of the sinus membrane, whereas postoperative complications included

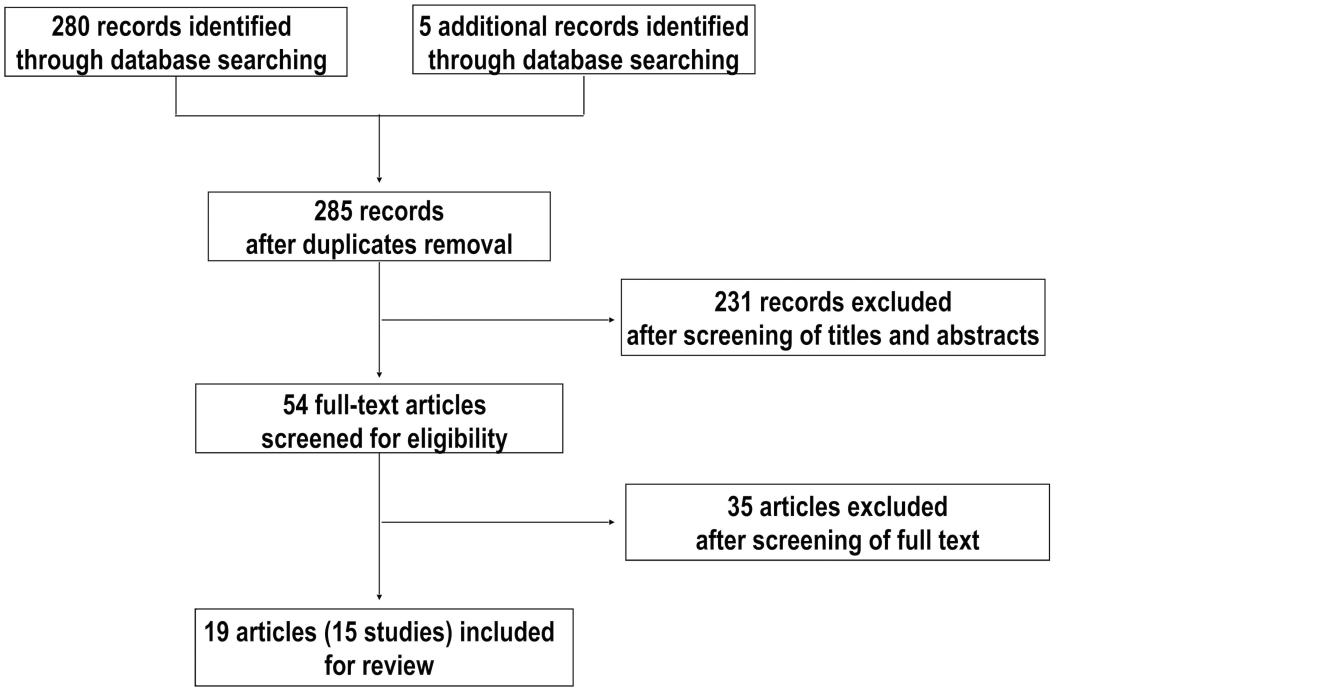

FIGURE 2 Flow chart of article screening and selection

TABLE 2 Characteristics of the studies included in the review

First author (year)	Source of funding	Transcrestal sinus floor elevation protocol (simultaneous to tooth extraction; delayed)	Implant placement (simultaneous to transcrestal sinus floor elevation; delayed)	Residual bone height (mm)	Study design	Intervention 1			Intervention 2			Length of follow-up (months from transcrestal sinus floor elevation)
						Number of patients	Technique	Grafting protocol	Number of patients	Technique	Grafting protocol	
Checchi (2010)[44]	Partial support from industry	Delayed	Simultaneous	4-7	Split-mouth randomized controlled trial	15	Osteotomes	Allograft (or xenograft, protocol deviation)	15	Drills	Allograft (or xenograft, protocol deviation)	12
Lai (2010)[52]	Public	Delayed	Simultaneous	2-8	Controlled trial	77	Drill + osteotomes	Autograft + allograft	125	Drill + osteotomes	No graft	9
Baldi (2011)[45]	Investigator-initiated study	Delayed	Simultaneous	3-7.5	Randomized controlled trial (quasi-parallel-arm, two patients received both treatments)	11	Round bur + osteotomes	Autograft + xenograft	16	Piezoelectric inserts	Autograft + xenograft	12-57 (mean: 19.29)
Sammartino (2011)[42]	Not reported	Delayed	Simultaneous	Not reported	Parallel-arm randomized controlled trial	98	Drill + mallet osteotome	No graft	98	Drill + screwable osteotome	No graft	6
Trombelli (2012)[50]	Public	Delayed	Simultaneous	≥4	Parallel-arm randomized controlled trial	15	Combination of osteotomes and burs with stop devices	Xenograft	15	Combination of osteotomes and burs with stop devices	Synthetic hydroxyapatite	6
Crespi (2013)[47]	Not reported	Delayed	Simultaneous	Not reported	Parallel-arm randomized controlled trial	5	Osteotomes pressed by hand mallet	No graft	5	Osteotomes pressed by electrical mallet	No graft	24
Nedir (2013)[53]	Public	Delayed	Simultaneous	≤4 mm	Randomized controlled trial (some patients were treated according to a split-mouth protocol)	10	Drills + osteotomes	Xenograft	9	Drills + osteotomes	No graft	12

TABLE 2 (Continued)

First author (year)	Source of funding	Transcrestal sinus floor elevation protocol (simultaneous to tooth extraction; delayed)	Implant placement (simultaneous to transcrestal sinus floor elevation; delayed)	Residual bone height (mm)	Study design	Intervention 1			Intervention 2			Length of follow-up (months from transcrestal sinus floor elevation)
						Number of patients	Technique	Grafting protocol	Number of patients	Technique	Grafting protocol	
Si (2013)[54]	Public	Delayed	Simultaneous	2-8	Parallel-arm randomized controlled trial	23	Drills + osteotomes	Autograft + xenograft	22	Drills + osteotomes	No graft	36
Crespi (2014)[48]	Not reported	Delayed	Simultaneous	Not reported	Parallel-arm randomized controlled trial	6	Osteotomes pressed by hand mallet	No graft	6	Osteotomes pressed by electrical mallet	No graft	24
Esposito (2014)[46 a]	Partial support from industry	Delayed	Simultaneous	4-7	Split-mouth randomized controlled trial	12	Osteotomes (Summers technique)	Allograft (or xenograft, protocol deviation)	12	Drills (Cosci technique)	Allograft (or xenograft, protocol deviation)	36
Trombelli (2014)[51]	Investigator-initiated study	Delayed	Simultaneous	≥4	Parallel-arm randomized controlled trial	19	Combination of osteotomes and burs with stop devices	Xenograft	19	Combination of osteotomes and burs with stop devices	Beta-tricalcium phosphate	6
Nedir (2016)[57 b]	Investigator-initiated study (public grant supported only the first year of study)	Delayed	Simultaneous	≤4	Randomized controlled trial (some patients were treated according to a split-mouth protocol)	10	Drills + osteotomes	Xenograft	9	Drills + osteotomes	No graft	36
Nedir (2017)[58 b]	Investigator-initiated study (public grant supported only the first year of study)	Delayed	Simultaneous	≤4	Randomized controlled trial (some patients were treated according to a split-mouth protocol)	10	Drills + osteotomes	Xenograft	9	Drills + osteotomes	No graft	60

(Continues)

TABLE 2 (Continued)

First author (year)	Source of funding	Transcrestal sinus floor elevation protocol (simultaneous to tooth extraction; delayed)	Implant placement (simultaneous to transcrestal sinus floor elevation; delayed)	Residual bone height (mm)	Study design	Intervention 1			Intervention 2			Length of follow-up (months from transcrestal sinus floor elevation)
						Number of patients	Technique	Grafting protocol	Number of patients	Technique	Grafting protocol	
Chandra (2018)[43]	Not reported	Delayed	Delayed	About 4	Parallel-arm randomized controlled trial	17	Drills + osteotomes	Xenograft	17	Trephine + osteotome	Xenograft	4-6
Liu (2019)[49]	Public	Delayed (control group) or simultaneous (test group)	Simultaneous	≤7	Parallel-arm randomized controlled trial	35	Drills + osteotomes	No graft	33	Drills + osteotomes	No graft	18/21
Merheb (2019)[55]	Not reported	Delayed	Simultaneous	≤4	Randomized controlled trial (some patients were treated according to a split-mouth protocol)	9	Drills + osteotomes	Xenograft	10	Drills + osteotomes	No graft	60
Cho (2020)[60]	Public	Delayed	Simultaneous	≥5	Parallel-arm randomized controlled trial	20	Drills + hydraulic transcrestal sinus floor elevation	Platelet-rich fibrin	20	Drills + hydraulic transcrestal sinus floor elevation	Saline	12
Qian (2020)[59 c]	Public	Delayed	Simultaneous	2-8	Parallel-arm randomized controlled trial	23	Drills + osteotomes	Autograft + xenograft	22	Drills + osteotomes	No graft	120
Starch-Jensen (2021)[56]	Partial support from industry	Delayed	Simultaneous	6-10	Parallel-arm randomized controlled trial	20	Drills, osteotome and piezosurgery, and hydraulic pressure technique	Collagenated xenograft	20	Drills, osteotome and piezosurgery, and hydraulic pressure technique	No graft	1

[a]Follow-up study conducted on the same study population from Checchi et al.[44]

[b]Follow-up study conducted on the same study population from Nedir et al.[53]

[c]Follow-up study conducted on the same study population from Si et al.[54]

TABLE 3 Main findings of included studies comparatively evaluating the intra- and post-operative morbidity and/or patient preference for two or more transcrestal sinus floor elevation procedures

	Intervention 1		Intervention 2				
First author (year)	Number of patients	Transcrestal sinus floor elevation protocol	Number of patients	Transcrestal sinus floor elevation protocol	Intra-operative morbidity: main findings	Postoperative morbidity: main findings	Patient preference
Checchi (2010)[44]	15	Implant site preparation: drills + osteotomes Fracture of the sinus floor: osteotome + hand mallet Graft: allograft (or xenograft, protocol deviation)	15	Implant site preparation: drills Fracture of the sinus floor: drills Graft: allograft (or xenograft, protocol deviation)	• One sinus membrane perforation in osteotome group (operation aborted and repeated), no perforations in the drills group • Patients experiencing an unpleasant sensation at surgery: 12/15 in osteotome group, 0/15 in drills group	• Patients experiencing swelling after surgery: 3/15 in osteotome group, 0/15 in drills group • No implant loss at 1 y in both groups	• Patient preference at 1 mo: 14/15 preferred drills, 1/15 expressed no preference (equally acceptable) • Patient preference at 1 y: 13/15 preferred drills, 2/15 expressed no preference (equally acceptable)
Baldi (2011)[45]	11	Implant site preparation: drills + osteotomes Fracture of the sinus floor: osteotome + hand mallet Graft: 50% autograft, 50% xenograft	16	Implant site preparation: piezoelectric inserts Fracture of the sinus floor: piezoelectric inserts Graft: 50% autograft, 50% xenograft	• One sinus membrane perforation in the osteotome group, with no unfavorable consequences. No sinus membrane perforation in the group treated with piezoelectric inserts	• One implant loss in piezosurgery group, no implant loss in the osteotome group	—
Sammartino (2011)[42]	98	Implant site preparation: drills Fracture of the sinus floor: osteotome + hand mallet Graft: none	98	Implant site preparation: drills Fracture of the sinus floor: screwable osteotome Graft: none	• Three membrane perforations (preventing simultaneous implant placement) in the hand mallet group, no membrane perforations in the screwable osteotome group	• Three cases of benign paroxysmal positional vertigo (treated by the otolaryngologist, with no recurrence at 6 mo) in the hand mallet group, no benign paroxysmal positional vertigo cases in the screwable osteotome group	—

(Continues)

TABLE 3 (Continued)

First author (year)	Intervention 1		Intervention 2		Intra-operative morbidity: main findings	Postoperative morbidity: main findings	Patient preference
	Number of patients	Transcrestal sinus floor elevation protocol	Number of patients	Transcrestal sinus floor elevation protocol			
Crespi (2013)[47]	5	Implant site preparation: drills + osteotomes (hand mallet) Fracture of the sinus floor: osteotomes (hand mallet) Graft: none	5	Implant site preparation: drills + osteotomes (electrical mallet) Fracture of the sinus floor: osteotomes (electrical mallet) Graft: none	• No sinus membrane perforation in both groups	• No pain in both groups • No prosthesis mobility in both groups • No mucositis or flap dehiscence with suppuration in both groups • Two cases of benign paroxysmal positional vertigo (one with severe symptoms) in the hand mallet group, with spontaneous recovery after 1 d. No benign paroxysmal positional vertigo cases in the electrical mallet group • 2-y implant survival rate: 100% in both groups	–
Crespi (2014)[48]	6	Implant site preparation: drills + osteotomes (hand mallet) Fracture of the sinus floor: osteotomes (hand mallet) Graft: none	6	Implant site preparation: drills + osteotomes (electrical mallet) Fracture of the sinus floor: osteotomes (electrical mallet) Graft: none	• No sinus membrane perforation in both groups	• No pain in both groups • No prosthesis mobility in both groups • No mucositis or flap dehiscence with suppuration in both groups • Two cases of benign paroxysmal positional vertigo with severe symptoms in the hand mallet group, with spontaneous recovery after 1 d. No benign paroxysmal positional vertigo cases in the electrical mallet group • 2-y implant survival rate: 100% in both groups	–
Esposito (2014)[46 a]	15	Implant site preparation: drills + osteotomes Fracture of the sinus floor: osteotome + hand mallet Graft: allograft (or xenograft, protocol deviation)	15	Implant site preparation: drills Fracture of the sinus floor: drills Graft: allograft (or xenograft, protocol deviation)	• See Checchi et al[44]	• One prosthetic complication in each group after 1-y follow-up • No implant loss at 3 y in both groups	• See Checchi et al[44]

TABLE 3 (Continued)

First author (year)	Intervention 1		Intervention 2		Intra-operative morbidity: main findings	Postoperative morbidity: main findings	Patient preference
	Number of patients	Transcrestal sinus floor elevation protocol	Number of patients	Transcrestal sinus floor elevation protocol			
Chandra (2018)[43]	17	Implant site preparation: conventional drills Fracture of the sinus floor: osteotome + hand mallet Graft: hydroxyapatite-based graft	17	Implant site preparation: trephine drill Fracture of the sinus floor: osteotome + hand mallet Graft: hydroxyapatite-based graft	-	• No significant intergroup differences for measures related to swelling, pain, and quality of early wound healing up to 2 wk postsurgery	• Patient complaints for excessive pain in the first week: two (associated with nasal discharge) in drills + osteotome, two in trephine + osteotome

[a]Presents the 3-year follow-up data of the study by Checchi et al.[44]

exacerbation of clinical signs and symptoms (eg, pain and swelling) motivating patient complaints, benign paroxysmal positional vertigo, and implant loss. When the complication did not resolve spontaneously, it resulted in protocol deviations (ie, a delay in the administration of the treatments and implant-supported rehabilitation) or required additional treatments (eg, otolaryngologist consultation) for its resolution. None of the reported events determined permanent consequences.

In the study by Chandra et al,[43] two different modalities to prepare the implant site (before fracturing the sinus floor) were compared for morbidity. Patients were randomly assigned to implant site preparation with a sequence of conventional drills or a trephine drill; then, the sinus floor was fractured with an osteotome pressed by a hand mallet in both groups. The results showed no significant intergroup differences between conventional drills and trephine drill for measures related to swelling, pain, and quality of early wound healing up to 2 weeks postsurgery. Also, two patients (11.8%) in each group complained of excessive pain in the first week.[43]

In the study by Sammartino et al,[42] two different modalities to fracture the maxillary sinus floor during transcrestal sinus floor elevation were compared for morbidity. At sites where implant site preparation had been performed with a sequence of drills at a safe distance from the sinus cortical floor, patients were randomly assigned to the fracture of the sinus floor with osteotomes activated by hand mallet or a screwable concave osteotome.[42] The results of the study showed no complications in the group assigned to the screwable osteotome. Differently, three from 98 (3.1%) cases treated with osteotomes and hand mallet experienced perforation of the sinus membrane to an extent that prevented the immediate placement of the implant. Also, in the same group, three cases (3.1%) reported benign paroxysmal positional vertigo motivating an otolaryngologist consultation, with no persistence or recurrence of the complication at 6 months postsurgery.[42]

Another four controlled studies that comparatively evaluated two transcrestal sinus floor elevation interventions (differing for both implant site preparation and procedure for fracturing the sinus floor) reported data on morbidity. In all these studies, osteotomes pressed by a hand mallet (used for both implant site preparation and elevating the sinus floor) comprised one of the two treatment groups and was compared with drills,[44,46] piezoelectric instruments,[45] and osteotomes pressed by an electrical mallet.[47,48]

Sinus membrane perforation was the only intra-operative complication that was reported, occurring in two of the four study arms consisting of osteotomes pressed by a hand mallet.[44,45] Its incidence, however, was limited, consisting of a single case over 15 patients (6.7%)[44] or single case over 11 patients (9.1%).[45] In one study, 12/15 patients (80%) experienced an unpleasant sensation at surgery in the osteotomes group, whereas no patients reported this type of event when undergoing transcrestal sinus floor elevation with drills.[44]

Postsurgery adverse events consisted of benign paroxysmal positional vertigo, swelling, implant loss, and prosthetic complications. Specifically, benign paroxysmal positional vertigo was reported in two[47,48] of the four studies and was related only to the group undergoing transcrestal sinus floor elevation with osteotomes pressed

TABLE 4 Main findings of included studies comparatively evaluating the number of surgical sessions and/or chair time for two or more transcrestal sinus floor elevation procedures

	Intervention 1		Intervention 2		
First author (year)	Number of patients	Transcrestal sinus floor elevation protocol	Number of patients	Transcrestal sinus floor elevation protocol	Main findings
Checchi (2010)[44]	15	Implant site preparation: drills + osteotomes Fracture of the sinus floor: osteotome + hand mallet Graft: allograft (or xenograft, protocol deviation)	15	Implant site preparation: drills Fracture of the sinus floor: drills Graft: allograft (or xenograft, protocol deviation)	Transcrestal sinus floor elevation procedure was significantly faster when performed according to intervention 2 (23.7 ± 3.5 min) compared with intervention 1 (33.3 ± 3.1 min)
Trombelli (2012)[50]	15	Implant site preparation: drills with stop device Fracture of the sinus floor: osteotome with stop device Graft: bovine-derived xenograft	15	Implant site preparation: drills with stop device Fracture of the sinus floor: osteotome with stop device Graft: synthetic hydroxyapatite	The median duration of the transcrestal sinus floor elevation procedure was 25.0 min and 20.5 min for interventions 1 and 2, respectively, with no significant intergroup differences
Trombelli (2014)[51]	19	Implant site preparation: drills with stop device Fracture of the sinus floor: osteotome with stop device Graft: bovine-derived xenograft	19	Implant site preparation: drills with stop device Fracture of the sinus floor: osteotome with stop device Graft: beta-tricalcium phosphate	The median duration of the transcrestal sinus floor elevation procedure was 20.0 min and 20.5 min for interventions 1 and 2, respectively, with no significant intergroup differences
Liu (2019)[49]	35	Implant site preparation (at 3 mo following tooth extraction): drills Fracture of the sinus floor: osteotome Graft: none	33	Implant site preparation (simultaneous to tooth extraction): drills Fracture of the sinus floor: osteotome Graft: none	Interventions 1 and 2 were associated with: • similarly high implant survival rates (100%) • similarly limited rate of membrane perforations (one in intervention 1, two in intervention 2, with no impact on final outcome) • no significant difference in patient satisfaction, as evaluated on a 10-point visual analog scale (intervention 1: 8.14; intervention 2: 8.36)

TABLE 5 Main findings of included studies (randomized controlled trials or controlled trials) comparatively evaluating the invasiveness of the intervention when a transcrestal sinus floor elevation procedure was performed with or without a graft material

First author (year)	Transcrestal sinus floor elevation procedure	No graft (number of patients)	Graft (number of patients)	Main findings related to the invasiveness of transcrestal sinus floor elevation	Main findings related to reconstructive outcomes, implant survival, and success
Lai (2010)[52]	Round bur + drills + osteotome	(n = 125)	Autogenous bone + beta-tricalcium phosphate (n = 77)	Incidence of membrane perforation: no graft, 2.4%; autogenous bone + beta-tricalcium phosphate, 2.6% (no significant difference)	5-y cumulative survival rate: no graft: 97.38%; graft: 92.13% (no significant difference)
Si (2013)[54]	Round bur + osteotomes	(n = 22)	Autogenous bone + deproteinized bovine bone mineral (n = 23)	Incidence of membrane perforation: no graft, 9.1%; autogenous bone + deproteinized bovine bone mineral, 13.0% Implant loss due to peri-implantitis: one case in each group	3-y endo-sinus bone gain: no significant intergroup difference 3-y cumulative survival rate: no graft, 95.0%; autogenous bone + deproteinized bovine bone mineral, 95.2%
Nedir (2013)[53]	Round bur + osteotomes and hand mallet	(n = 9)	Deproteinized bovine bone mineral (n = 10)	Incidence of membrane perforation: 0% in both groups	1-y endo-sinus bone gain: no graft, 3.9 mm; deproteinized bovine bone mineral, 5.0 mm (significant difference) Percentage of implants completely embedded by radiopacity at 1 y: no graft, 11.8%; deproteinized bovine bone mineral, 72.2% Implant loss: two cases in deproteinized bovine bone mineral group Implant success: no graft, 100%; deproteinized bovine bone mineral, 90% (no significant difference)
Nedir (2016)[57 a]	Round bur + osteotomes and hand mallet	(n = 9)	Deproteinized bovine bone mineral (n = 10)	Peri-implantitis leading to implant loss: one case in no graft	3-y mean endo-sinus bone gain: no graft, 4.1 mm; deproteinized bovine bone mineral, 5.1 mm (significant difference) Number of implants completely embedded by radiopacity at 3 y: no graft, two implants; deproteinized bovine bone mineral, 11 implants 3-y implant success rate: no graft, 94.1%; deproteinized bovine bone mineral, 90.0%
Nedir (2017)[58 a]	Round bur + osteotomes and hand mallet	(n = 9)	Deproteinized bovine bone mineral (n = 10)	No further complications or implant loss between 3- and 5-y follow-up visit	5-y endo-sinus bone gain: no graft, 3.8 mm; deproteinized bovine bone mineral, 4.8 mm (significant difference) Number of implants completely embedded by radiopacity at 5 y: no graft, four implants; DBBM, eleven implants 5-y implant success rate: no graft, 94.1%; deproteinized bovine bone mineral, 90.0%

(Continues)

TABLE 5 (Continued)

First author (year)	Transcrestal sinus floor elevation procedure	No graft (number of patients)	Graft (number of patients)	Main findings related to the invasiveness of transcrestal sinus floor elevation	Main findings related to reconstructive outcomes, implant survival, and success
Merheb (2019)[55]	Osteotomes and hand mallet	(n = 10)	Deproteinized bovine bone mineral (n = 9)	Incidence of membrane perforation: 0% in both groups Incidence of peri-implantitis: no graft, one case; deproteinized bovine bone mineral, no cases	Implant stability quotient: no significant intergroup differences at any time point
Qian (2020)[59 b]	Drills + osteotomes and hand mallet	(n = 22)	Autogenous bone + deproteinized bovine bone mineral (n = 23)	Incidence of peri-implant mucositis: no graft, six cases; autogenous bone + deproteinized bovine bone mineral, seven cases Incidence of peri-implantitis: no graft, one case; autogenous bone + deproteinized bovine bone mineral, two cases	10-y endo-sinus bone gain: no significant intergroup difference 10-y marginal bone loss: no significant intergroup difference 10-y implant survival rate: no graft, 95.0%; autogenous bone + deproteinized bovine bone mineral, 90.7% (no significant intergroup difference)
Starch-Jensen[56]	Drills, osteotome and piezosurgery, and hydraulic pressure technique	(n = 20)	Collagenated deproteinized bovine bone mineral (n = 20)	Incidence of membrane perforation: no graft, one case; collagenated deproteinized bovine bone mineral, no cases Mean Oral Health Impact Profile–14 score: no graft, 6.0; collagenated deproteinized bovine bone mineral, 7.6 (no significant difference; however, number of days with pain, eating difficulties, and sleep disturbances were significantly increased in collagenated deproteinized bovine bone mineral group)	–

[a]Follow-up study conducted on the same study population from Nedir et al.[53]

[b]Follow-up study conducted on the same study population from Si et al.[54]

TABLE 6 Main findings of included studies (randomized controlled trials or controlled trials) comparatively evaluating the invasiveness of the intervention when a transcrestal sinus floor elevation procedure was associated with two or more different grafting procedures

First author (year)	Transcrestal sinus floor elevation technique	Number of patients receiving							Main findings (morbidity/invasiveness/complications)	Main findings (reconstructive outcomes, implant survival and success)
		Deproteinized bovine bone mineral	Beta-tricalcium phosphate	Synthetic hydroxyapatite	Autogenous bone	Platelet-rich fibrin	Saline	Graft combinations (type of combination)		
Trombelli (2012)[50]	Drills and osteotome with stop devices	15	—	15	—	—	—	—	Incidence of membrane perforation: deproteinized bovine bone mineral, 0%; synthetic hydroxyapatite, 6.7% (no significant difference) Similarly low visual analog scale scores for pain at postsurgery and at 7 d Similarly low postoperative dose of rescue anti-inflammatory tablets	Extent of vertical augmentation at 6 mo: deproteinized bovine bone mineral, 6.60 mm; synthetic hydroxyapatite, 7.50 mm (significant difference) 6-mo implant survival: 100% in both groups
Trombelli (2014)[51]	Drills and ostetotome with stop devices	19	19	—	—	—	—	—	Incidence of membrane perforation: deproteinized bovine bone mineral, 5.3%; beta-tricalcium phosphate, 21.1% (no significant difference) Benign paroxysmal positional vertigo: one case in beta-tricalcium phosphate, resolved spontaneously within the first week Similarly low visual rating scale values for discomfort and visual analog scale values for pain Similarly low dose of rescue anti-inflammatory tablets	Extent of vertical augmentation at 6 mo: deproteinized bovine bone mineral, 6.1 mm; beta-tricalcium phosphate, 6.4 mm (no significant difference) 6-mo implant survival: 100% in both groups
Cho (2020)[60]	Drills + hydraulic sinus lift	—	—	—	—	20	20	—	No complications in both groups	12-mo intra-sinus bone gain: platelet-rich fibrin, 2.6 mm; saline, 1.7 mm (significant difference) 12-mo implant survival rate: 100% in both groups

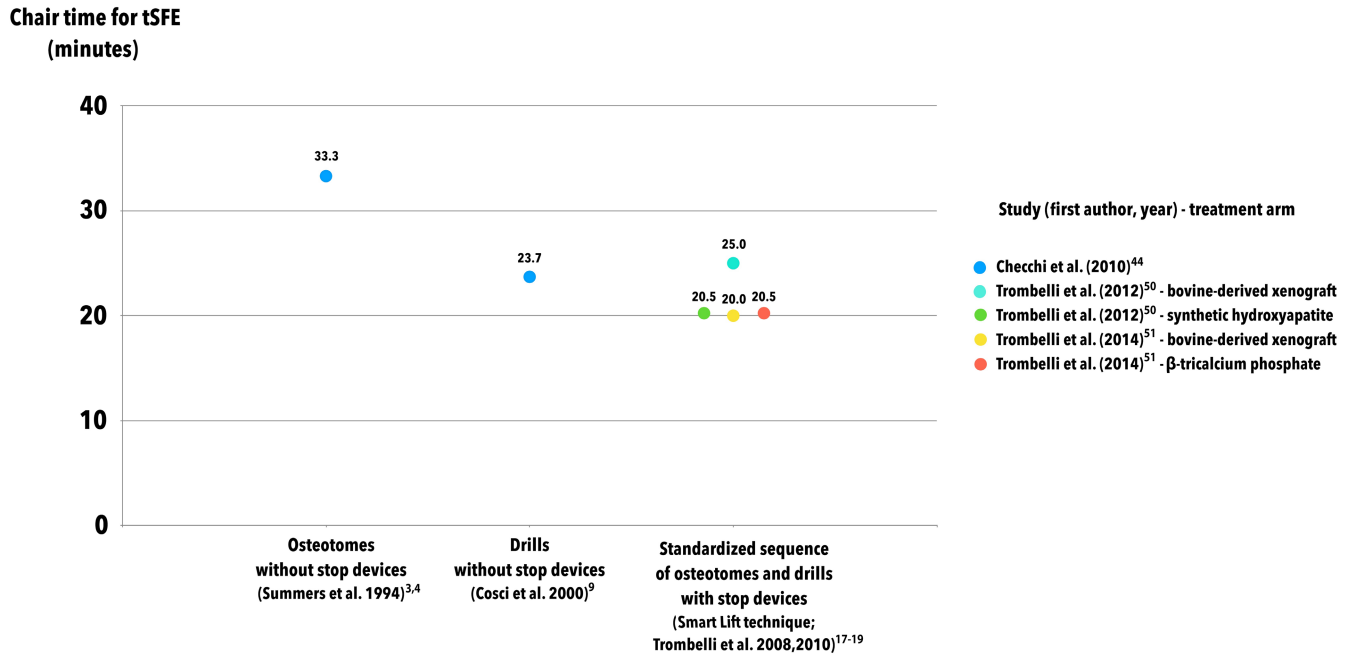

FIGURE 3 Chair time (measured from the preparation of the implant site to implant placement), as reported for single arms of controlled studies comparing two different transcrestal sinus floor elevation procedures

by hand mallet; it occurred with an incidence of two from five cases (40%)[47] and two from six cases (33.3%).[48] In some of these cases, benign paroxysmal positional vertigo manifested with severe symptoms (including intense vertigo, dizziness, and disorientation accompanied by distress, nausea, and vomiting, and sensation of objects moving around the patient), but all cases underwent resolution. Implant survival was 100% in all treatment groups in three out of the four studies, whereas in one study an implant was lost in the group undergoing transcrestal sinus floor elevation with piezoelectric instruments.[45] In a split-mouth study,[44] 3/15 (20%) patients self-reported swelling after surgery with osteotomes and hand mallet, whereas no patients reported this symptom in the group undergoing transcrestal sinus floor elevation with drills. When patients were interviewed at 1 month and 1 year postsurgery about their preference for one of the treatments investigated, 14/15 (93.3%) and 13/15 (86.7%) patients, respectively, manifested their preference for drills, whereas the remaining patients considered the two options investigated (osteotomes plus hand mallet or drills) equally acceptable.[44] In the 3-year follow-up of the same study, implant survival rates were similar between treatment groups.[46]

Whenever the magnitude of the subantral ridge augmentation obtained with transcrestal sinus floor elevation[43,45,48] and implant survival rates following this procedure[44–48] were evaluated in the studies mentioned, no significant differences between treatment groups were reported.

Overall, data on morbidity from controlled studies comparatively evaluating different transcrestal sinus floor elevation techniques indicate the following:

- Although transcrestal sinus floor elevation is generally associated with low intra- and postoperative morbidity, the replacement of manual instruments (ie, osteotomes and hand mallet) with powered instruments (eg, piezoelectric inserts, drills, electrical mallet) may result in a further reduction of the morbidity of the intervention while maintaining the reconstructive performance of the latter. Moreover, the use of drills may result in markedly lower patient discomfort during surgery and substantially higher patient preference compared with osteotomes.
- Within the transcrestal sinus floor elevation intervention, the procedure to fracture the sinus floor seems more relevant for transcrestal sinus floor elevation morbidity than the procedure for implant site preparation. In this context, the use of screwable osteotomes may result in a lower incidence of membrane perforation and benign paroxysmal positional vertigo compared with osteotomes pressed by a hand mallet.

2.7.2 | May the number of surgical sessions and chair time be reduced without affecting the reconstructive performance of transcrestal sinus floor elevation?

The list of studies contributing to this section and their main findings are reported in Table 4.

Whereas one study informed about the effectiveness of transcrestal sinus floor elevation when combined with immediate or delayed implant placement,[49] three studies (six treatment arms) reported data on surgery-related chair time of two different transcrestal sinus floor elevation procedures.[44,50,51]

In the randomized study by Liu et al,[49] transcrestal sinus floor elevation was performed at maxillary molar edentulous sites (with

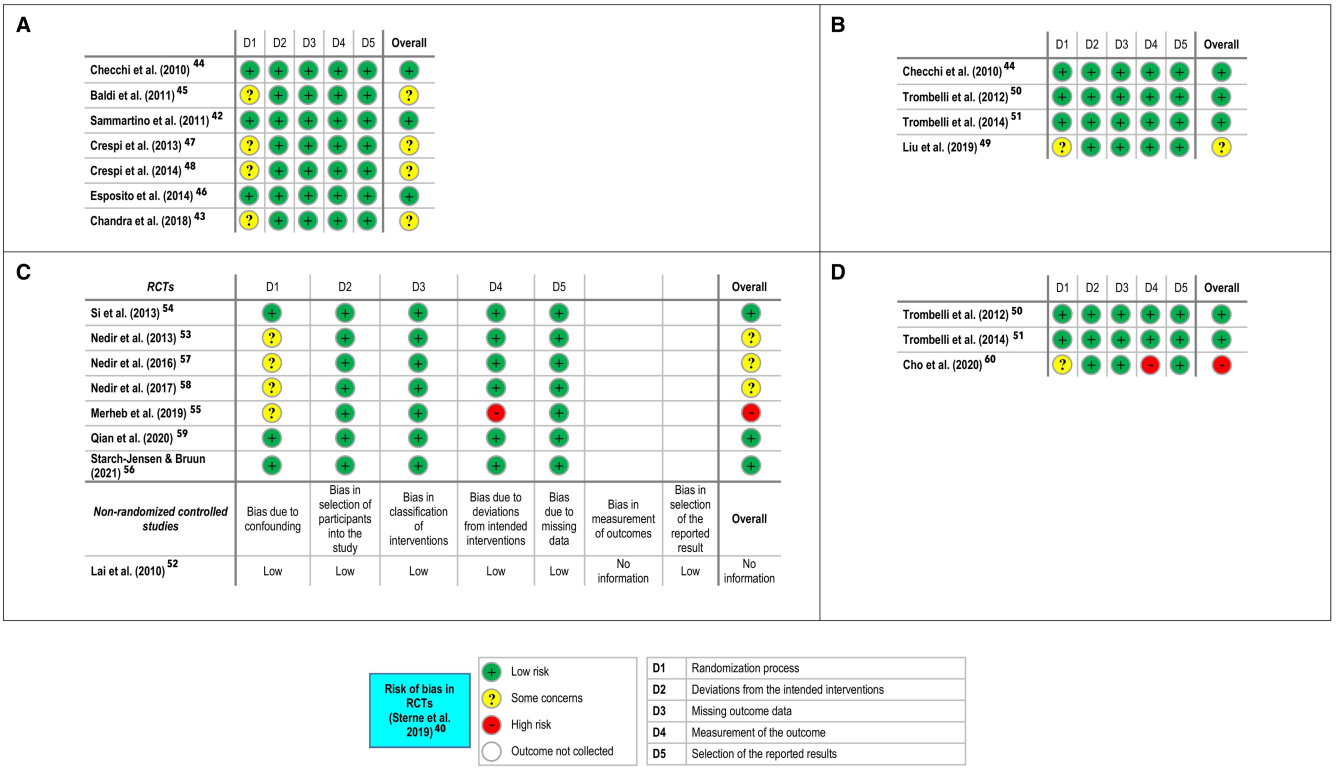

FIGURE 4 Risk-of-bias summary of the studies included for evaluation. A, Intra- and postoperative morbidity and/or patient preference. B, Number of surgical sessions and/or chair time. C, Invasiveness of transcrestal sinus floor elevation with or without a graft material. D, Invasiveness of transcrestal sinus floor elevation with two or more different grafting procedures. RCTs: randomized controlled trials

a height of alveolar ridge to maxillary sinus of less than 7 mm and a height of the interradicular bone septum of more than 4 mm) either simultaneous to immediate implant placement (33 patients) or following a 3-month delay after tooth extraction (35 patients). In the immediate implantation group, the alveolar socket was drilled from the top of root septum up to 1 mm from the maxillary sinus floor, the alveolar septum was pushed laterally by a bone extrusion drill connected with a ratchet spanner to expand the implant site, an osteotome was used to elevate the maxillary sinus floor by hand malleting, and the implant site was enlarged to its final diameter. In the delayed implantation group, the healed ridge was prepared with drills, and sinus floor elevation was performed with an osteotome, restricting the final use of a drill for final diameter preparation if needed. In both treatment groups, 6-mm wide implants were placed with a transmucosal healing protocol. Membrane perforation occurred with a low frequency in both groups (two in the immediate implantation group, one in the delayed implantation group), and the complication did not have an impact on the final outcome. At 12 months following implant loading, similarly high (100%) implant survival rates were observed in both groups, with a similar level of patient satisfaction (8.36 and 8.14 on a 10-point visual analog scale).[49]

Data on surgery-related chair time needed to perform transcrestal sinus floor elevation (as measured from the preparation of the implant site to implant placement) is illustrated in Figure 3 according to study, transcrestal sinus floor elevation technique, and graft material.

In a split-mouth randomized controlled trial,[44] transcrestal sinus floor elevation was performed with manual osteotomes according to the Summers' technique[3,4] or using the standardized sequence of burs proposed by Cosci and Luccioli.[9] The results of the study indicated that the use of burs may result in a significantly faster transcrestal sinus floor elevation procedure (23.7 ± 3.5 min) compared with osteotomes (33.3 ± 3.1 min).[44] In two parallel-arm randomized controlled trials, chair time needed for the administration of the transcrestal sinus floor elevation intervention was evaluated in two groups receiving the same surgical technique (Smart Lift, based on a standardized sequence of manual and rotating instruments used with stop devices) in association with an autogenous bone core (obtained during site preparation with a trephine drill) and different graft materials.[50,51] Deproteinized bovine bone mineral and synthetic hydroxyapatite were used in the study by Trombelli et al,[50] whereas they used deproteinized bovine bone mineral and beta-tricalcium phosphate in a different study.[51] Overall, median time for transcrestal sinus floor elevation was limited (between 20 and 25 min) in all study arms.[50,51]

In three of these studies, postsurgery radiographic assessments of the augmented ridge were included.[49–51] Two of these failed to find significant intergroup differences in either the magnitude of the subantral ridge augmentation obtained with transcrestal sinus floor elevation[51] or the 1-year changes in vertical and horizontal dimension of the residual ridge.[49] In the other study, the extent of subantral augmentation at 6 months postsurgery was substantial in both treatment groups

but was significantly greater when using synthetic hydroxyapatite (7.50 mm) rather than deproteinized bovine bone mineral (6.60 mm).[50] Implant survival rate was 100% in all study arms.[44,49–51]

Overall, data on the timing of implant placement and chair time from controlled studies comparatively evaluating two different transcrestal sinus floor elevation procedures indicate that:

- at maxillary molar extraction sites with a height of the interradicular septum of 4 mm or greater, immediate transcrestal sinus floor elevation and implant placement can be performed without affecting the reconstructive and rehabilitation outcomes;
- chair time to perform transcrestal sinus floor elevation can be significantly reduced by adopting transcrestal sinus floor elevation procedures based on a standardized sequence of drills rather than manual osteotomes;
- the type of graft (when used) seems not to have a significant impact on the duration of the surgical procedure.

2.7.3 | Does the method to provide and maintain the space underneath the sinus membrane influence transcrestal sinus floor elevation invasiveness?

The list of studies comparatively evaluating the invasiveness of the intervention when a transcrestal sinus floor elevation procedure was performed with or without a graft material,[52–56] their follow-up[57–59] and their main findings are summarized in Table 5.

Membrane perforation was the only intraoperative complication, occurring in three out of five studies.[52,54,56] In two studies, the reported incidence was 0%.[53,55] The incidence of membrane perforation was low in both the graft and graftless groups, with no major intergroup differences. Two studies showed a tendency to higher incidence in the graft group,[52,54] whereas membrane perforation occurred only in the graftless group in the remaining study.[56]

In general, biological complications manifested with low incidence rates irrespective of the adjunctive use of a graft, and peri-implantitis leading to implant loss (when occurred) was limited to one case per treatment arm. No evident differences were found in the incidence of biological complications or implant loss due to peri-implantitis in the studies available. No additional complications were reported for the graft and graftless groups in the follow-up studies.[57–59]

In a study evaluating oral health–related quality of life following graft and graftless transcrestal sinus floor elevation, no significant differences were found between treatments in Oral Health Impact Profile–14 total scores. However, specific scores related to number of days with pain, eating difficulties, and sleep disturbances were significantly increased in the graft group.[56]

Contrasting findings were reported for the adjunctive effect of the graft on vertical endo-sinus bone gain. Whereas one study reported greater bone gain and higher proportions of implants completely embedded in a radiopaque area for the graft group[53] even at longer follow-up intervals,[57,58] another study[54] or its follow-up[59] failed to find a significant adjunctive effect of the graft. These findings were paralleled by similarly high implant survival rates in graft and graftless groups.[53,54,57–59]

Overall, data from controlled studies evaluating the invasiveness of a transcrestal sinus floor elevation procedure with or without a graft material seem to indicate that the additional use of a bone substitute (either alone or in combination with an autogenous bone graft) does not impact on the rate of intra- and postoperative complications of the transcrestal sinus floor elevation procedure. The indication to the use of a graft in transcrestal sinus floor elevation, however, remains matter of debate, due to its transient impact on oral health–related quality of life and the contrasting results regarding its adjunctive efficacy on reconstructive outcomes.

The list of studies comparatively evaluating transcrestal sinus floor elevation invasiveness when the intervention was performed with different grafting procedures[50,51,60] as well as their main findings are summarized in Table 6.

Two over three studies reported some complications, consisting of membrane perforation and benign paroxysmal positional vertigo.[50,51] Incidence rates of these complications were low irrespective of the use of a bone substitute, and did not show significant differences between different materials in both studies.[50,51] Also, similarly low levels of pain, discomfort, and dose of analgesics were reported for all types of graft, with no inter-group differences.[50,51]

Interestingly, no complications were reported in a study evaluating the outcomes of transcrestal sinus floor elevation when performed with platelet-rich fibrin or saline,[60] thus suggesting that these materials might be associated with lower morbidity than particulate grafts are. However, both platelet-rich fibrin and saline were also accompanied by a markedly lower vertical increase in bone dimensions[60] than achieved with particulate grafts.[50,51]

Overall, data from controlled trials evaluating the invasiveness of transcrestal sinus floor elevation when this was performed with different grafting procedures seem to indicate that:

- the type of particulate bone substitute has limited impact on the morbidity of the transcrestal sinus floor elevation intervention;
- both platelet-rich fibrin and saline were associated with no complications, but should be considered with caution due to the limited extent of subantral augmentation when they are used in a transcrestal sinus floor elevation procedure.

2.8 | Risk of bias

The risk of bias in the studies included is illustrated in Figure 4. Among studies informing on the effect of the technique on transcrestal sinus floor elevation morbidity (Figure 4A), two studies[42,44] and the 3-year follow-up[46] of the study by Checchi et al[44] were judged to be at low risk of bias, whereas four studies were classified as having "some concerns."[43,45,47,48]

The study comparing transcrestal sinus floor elevation when performed simultaneous to immediate implant placement or delayed at 3 months after tooth extraction was classified as having "some

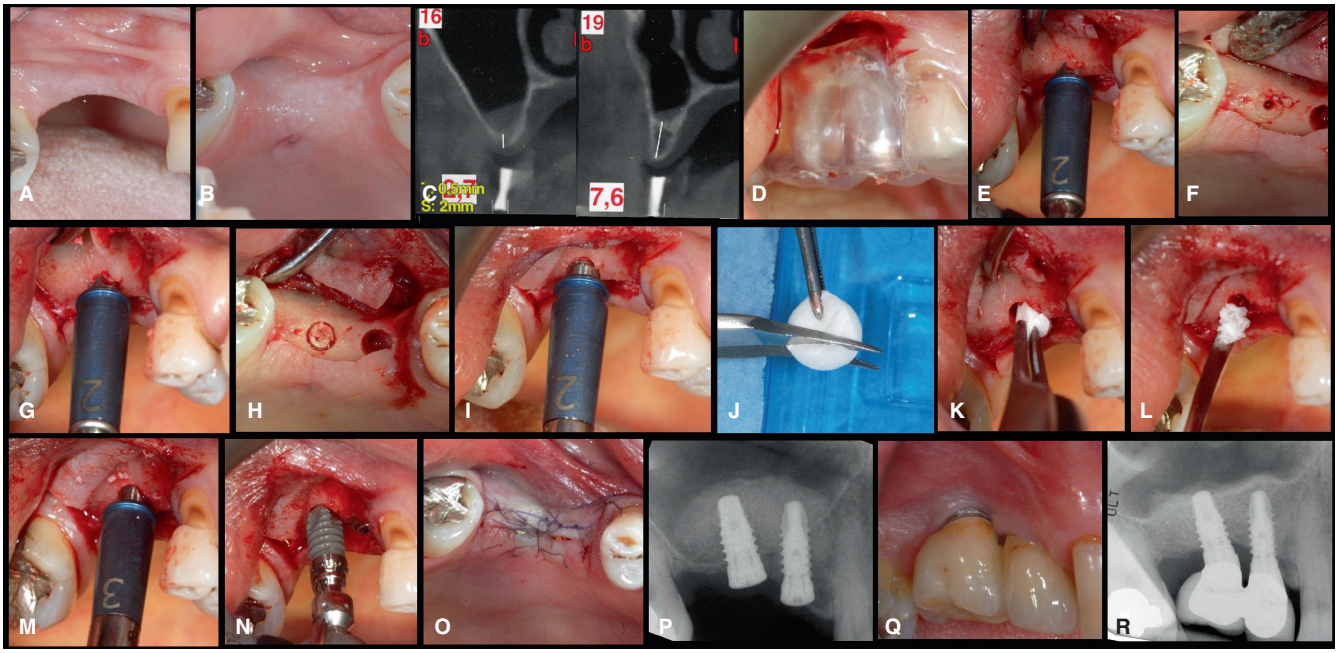

FIGURE 5 Transcrestal sinus floor elevation according to a standardized sequence of drills and manual instruments used with stop devices (Smart Lift)[18–20] as performed at healed second premolar and first molar extraction sites. A, B, Presurgery clinical aspect. C, Presurgery tomography scans showing a residual bone height of 7.6 mm (second premolar site) and 2.7 mm (first molar site). D, Placement of the surgical guide prepared on diagnostic wax-up. E, A guide drill used with a stop device perforates the bone up to 1 mm from the radiographic position of the sinus floor. F, A countersink is created with a guide drill. The countersink will allow for positioning the trephine drill. G, H, The trephine drill (Smart Lift drill) is used with a stop device to isolate a bone core. I, An osteotome (Smart Lift elevator) is used with a stop device to implode the bone core and fracture the sinus floor. J, K, A plug of collagen matrix is placed into the future implant site and pushed apically with the osteotome. L, M, Additional increments of a bone substitute (bovine-derived xenograft) are performed using the osteotome. N, Implant placement. O, Postoperative clinical aspect. P, Postoperative radiographic aspect. Q, Clinical aspect at 3 y postsurgery. R, Radiographic aspect at 3 y postsurgery

concerns," whereas the three randomized controlled trials reporting information on surgery-related chair time[44,50,51] were judged as of low risk of bias (Figure 4B).

The risk of bias as evaluated in studies comparatively evaluating the invasiveness of transcrestal sinus floor elevation performed with or without a graft material is illustrated in Figure 4C. Among randomized controlled trials, two studies[54,56] and the 10-year follow-up of the study by Si and coworkers[59] were judged to be of low risk of bias, one study[53] and its follow-up[57,58] were classified as having "some concerns," and one study[55] was characterized by a high risk of bias. One nonrandomized controlled study[52] was classified as "No information".

The risk of bias as evaluated in the studies comparatively evaluating the invasiveness of transcrestal sinus floor elevation performed with different grafting procedures is illustrated in Figure 4D. Two studies[50,51] were at low risk of bias, whereas one study[60] was judged at high risk of bias.

3 | CONCLUDING REMARKS AND RECOMMENDATIONS FOR PRACTICE

Invasiveness is a key factor to inform clinical decision-making when planning a surgical intervention. In the attempt to reduce the invasiveness of a peri-implant bone reconstructive procedure, different aspects of the reconstructive surgery must be considered under the broad term "invasiveness"; that is, the minimization of intra- and postsurgery morbidity, the reduction of treatment time (in terms of number of surgical sessions and chair time), and the simplification/elimination of the reconstructive technology. Ideally, the management of all these aspects should contribute to the reduction of invasiveness without affecting the reconstructive performance of the procedure. In this review, the basic assumption was the need for the clinician to perform a transcrestal sinus floor elevation procedure, minimizing its invasiveness. Within this context, a systematic literature search was performed for controlled clinical trials, and 19 articles (corresponding to 15 studies) were included.

Overall, the results of this systematic review confirmed that transcrestal sinus floor elevation is a minimally invasive and effective option for bone augmentation in the edentulous, atrophic posterior maxilla. The invasiveness of transcrestal sinus floor elevation can be further reduced without affecting its effectiveness by using powered instruments (ie, drills, piezoelectric inserts, electrical mallet) rather than manual instruments (ie, osteotome and hand mallet). To effectively impact on morbidity, the key elements to consider when selecting powered instruments for transcrestal sinus floor elevation are (a) their availability as a standardized sequence, to be adapted on predetermined residual bone height, and (b) the possibility to control

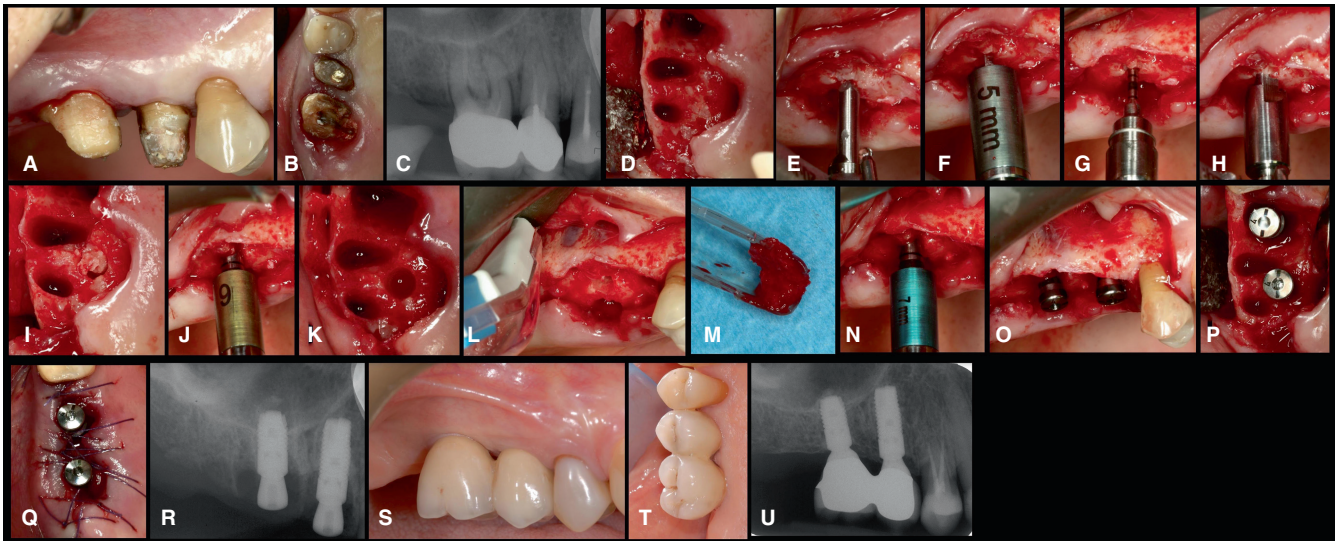

FIGURE 6 Transcrestal sinus floor elevation according to a standardized sequence of drills and manual instruments used with stop devices (Smart Lift)[18–20] as performed immediately after extraction of a first molar. A, B, Presurgery clinical aspect. C, Presurgery periapical radiograph showing a well-preserved interradicular septum (height 6 mm) of the first molar. D, Occlusal view of the socket immediately after extraction of the first molar. E-H, Creation of the access to the sinus floor at the level of the interradicular septum according to the standardized sequence of drills of the Smart Lift technique. I, Bone core isolated with the trephine drill at the future implant site. J, K, An osteotome (Smart Lift elevator) is used with a stop device to implode the bone core and fracture the sinus floor. L, M, Autogenous bone is collected from the periphery of the surgical area. N, Autogenous bone is pushed apically with an osteotome. O, P, Implant placement. Q, Postoperative clinical aspect. R, Postoperative radiographic aspect. S, T, Clinical aspect at 4 y postsurgery. U, Radiographic aspect at 4 y postsurgery

pressure (eg, with screwable osteotomes) and/or instrument excursion (eg, with stop devices) to fracture of the maxillary sinus floor (Figure 5). Among powered instruments, standardized sequence of drills seems to be particularly indicated due to reduced chair time and high tolerability for the patient. Since the type of drill (conventional vs trephine) was shown to have a limited relevance for transcrestal sinus floor elevation invasiveness[43] and autogenous bone grafts contribute for superior histomorphometric outcomes in sinus augmentation procedures,[61] the use of drill sequences incorporating a trephine drill to isolate a bone core during access preparation is encouraged. The adjunctive use of a bone substitute (irrespective of its type) does not have a relevant impact on the invasiveness of the procedure, but its indication when performing a transcrestal sinus floor elevation procedure remains a matter of debate due to contrasting evidence regarding its adjunctive efficacy on reconstructive outcomes.

After tooth extraction, immediate transcrestal sinus floor elevation and implant placement can be considered under specific local conditions. In particular, at molar extraction sites with an interradicular septum characterized by a height of at least 4 mm, immediate transcrestal sinus floor elevation and implant placement was shown to be a valid option to shorten treatment time (Figure 6).

4 | RECOMMENDATIONS FOR RESEARCH

While tracing the technical and technological elements that may help the clinician to reduce the invasiveness of a transcrestal sinus floor elevation procedure, this systematic review may also be functional to delineate some topics that might inspire the development of future research lines with high clinical relevance/impact. In particular:

- The role of flap design on transcrestal sinus floor elevation morbidity remains to be investigated.
- It is presently unknown whether and to what extent a flapless approach to transcrestal sinus floor elevation (eventually combined with computer-based programming of the intervention) may be beneficial for the invasiveness of the intervention.
- The association (if any) between residual bone height and transcrestal sinus floor elevation morbidity should be evaluated in order to better define the indications for specific transcrestal sinus floor elevation procedures based on residual bone height.
- New transcrestal sinus floor elevation techniques based entirely on a standardized sequence of powered instruments should be developed, incorporating systems to preserve bone from the future implant site and control the pressure to fracture the sinus floor. Beyond the invasiveness and effectiveness, the learning curve of these techniques must be evaluated.
- Novel transcrestal sinus floor elevation techniques should be developed to allow for their applicability at tooth extraction sites with unfavorable characteristics (eg, single-rooted teeth, limited height of the interradicular septum at molar sites).
- The adjunctive clinical efficacy of bone substitutes in transcrestal sinus floor elevation procedures needs to be further evaluated in order to better define the indications for their use.

Based on biases that were most frequently detected in the randomized controlled trials included in this review, the recommendation to report details on the randomization process can be transferred to researchers seeking to publish the results of a randomized controlled trial that includes the assessment of transcrestal sinus floor elevation invasiveness. In particular, researchers are encouraged to make explicitly clear if, to whom, and how the allocation sequence was concealed until participants were enrolled and assigned to interventions.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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