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MINI-REVIEW **OPEN ACCESS**

Effectiveness of Graftless Maxillary Sinus Floor Augmentation on Alveolar Crest Height and Implant Survival: A Review of Randomized Controlled Studies

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Abstract:

Introduction: Recent research has documented that new bone can form in and around the dental implants placed after maxillary sinus floor elevation (SFE) without the use of bone grafts. This article reviews the existing literature on the SFE technique without the use of bone grafts to determine the extent of research on this topic. The objectives of the study are to evaluate the vertical bone gain and implant survival rates associated with the technique.

Materials and Methods: A review was conducted by searching the relevant articles based on the inclusion and exclusion criteria. The main search engines were PubMed, Google Scholar, and Cochrane. We used special algorithms related to the keywords 'maxillary sinus lift' and 'graftless' to identify the randomized controlled trials (RCTs) that studied the effectiveness of the graftless SFE with respect to implant survival and vertical bone gain. We included only RCTs that studied the graftless sinus lift technique related to implant survival rates and vertical bone gain, including both direct and indirect approaches to graftless SFE, and studies with at least 6 months of follow-up. Only English-language articles were considered. We excluded non-randomized studies and studies that did not report implant survival rates and vertical bone gain.

Results: Out of 429 articles, only ten RCTs involving 209 participants satisfied the inclusion criteria. Increased implant survival rates were demonstrated with the graftless procedure, using both direct and indirect approaches. Significant effectiveness in terms of endosinus bone gain (ESBG) using the graftless SFE technique was reported. The results were comparable to SFE with graft placement.

Discussion: Traditional approaches for the maxillary sinus floor augmentation have utilised the use of bone grafts. Regardless of the high success documented with these techniques, the use of bone grafts has several limitations, such as prolonged operating time and disease transmission. Additionally, the risk of complications and failures is common. Consequently, the graft-free SFE appears to be a valid minimally invasive alternative. Using this approach, most of the complications can be prevented or eliminated. Therefore, understanding this technique is essential for optimizing dental implantology practices.

Conclusion: Graftless SFE may be a viable technique for maxillary sinus floor augmentation. The utility of this technique lies in mitigating the complications associated with the grafting materials, thereby reducing the morbidity of the procedure and the cost burden. Future research with large RCTs using standardised methods and outcome measures is required to provide more robust evidence on the utility of this technique.

Keywords: Maxillary sinus augmentation, Sinus floor elevation, Graftless sinus lift, Randomized controlled trials, Endosinus bone gain, Bone grafts.

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1. INTRODUCTION

Dental implant rehabilitation of the posterior edentulous maxilla is a challenging procedure due to reduced alveolar ridge height following tooth extractions. The situation is further worsened by maxillary sinus pneumatization, which precludes implant placement. Therefore, maxillary sinus floor elevation (SFE) to augment the alveolar ridge height for the placement of dental implants is a predictable and successful treatment option in these cases [1]. SFE can be performed using a direct open lateral approach or an indirect transcrestal approach [2]. The lateral approach to maxillary sinus floor augmentation was first introduced by Tatum and published by Boyne and James [3, 4]. The less invasive transcrestal technique was also first described by Tatum and later modified by Summers [4, 5]. The choice of the surgical approach depends on various factors, including the residual alveolar bone height (RBH). SFE procedures may be indicated if there is insufficient bone height to place conventional implants and in the absence of any local or systemic conditions that would compromise bone healing. Traditional approaches have often necessitated the use of bone grafts. Studies have shown the predictability and safety of the SFE procedure using bone grafts to augment the alveolar ridge height. Various bone grafting strategies have been utilized, including autogenous grafts, allografts, alloplastic materials, or a combination of these [6]. However, all these grafting techniques are associated with several disadvantages, such as increased donor site morbidity, prolonged operating time, and risk of infection and disease transmission [7]. These multiple procedures ultimately lead to an increased financial burden for the patients. Furthermore, failures and complications are common with such procedures [8-10].

In this context, the graftless approach for maxillary sinus floor augmentation appears as a viable, minimally invasive procedure. Studies have shown that the blood clot formed under the elevated maxillary sinus floor membrane is sufficient for neobone formation without the use of graft materials [11-13]. The presence of osteoprogenitor cells and the innate osteogenic potential of the Schneiderian membrane have been demonstrated through *in vivo* and *in vitro* studies [14, 15]. This technique is aimed at overcoming the drawbacks associated with the use of graft materials and offers various advantages to patients, including reduced postoperative pain, faster healing, and cost-effectiveness. Studies on implant survival rates have shown comparable results between the graftless and conventional techniques using bone grafts.

The aim of this article is to perform a critical appraisal of the evidence on the effectiveness of the graftless technique for maxillary sinus floor augmentation in terms of vertical bone gain (VBG) and implant survival rates.

2. METHODOLOGY

A literature search was carried out for various clinical and experimental studies on the graftless maxillary sinus floor augmentation technique. Articles published between January 2000 and February 2024 were searched in PubMed, Google Scholar, and Cochrane databases. The following keywords were used in the search: maxillary sinus augmentation, sinus floor elevation, graftless sinus lift, randomized controlled trials. Only articles written in the English language that satisfied the predetermined criteria were included. A total of 429 articles were searched and analyzed with reference to scientific evidence.

2.1. Inclusion Criteria

(a) Only RCTs that studied the graftless sinus lift technique related to the outcomes: implant survival rates and Vertical Bone Gain.

(b) Both direct and indirect approaches to graftless SFE were included.

(c) All articles written in the English language only were included.

(d) Studies with at least 6 months of follow-up were included.

2.2. Exclusion Criteria

(a) Non-randomized studies (cohort, case-control, cross-sectional, case reports).

(b) Studies involving zygomatic, pterygoid, or short implants without sinus elevation were excluded.

(c) Studies that do not report implant survival or vertical bone gain.

(d) Studies not published in English were excluded.

3. RESULTS

A total of 429 studies were found after an electronic and manual database search, and finally, 10 randomized prospective studies were included in the review. Studies that focused on the outcomes of interest, implant survival rates, and vertical bone gain were reviewed. Nine studies evaluated implant survival rates using the graftless technique Table **1**; ten studies were related to bone gain, comparing the graftless technique with the gold standard sinus floor augmentation with grafts (Table **2**).

3.1. Implant Survival Rates Data

Implant survival can be defined as ‘the implant remaining *in situ* at the follow-up examination’. Several studies have shown the long-term survival of implants. The 10-year survival at the implant level using contemporary implant systems was found to be 96.4% (95% CI 95.2%–97.5%) [3]. Studies reviewed in this article have shown good implant stability and high survival rates using the graft-free procedure. When comparing the sinus lift procedure with and without grafts, results of a single-blinded RCT in 40 patients found no significant differences in implant survival rates between the two techniques [4]. Data from another RCT showed the 3-year cumulative implant survival rate of 95% in cases of SFE without grafting [5].

Table 1. Results of % implant survival rates using the graft less sinus lift procedure from randomized controlled trials.

Study	Year of Study	Study Design	Number of Patients	Open/Closed Sinus lift Graft less	Follow up Periods. (Years)	Implant Survival Rates (%)/ Mean ISQ
Si *et al* [17]	2013	RCT	20	Closed	3	95 %
Fouad *et al* [26]	2018	RCT	20	Open	0.5	74 ±3.19
Qian *et al* [8]	2020	RCT	40	Closed	10	95 %
Nedir *et al* [46]	2013	RCT	17	Closed	1	100 %
Starch-Jensen *et al* [16]	2023	RCT	20	Closed	1	100 %
Lie *et al* [38]	2021	RCT	29	Open	0.5	86.2 %
Merheb *et al* [40]	2019	RCT	17	Closed	5	79.7±4.3
Nedir *et al* [47]	2017	RCT	17	Closed	5	94.1 %
Khaled *et al* [27]	2019	RCT	10	-	0.5	77±5

Table 2. Comparison of the endo sinus bone gain (ESBG) using the sinus lift with graft *versus* graft less procedure.

Randomized Study	Year of Study	Sample Size	Endo Sinus BG with Graft (mm)	Endo Sinus BG without Graft(mm)	Statistical Significance (*P*-value)	Graft Material	Follow up. (Years)
Trinh *et al* [45]	2019	30	3.2±0.3	1.6±0.3	*P*<0.5	Ace Mannan sponge	0.5
Si *et al* [17]	2013	41	3.17±1.95	3.07±1.68	0.920	deproteinized bovine bone mineral (DBBM)	3
Fouad *et al* [26]	2018	17	8.59 ± 0.74	4.85 ± 0.5	*P*<0.5	Deproteinized bovine bone (Xenograft)	0.5
Khaled *et al* [27]	2019	20	7.0 ± 0.8	5.0 ± 1.5	*P*=.002	Nano hydroxyapatite	0.5
Kandel *et al* [28]	2022	18	10.2 mm ± 2.5	5.4 mm ± 2.0	*P*<0.001	An organic bone bovine mineral (ABBM)	0.5
Nedir *et al* [46]	2013	37	5.0 ±1.3	3.9 ±1.0	*P*=0.003	Bio Oss	1
Lie *et al* [38]	2021	10	9.69	6.2	*P*=0.041	Autografts + Xenograft	0.5
Starch-Jensen *et al* [16]	2024	40	7.2±1.9	4.1±1.0	0.004*	1:1 Autograft + deproteinized porcine bone mineral	1
Zahedpasha *et al* [29]	2021	20	9.58	6.21	*P*<0.001	Cerabone	0.5
Nedir *et al* [47]	2017	37	4.8±1.2	3.8±1.0	*P*=0.004	Anorganic bovine bone	1

Mean implant stability quotient (ISQ) values of implants 6 months after the procedure in non-grafted sinuses were found to be 74 ± 3.19 [6]. The mean ISQ values in another study after a 6-month period for non-grafted implant sites were 77 ± 5 [7]. Long-term data from a study showed that the 10-year cumulative survival rate of implants was 95.0% in the graftless sinus lift procedure [8].

3.2. Vertical Bone Gain (VBG) Data

Various studies have compared endosinus bone gain (ESBG) after sinus augmentation with and without the addition of graft materials Table **2**. Many randomized controlled trials from 2013 through 2024 have evaluated ESBG comparing the two techniques. All these studies have shown greater bone gain after sinus lift with bone grafts when compared to the graftless technique Table **2**. In a RCT by Starch-Jensen *et al.*, significantly higher ESBG was observed in the control group (maxillary sinus floor augmentation with bone grafts) compared to the test group (maxillary sinus floor augmentation without bone grafts). A significant decrease in bone gain was noted after 1 year of treatment in both groups [16]. Interestingly, Si *et al.*, after 3 years of follow-up, showed comparable mean vertical bone gain of 3.17 ± 1.95 mm *vs* 3.07 ± 1.68 mm between grafting and graftless techniques [17].

4. DISCUSSION

The Maxillary sinus lift technique has been the gold standard for augmenting the deficient maxillary alveolar ridge for successful dental implant placement. Traditional approaches have often necessitated and demonstrated high success with the use of bone grafts to enhance the new bone formation following maxillary sinus floor elevation [18-20]. This surgical procedure involves elevating the sinus membrane and adding bone grafting material to create adequate vertical bone height, thus facilitating the placement of dental implants. Dental implants can be placed simultaneously (one-stage) or as a delayed approach once adequate bone volume has been restored (two-stage). As evidenced in the literature, these techniques greatly improve the implant treatment outcomes [3, 4, 21]. However, regardless of the high success documented with these techniques, the use of

bone grafts has several limitations, such as prolonged operating time and disease transmission. Additionally, the risk of complications and failures is common. The most frequent complications are infection (21%), bleeding (9%), migration, and benign paroxysmal positional vertigo (BPPV) [22, 23]. Studies evaluating the prevalence of sinusitis as a complication also stress the importance of meticulous surgical technique in minimizing adverse effects, with rates documented as low as 1.11% following sinus lift procedures [9, 24, 25]. Consequently, the graft-free SFE technique appears to be a valid minimally invasive alternative. Using this approach, most of the complications can be prevented or eliminated. Therefore, understanding this technique is essential for optimizing dental implantology practices.

A growing body of research highlights the efficacy of the graftless technique in the context of maxillary sinus lift procedures. This approach circumvents the use of traditional bone grafts by leveraging the blood clot from the surgical site, which allows for a natural regeneration process. Studies have shown that when this method is employed, satisfactory gains in bone height can be achieved, facilitating successful rehabilitation with Osseo-integrated dental implants [26-29]. Bone height gain up to 6.21 mm has been reported with this technique [29]. Furthermore, the absence of grafting material not only reduces potential complications associated with biomaterials but also simplifies the surgical procedure. However, careful patient selection and thorough treatment planning are critical, as they significantly impact outcomes and minimize risks, such as implant migration into the maxillary sinus cavity, which is often linked to inadequate initial bone height [30]. Thus, mastering this technique presents a promising opportunity in dental implant rehabilitation of our patients.

This minimally invasive approach relies on using available bone and biologic principles to elevate the sinus membrane and create conditions favorable for osseointegration. New bone formation is attributed to the presence of osteoprogenitor cells and the innate osteogenic potential of the Schneiderian membrane, as demonstrated by Srouji *et al.* [14, 15]. Human Schneiderian membrane cells (hSM) have been demonstrated to express various osteogenic markers, such as alkaline phosphatase, bone morphogenetic protein 2, osteonectin, and osteocalcin. This was proven histologically by the new bone formation from the hSM at ectopic sites, as shown *in vivo* [15]. Another probable theory explaining the new bone formation beneath the hSM is attributed to the formation of a stable clot, which undergoes secondary ossification.

One key advantage of this technique is a reduced recovery time, which alleviates patient anxiety and minimizes surgical complications traditionally associated with grafting procedures. Additionally, the elimination of graft materials decreases the overall treatment cost while mitigating donor site morbidity, making the procedure significantly more appealing to patients. By employing precise principles and techniques, the graft less maxillary sinus lift offers a reliable alternative that aligns with contemporary surgical trends, ultimately enhancing the efficacy of dental implant placements in challenging anatomical situations.

The clinical applications of the graftless maxillary sinus lift procedure present a compelling alternative to traditional augmentation techniques. Current research suggests that the use of platelet concentrates, while showing potential in enhancing bone regeneration, lacks robust evidence for its sole application in sinus augmentation, as noted in studies revealing that outcomes might not significantly differ from grafting materials [31-33]. Moreover, guided bone regeneration techniques emphasize the significance of barrier materials, which not only support the healing process but also optimize bone quality by minimizing complications associated with filler granules [34]. The recent emphasis on utilizing natural scaffolds, like blood clots, further underscores a paradigm shift towards biological healing processes in sinus lifts. By integrating these elements, clinicians can navigate the complexities of maxillary augmentation with enhanced outcomes and minimized intervention risks, reinforcing the clinical considerations essential for successful implementation.

When considering a graftless maxillary sinus lift, specific indications and patient selection criteria play crucial roles in determining the success of the procedure. The primary indication for this approach often involves patients with adequate residual bone height, as a graftless lift aims to maximize the use of existing bone while minimizing surgical intervention. Additionally, the anatomy of the sinus cavity must be assessed, as variations such as exaggerated sinus pneumatization can influence treatment outcomes [35]. According to recent findings, careful case selection, grounded in the dimensions of remaining crestal bone, significantly contributes to achieving predictable results in patients with posterior maxillary atrophy [36, 37]. For successful implant outcomes, subjects should also demonstrate a commitment to oral hygiene and possess no contraindications, such as active infections or systemic conditions that may impede healing. Ultimately, each case must be thoroughly evaluated to ensure that the graftless technique not only addresses anatomical challenges but also aligns with the patient's overall health status.

Many studies have assessed the graftless sinus lift procedure [36-38]. A recent systematic review and meta-analysis has shown the implant survival percentages to be 97.92% without graft techniques [39]. However, it is to be noted that the follow-up period in these studies was only 6 months. Moreover, these studies encompassed a mix of retrospective, prospective clinical studies, and randomised studies, leading to greater heterogeneity. Our review has included only the RCTs comparing the graftless SFE and the SFE with augmentation materials. Both techniques demonstrate comparable implant survival rates. Of the ten studies that compared the implant survival rates, only one study by Qian *et al.* has shown the implant survival rate using the graftless technique over a period of 10 years to

be 95% [8]. Studies reviewed in this article have shown good implant stability and high survival rates using the graft-free procedure. The data from the single-blinded RCT in 40 patients found no significant differences in the implant survival rates between the graftless and the grafted techniques. However, another RCT has shown the 3-year cumulative implant survival rates of 95% in cases of SFE without grafting [17]. Implants placed 6 months after the procedure in non-grafted sinuses were found to have high stability values [26, 27, 40]. The mean follow-up period in these studies was 2.75 years. However, it is to be noted that the studies differed with respect to either open lateral or closed trans crestal sinus lift approach for augmentation.

The previous randomized studies have shown greater gain in bone height with the use of grafting materials when compared to the graft-less approach, regardless of the type of graft material used (Table **2**). However, it is to be noted that the same studies have demonstrated adequate gain in alveolar bone height following the elevation of the sinus membrane alone [27, 38]. Whether this difference in bone height gain under the sinus floor has any effect on the implant survival needs to be evaluated. Although this article included only randomised studies, there are some limitations. Included studies are not homogeneous and used different surgical approaches (direct open lateral or trans crestal) for sinus lift.

Based on the analyzed outcomes, we found that the graft-less SFE is a viable technique for dental implant rehabilitation of deficient posterior maxilla. For the implant therapy to be successful, primary stability is important. Various factors, such as the residual bone height between the floor of the maxillary sinus and the crest of the alveolar ridge, implant design, bone density, and surgical technique, influence implant stability [41-43]. Implant stability is significantly associated with residual bone height [44]. Taking all these factors into consideration can greatly enhance the success rate of the procedure.

CONCLUSION

This review provides valuable insight and makes an important contribution to the available literature investigating the effectiveness of the graftless sinus lift procedure. The available randomized trials demonstrate that this minimally invasive approach can achieve predictable implant survival rates and satisfactory vertical bone gain without the need for grafting materials. However, the existing studies remain limited in sample size, methodology, and duration of follow-up. Further prospective RCTs with long-term follow-up will help show the stability of the new bone formed after the graftless sinus lift procedure. This will help us understand the predictability of the procedure, ensuring successful osseointegration of the dental implants. This innovative approach signifies a shift towards a practice in oral rehabilitation that is minimally invasive and has a lower rate of complications.

AUTHORS' CONTRIBUTIONS

The authors confirm contribution to the paper as follows: S.S: Study conception and design, data collection and draft manuscript; S.S and A.S: Analysis and interpretation of results. All authors reviewed the results and approved the final version of the manuscript.

LIST OF ABBREVIATIONS

SFE	=	Sinus Floor Elevation
RCTs	=	Randomized Controlled Trials
ESBG	=	Endosinus Bone Gain
RBH	=	Residual alveolar bone height
VBG	=	Vertical Bone gain
ISQ	=	Implant Stability Quotient
BPPV	=	Benign Paroxysmal Positional Vertigo
hSM	=	Human Schneiderian membrane

CONSENT FOR PUBLICATION

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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