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Investigating Effective Factors in Maxillary Sinus Membrane Rupture and Its Treatment Methods: A Review

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ABSTRACT

Introduction: Maxillary sinus floor augmentation (MSFA) surgery is a reliable treatment for patients with atrophic posterior maxilla, which can be performed concurrently with or after implant installation. This study aimed to estimate the rate of sinus membrane perforation (SMP) during MSFA surgeries and examine various risk factors associated with SMP. The efficacy of perforation treatments was also evaluated.

Materials and Methods: A systematic search of Scopus, PubMed, and Web of Science databases was conducted using the search terms: Implant AND Sinus AND Membrane AND Risk factor. Statistical analyses and graph creation were performed using Comprehensive Meta-Analysis (CMA) version 3. A total of 635 publications were screened, and 11 studies met the inclusion criteria, involving 1362 patients who underwent 1603 MSFA surgeries through the lateral window technique (LWT).

Results: The prevalence of maxillary sinus membrane perforation among patients who had implants placed was 40.8% (Event: 0.331, 95% CI: 0.26-0.4). Implants placed near repaired perforated membranes demonstrated an average survival rate of 97.68%, whereas implants placed on intact sinus membranes had an average survival rate of 98.88%. Infection was identified as the primary complication associated with the repair of perforated sinus membranes.

Conclusion: Despite the high incidence of sinus membrane perforation during MSFA surgeries, the survival rates of implants near repaired membranes are comparable to those placed on intact membranes. Appropriate antibiotic prescriptions can prevent infections, contributing to favorable surgical outcomes.

Keywords: Maxillary sinus; Membrane rupture; Antibiotics; Survival rate.

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Introduction

Maxillary sinus floor augmentation (MSFA) surgery is a well-established treatment modality for patients with atrophic posterior maxilla, facilitating implant-supported rehabilitation by providing sufficient bone substance [1,2]. Following tooth extraction, bone crest loss may reduce the ridge, particularly in the posterior maxilla [3]. The sinus floor elevation (SFE) technique, first proposed by Tatum and later refined by Boyne and James, provides adequate bone height for implant placement. This procedure can be executed in a single stage with implant insertion or in a two-stage process for significant atrophies [4]. The survival rates of implants placed using MSFA are comparable to those in unaltered bone. SFE can be performed either in a single stage with simultaneous implant insertion or in a two-stage process in situations where significant maxillary atrophy prevents achieving satisfactory primary stability [5,6].

During surgery, the sinus membrane may be perforated due to iatrogenic factors stemming from suboptimal surgical techniques or individual anatomical variations, which can complicate the procedure [7]. Common errors associated with poor surgical technique include inappropriate selection of surgical instruments or the application of excessive force on the sinus membrane, leading to iatrogenic perforation. Additionally, anatomical factors such as a thin sinus membrane, lower friability and elasticity, and stronger bonds with bone surfaces and sinus septa can contribute to these complications [1]. Sinus membrane perforation (SMP) is the most prevalent complication associated with SFE, with reported prevalence rates ranging from 10.0% to 60.0%. SMP can result in implant failure and issues related to impaired augmentation post-surgery [8].

Surgeons may encounter several risk factors during SFE that could impact the surgery's outcome [8]. Numerous studies have investigated various potential causative factors, including anatomical variations of the maxillary sinus and different SFE methods, in relation to their propensity to cause SMP [8-11]. Membrane perforation remains the most common adverse event following SFA surgery, with reported incidences ranging from 7% to 60% [12-14]. This study aims to estimate the rate of SMP and identify various risk factors associated with this complication. Additionally, the efficacy of perforation treatment was evaluated during subsequent follow-up visits.

Materials and Methods

Search strategy

This systematic review and meta-analysis were conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Databases including Scopus, PubMed, and Web of Science were systematically searched. The search terms used were: "Implant AND Sinus AND Membrane AND Risk factor." Using Endnote software for citation management, we searched for and cataloged English-language publications. All articles included in this study were published between 2000 and January 2023. Studies were screened and selected based on inclusion criteria by reviewing the titles, abstracts, and full texts of the search results. Inclusion criteria comprised studies focusing on risk factors for maxillary sinus membrane rupture, original cohort studies, case-control studies, and clinical trials. Exclusion criteria included studies with less than six months of follow-up, case reports, review articles, and duplicate studies. No primary human or animal research was conducted for this review; thus, IRB approval and informed consent were not required. All studies included were independently reviewed and approved by their respective ethical boards.

Quality assessment and data extraction

The Rayyan platform was used to screen and extract data from the included studies. Two researchers performed the quality assessment using the nine-point Joanna Briggs Institute critical appraisal checklist for studies, resolving any disagreements through consensus. The included studies met more than half of the quality assessment criteria. Data extracted from the studies included publication year, country, number of subjects, sinus elevation technique, perforation occurrence, management of perforation complications, and mean follow-up period. Additionally, statistical data such as publication year, study design, research question, number and type of articles, language and country of the study, type of device used, and participants' profile data were obtained.

Statistical Analysis

Statistical analysis and graph creation were performed using Comprehensive Meta-Analysis (CMA) version 3 (Biostat Inc., Englewood, NJ), utilizing a random effects model based on forest plots, suitable for heterogeneous populations compared to fixed models. Data summary included the calculation of the standard deviation of the mean with a 95% confidence interval.

The I-squared (I^2) test was employed to determine sample heterogeneity. Visual bias was assessed using a funnel plot, and Egger's regression test was used to verify it, with P<0.05 indicating a statistically significant publication bias.

Results

Based on the purpose of the study, 635 publications from the Scopus, PubMed, and Web of Science databases were examined. After eliminating duplicate articles and screening according to the inclusion and exclusion criteria, nine studies were deemed eligible for full-text review (Figure 1). This investigation included studies with retrospective, prospective, case-control, and cohort designs. Table 2 presents the data extracted from each study, including authors, publication year, study type, number of patients treated, number of MSFAs performed using lateral approaches, number of perforations that occurred during surgery, percentage of perforations reported, management of perforations, and the main consequences observed when Schneiderian membrane perforation occurred. The eleven studies included a total of 1362 patients, with a mean age of 56 years, who underwent 1603 MSFA surgeries through lateral windows. The average rate of Schneiderian membrane perforation was 40.8% (540 perforations). The perforations were managed using various methods, including clot formation, sutures, collagen membranes, platelet-rich fibrin (PRF), hemostatic agents, laminar bone, and block grafts. The most frequent postoperative complication associated with perforated sinus membranes was the presence of infections. Park et al. reported higher rates of postoperative complications in patients with perforated membranes, such as bleeding at the perforation site, cystic fluid or purulent discharge, dislocation of the graft into the sinus, nasal bleeding, and facial swelling [15]. Membrane perforation is the most frequent complication in maxillary sinus floor augmentation. Based on the meta-analysis of the nine studies presented in Figure 2, the prevalence of maxillary sinus membrane perforation was 40.8% (Event: 0.331, 95% CI: 0.26-0.4) among patients who received implants.

Publication bias

A bias test was conducted using Egger's method, which revealed no significant bias in the prevalence of perforation according to Egger's test.

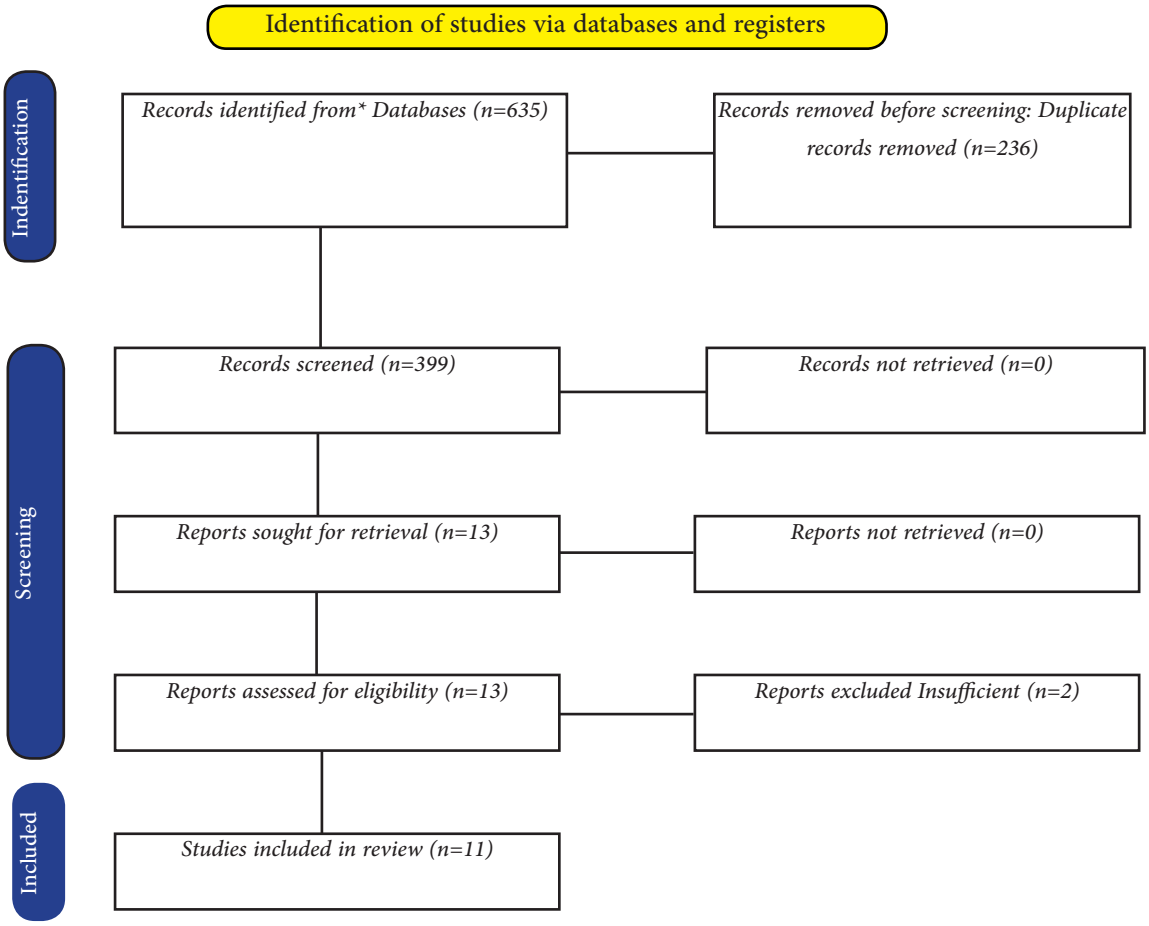

Figure 1. PRISMA flowchart.

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Table 1. Number of treated patients, number of perforations, percentage of recorded perforations, management of perforation performed and main complications in selected studies.

Author/ Year	Type of study	Patients (number)	Sinus lift (number)	Perforations (number)	Perforations rate	Management of Perforations	Complications	Ref
Park et al. 2019	Retrospective Cohort	63	65	24	39%	Clot formation	Infection	(15)
Boyacıgil eta l. 2021	Prospective Cohort	25	-	8	1802%	Crestal sinus grafting	infection, bleeding, swelling	(30)
de Almeida Malzoni et al. 2021	Following case series	13	-	9	69%	Clot formation	Infection-mucus	(13)
Garbacea et al. 2012	Retrospective Cohort	25	25	10	40%	-	Infection- Pain	(31)
Marin et al. 2019	Retrospective Cohort	137	40	19	13.9%	bone block	Pain	(8)
Beck- Brochsitter et al. 2018	Retrospective cohort	63	79	37	49.3%	<5 mm: collagen memb or fibrin glue or clot. >5 mm: suturing + collagen memb	Periimplantitis	(32)
De Almeida Ferreira et al. 2017	Retrospective cohort	531	745	237	31.8%	Collagen membr + Reabsorbable suture for all perforationsc	Areas with chronic inflammatory infiltration	(20)
Öncü E et al. 2017	Retrospective cohort	16	20	10	50%	PRF (<10 mm)	-	(25)
Froum et al. 2013	Retrospective cohort	23	40	15	37/5%	Resorbable collagen membrane (< 10 mm)	-	(33)
Oh et al. 2011	Retrospective cohort	128	175	60	34%	Resorbable hemostatic agente Surgicel (small-moderate perforations)	Infection in 3 of the 60 perforations	(34)
Hernández- Alfaro et al. 2008	Retrospective cohort	338	474	104	22%	0-5 -collagen membr o suturing 5- 10 -collagen membr + laminar Bone >10 -laminar bone, buccal fat pad, mandibular bone block	Pain/sensitivity	(18)
Total	-	1362	1603	540	40.8%	The main treatment was collagen Membrane	Infection was the most frequent complication	

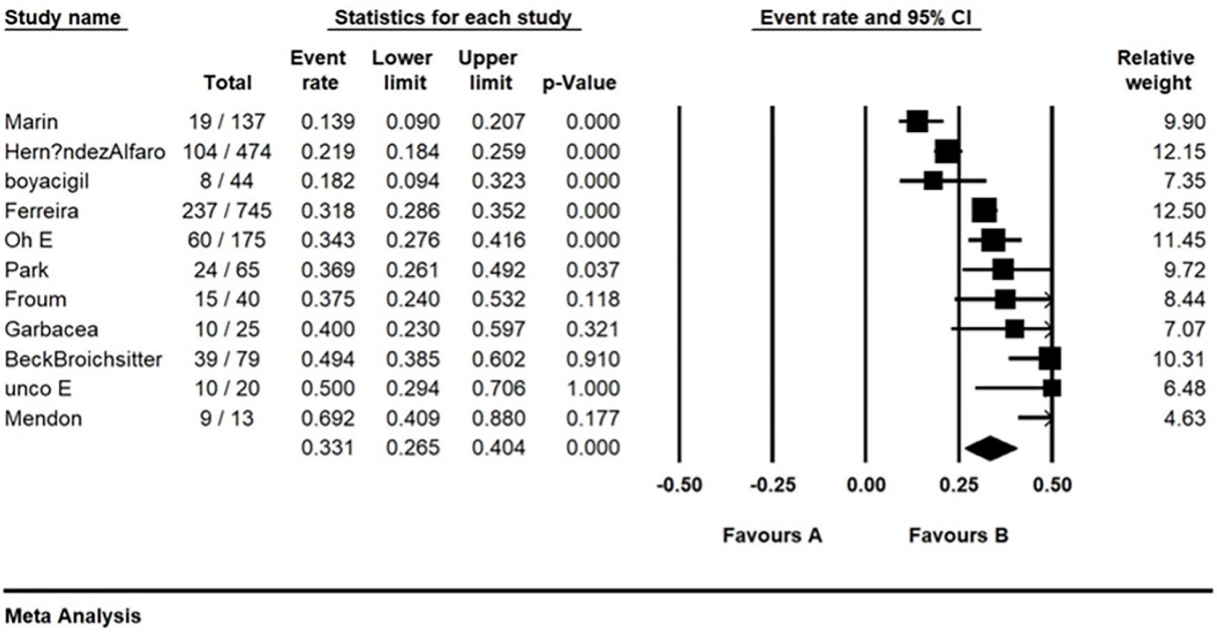

Figure 2. Membrane perforation prevalence in MSFA.

Table 2. Information on the total number of implants placed, the number of implants placed under perforated membranes, the number of implants placed under non-perforated membranes and their survival rate (%), and the average period after each Day.

Author/year	*Implants (number)*	*Implants inserted under perforated membranes (number)*	*Implants inserted under intact membranes (number)*	*Implant survival rate in perforated membranes*	*Implant survival rate in intact membranes*	*Mean follow-up (months)*
Park et al. 2019	*122*	*44*	*78*	*100%*	*100%*	*Perforation group: 11.52 (±6.6) Control group: 10.38 (6.73)*
Beck- Broichsitter et al. 2018	*175*	*92*	*89*	*9/98%*	*100%*	*Perforation group: 31 (±24) Control group: 20 (±18)*
De Almeida Ferreira et al. 2017	*1588*	*523*	*1065*	*1/97%*	*7/97%*	*Perforation group: 24 Control group: 24*
Öncü E et al. 2017	*35*	*15*	*20*	*100%*	*100%*	*Perforation group: 6-12 Control group: 6-12*
Froum et al. 2013	*80*	*35*	*45*	*100%*	*5/95%*	*Perforation group:6-32 Control group: 6-32*
Oh et al. 2011	*438*	*134*	*304*	*01/97%*	*99%*	*32-6*
Hernández- Alfaro et al. 2008	*1166*	*272*	*894*	*9081%*	*100%*	*12*
Total	*3604*	*1115*	*2495*	*68/97%*	*88/98%*	

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Discussion

The lateral window technique enables MSFA procedures with either simultaneous or delayed implant placement [16]. The success of this procedure depends on preserving the Schneiderian membrane and effectively sealing any perforations that occur [1,17]. During MSFA procedures utilizing the lateral window technique, membrane perforation is the most common intraoperative complication [1]. In this systematic review, which included 1362 patients undergoing 1603 MSFA procedures with lateral access, the mean perforation rate was 40.8%. Despite the widespread use and familiarity with MSFA, there are no established criteria for halting the procedure or evidence-based guidelines for sealing defects. Most reported cases involved the use of collagen membranes for repair, albeit in various manners. Based on the study results, it can be inferred that perforations smaller than 5 mm can be repaired by folding the membrane itself or using absorbable sutures [1,18]. For perforations between 5mm and 10mm, a slowly resorbable collagen membrane is preferred as it facilitates perforation repair and seals the defect. Additional treatments may include absorbable hemostatic agents, absorbable sutures, or platelet-rich fibrin (PRF) [19].

Ferreira et al. used adhesives to fix a collagen membrane to the perforations and secure the graft material [20]. Testori et al. noted that significant defects might cause collagen membrane displacement during grafting material placement, leading to inadequate graft accommodation [21]. They recommended that repair membranes be rigid enough to prevent collapsing into holes when wet and cover the hole and the surrounding area. After repairing the hole, sinus augmentation should be delayed for 3-6 weeks [22]. This waiting period allows the membrane to heal, facilitating the re-entry process. Conversely, defects treated with collagen membranes exhibited a high degree of fibrosis, inflammatory infiltrate, and epithelial deficiency [23,24].

PRF stimulates angiogenesis and the vascularization [25]. The fibrin network in PRF ensures that implant particles do not enter the sinuses. Additionally, activated platelets gradually release various proteins and growth factors (BMPs, PDGFs, IGFs, VEGF, TGF-b1, TGF-b2) that contribute to the healing of bone tissue and regulate inflammation and infection [1]. However, this method is recommended only for perforations up to 5 mm due to its inherent difficulty, limited accessibility, and membrane fragility [26,27]. This systematic review highlights the importance of accurately the size of the membrane perforation to select the appropriate treatment. While many treatment reports published, comprehensive guidelines are limited. Upon membrane perforation, MSFA should be performed without further enlarging the hole [28,29].

Conclusion

This systematic review revealed that implants placed near repaired perforated membranes have an average survival rate of 97.68%. While implants placed on intact membranes have an average survival rate of 98.88&. Infection was identified as the primary complication associated with the repair of perforated membranes. The use of antibiotics can prevent these adverse outcomes and contribute to a natural recovery and favorable surgical results.

Conflict of Interest

There is no conflict of interest to declare.

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