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RESEARCH

Influence of Schneiderian membrane perforation during maxillary sinus floor augmentation with lateral approach on dental implant survival rates: a retrospective study in a university setting

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Abstract

Objectives The primary objective of this study was to compare implant survival rates (ISR) in patients undergoing maxillary sinus floor augmentation (MSFA) with lateral approach with and without membrane perforation. Secondary objectives were to establish the percentage of perforations in these procedures and to evaluate the influence of perforation size on ISR.

Materials and methods This retrospective study included patients requiring MSFA with lateral approach. Cases were assigned to two groups according to the occurrence or not of perforation. The exact size of each perforation was registered. Descriptive statistics and associations between the groups were calculated.

Results This study analyzed data from 90 MSFA in 72 patients. Membrane perforation occurred in 24.44%. A total of 170 implants were placed; 72.35% were placed under intact membranes and 27.65% on repaired membranes. The overall ISR in MSFA procedures with intact membranes was 98.37%, and 93.62% in perforated membranes. No statistically significant relationship between groups was observed although the odds of implant failure increased by 4.125 times when perforation occurred. In turn, no statistically significant relationship was observed between perforation size and ISR.

Conclusions Implants inserted below repaired membranes had a lower ISR compared with implants inserted below intact membranes although the difference was not statistically significant. Moreover, no significant statistical correlation was observed between perforation size and ISR.

Clinical relevance Membrane perforation does not have a significant influence on subsequent implant survival rates. Knowledge of the exact size of the membrane perforation is essential for deciding on the right treatment plan.

Keywords Maxillary sinus floor augmentation · Lateral approach · Survival · Membrane perforation

Introduction

In cases of atrophic posterior maxilla, there is insufficient residual bone heigh for the placement of dental implants. This problem can be overcome through maxillary sinus floor augmentation (MSFA) surgery, with simultaneous or delayed implant placement. MSFA has been found to be a highly predictable technique [1]. In fact, implant survival rates following MSFA are similar to rates observed in pristine bone [2, 3]. In some cases, MSFA surgery can result in sinus membrane (SM) perforations, whether due to iatrogenic causes relating to incorrect surgical management or to challenging anatomical situations derived from the individual patient that make the procedure more complicated [4, 5]. Iatrogenic perforations may be due to uncontrolled pressure on the membrane or to the inappropriate choice of surgical instruments [6]. Anatomical difficulties are related to reduced thickness of the membrane [7], unfavorable stretching potential [8], strong adhesion to the surface of the bone [9], or the presence of the sinus septa [10].

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Membrane perforation is the most frequent complication in this type of procedure [11]. According to the various authors reviewed, frequency varies between 7 and 60% [12–14].

In most cases, providing these perforations are not overly large, they can be resolved intraoperatively before continuing with the regenerative procedure [15]. However, there are divergent opinions in the literature as to the influence of these perforations on subsequent implant survival rates (ISR) [13, 16]. At the same time, there is no consensus as to the treatment required to restore the integrity of perforated membranes. Nevertheless, most authors consider it vital to know the exact size of the perforation, especially as the size of the perforated membrane appears to be the key factor influencing ISR, with the survival rate being lower for larger perforations [17, 18].

Therefore, this study investigated a controlled group of patients in a university setting, in which the same therapeutic protocols were applied to restore perforated membranes depending on the size of the perforation, in order to find out to what extent perforation and perforation size may condition ISR.

The primary objective of the present retrospective study was to compare the clinical ISR in patients undergoing MSFA with lateral approach with and without membrane perforation. Secondary objectives were to establish the percentage of perforations in these procedures and to evaluate the influence of perforation size on ISR.

Materials and methods

Study design and registration

This retrospective clinical cohort study included a total of 90 MSFA with lateral approach in 72 patients performed at the Postgraduate Oral Surgery and Implantology Service at the Faculty of Dentistry, Complutense University of Madrid, Spain, between September 2012 and September 2021. The selection of patients indicated for the MSFA procedure with lateral approach and placement of posterior dental implants was based on previous oral and radiological examination by cone beam computed tomography (CBCT). All patients signed an informed consent form to participate in the study.

The study was conducted following STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines [19]. All procedures involving human participants fulfilled ethical standards established by institutional and/or national research committees in accordance with the 1964 Helsinki declaration and subsequent amendments. The study protocol was assessed and approved by the Research Ethics Committee at the San Carlos Hospital of Madrid, Spain (Registration Code Nº E23/740-E); it was also approved by the Faculty of Dentistry of the UCM in January 2024 and was registered with the following number: 119-150124.

Inclusion criteria were: need for MSFA with lateral approach; a residual ridge equal to or less than 4 mm; patients aged over 18 years; no relevant systemic diseases (American Society of Anesthesiologists classification ASA I and ASA II). Exclusion criteria were: disease or medication preventing oral surgery, pregnancy or lactation, patients who were unable to attend follow-up visits, and those patients in which implant placement was performed simultaneously with the MSFA procedure.

Surgical procedure

All patients underwent surgery with the same standardized protocol performed by third-year residents.

The surgical procedure used was the lateral window technique (lateral or direct sinus lift) without simultaneous insertion of implants. The modified Caldwell-Luc approach was used to access the maxillary sinus through the lateral wall. A medial ridge incision was made with anterior and posterior vestibular incisions placed at some distance from the proposed osteotomy site. A full-thickness flap was raised to expose the lateral maxillary wall, and an oval or round bony window was created with a tungsten carbide round bur and surgical handpiece to make the Schneider membrane visible. The sinus membrane was carefully elevated. The cavity between the sinus membrane and the sinus floor was filled with Bio-Oss® (Geistlich Pharma AG). The osteotomy window was covered with Bio-Guide® Geistlich Pharma AG membrane before flap closure. Finally, the flap was sutured with simple interrupted sutures using 5.0 Supramid (Proclinic®, Zaragoza, Spain).

All patients were prescribed 1 g of amoxicillin (clindamycin in penicillin allergies) one hour before the surgical procedure and anti-inflammatory 400 mg Ibuprofen (every 6 h for 4 days) in combination with 500 mg acetaminophen (every 8 h for 5 days) for pain relief. The sutures were removed 10–14 days after surgery.

If a membrane perforation occurred during the procedure, it was subsequently repaired intraoperatively providing it did not exceed 10 mm, in which case the procedure was postponed. The exact size of each perforation was measured, and the corresponding reparative treatment was applied. When perforations were smaller than 5 mm, they were treated by folding the membrane itself or by applying a collagen membrane. When the perforations were between 5 and 10 mm, the treatment used was a slowly resorbing collagen membrane. Finally, when the perforation was larger than 10 mm, the procedure was postponed, and the

biomaterial was mixed with plasma rich in growth factors (PRGF) during re-entry.

Six months after the MSFA procedure, a new CBCT was performed to evaluate bone gain, and implants were scheduled for placement. Restoration was performed after the appropriate period of osseointegration.

Data collection

Patient profiles were assigned to two cohorts based on the occurrence of Schneiderian membrane perforation during the MSFA procedure. Group 1 included cases in which perforation did not occur (Fig. 1). Group 2 included cases which underwent an intraoperative perforation (Figs. 2 and 3).

A case history for each subject was created. Two researchers jointly (G.F.N and L.A.D.O.) reviewed the medical records entered in a database collecting the following information: sex, age, perforation or not of the membrane, size of the perforation, treatment performed, other intra- or post-operative complications, implant survival, and follow-up time.

Survival was understood as the implant remaining free of mobility, progressive marginal bone loss, and infection requiring implant removal [20, 21].

Statistical analysis

Statistical analysis was conducted at the Data Processing Center of the Complutense University of Madrid by an independent statistician. Data were analyzed with SPSS* Statistics 28.0 software (SPSS® inc, Chicago IL, USA).

Descriptive statistics (mean, median, standard deviation, percentage distribution, confidence interval) were calculated. Secondly, association between the groups (with and without perforation) were analysed by means of logistic regression. The statistical relationship was determined using the chi-square test or Fisher test. Statistical significance was established with a 95% confidence interval (CI) ($p < 0.05$, two-tailed).

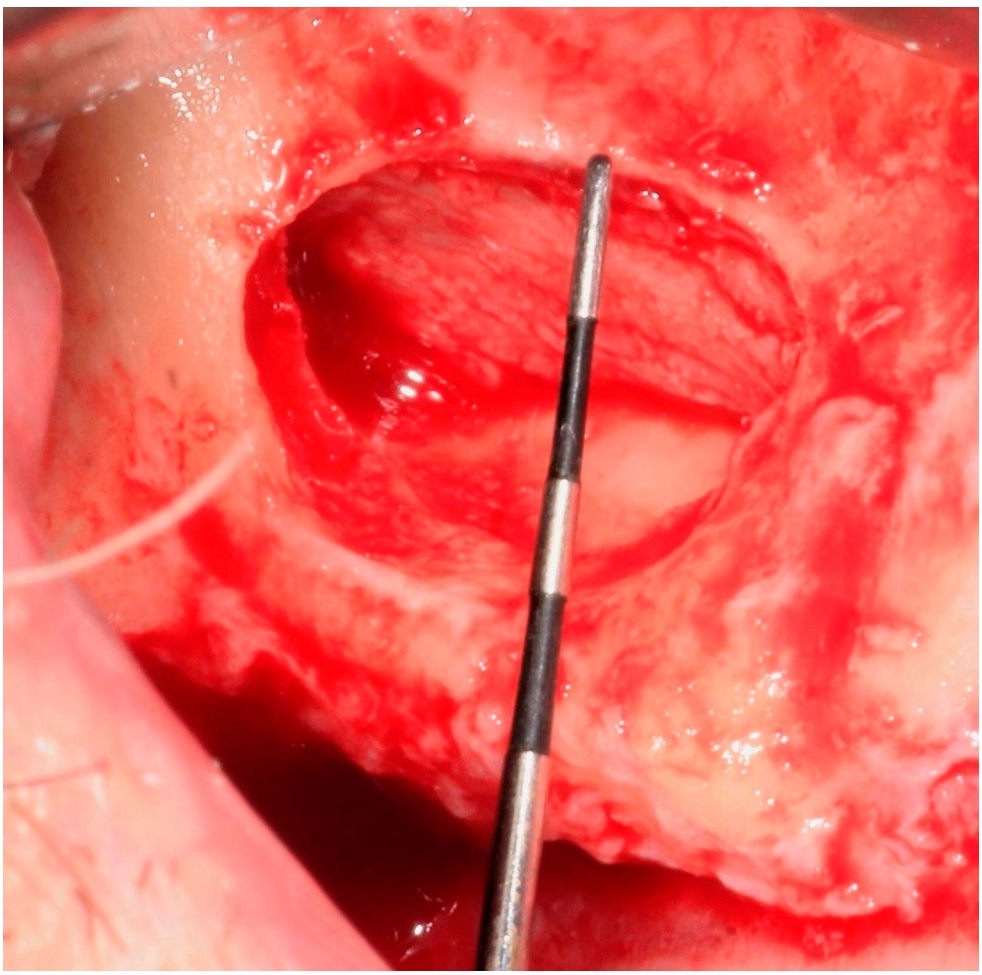

Fig. 1 Clinical image of an intact sinus membrane once elevated

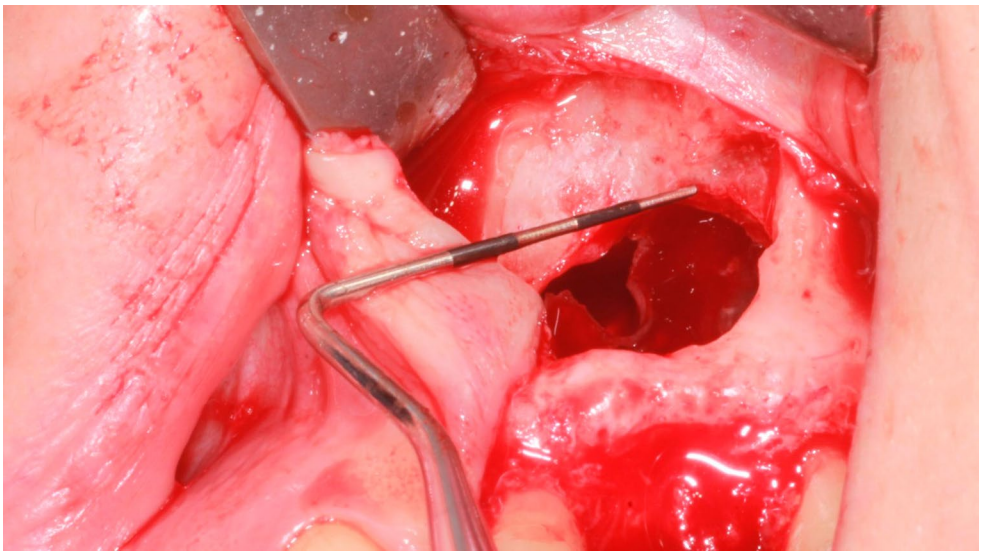

Fig. 2 Clinical image of intraoperative sinus membrane perforation (perforation ≥ 5 mm)

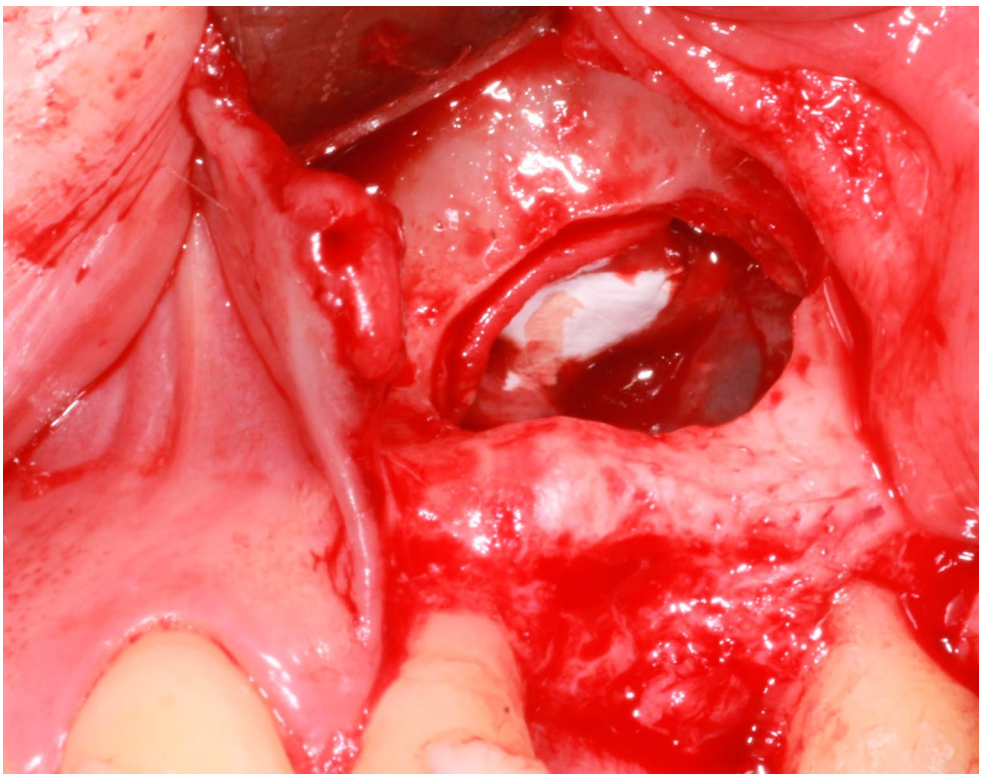

Fig. 3 Intraoperative perforation repaired with a slowly resorbing collagen membrane

Results

Initially, a total of 98 MSFA procedures with lateral approach and delayed implant placement in 79 patients were included in the study. However, seven patients (eight MSFA procedures) missed their check-up appointments and/or disappeared at some point during the therapeutic process and were withdrawn from the study. Consequently, data from 90 MSFA procedures in 72 patients were analysed.

The mean age of patients was 60.26 ± 11.03 years. The sample comprised 45 women (62.50%. CI 95%: 51.0-73.01%) and 27 men (37.5%. CI 95%: 26.99-49.0%).

Fifty-four patients (75%. CI 95%: 64.15-83.88%) underwent unilateral sinus floor augmentation, and 18 (25%. CI 95%: 16.12-35.85%) had the procedure performed bilaterally (Figs. 4 and 5).

SM perforations occurred in 22 cases (24.44%. CI 95%: 16.47-34.03%), while in 68 cases (75.56%. CI 95%: 65.97-83.53%) no perforation of the membrane was observed. Perforations were treated according to size, finding six (6.67%.

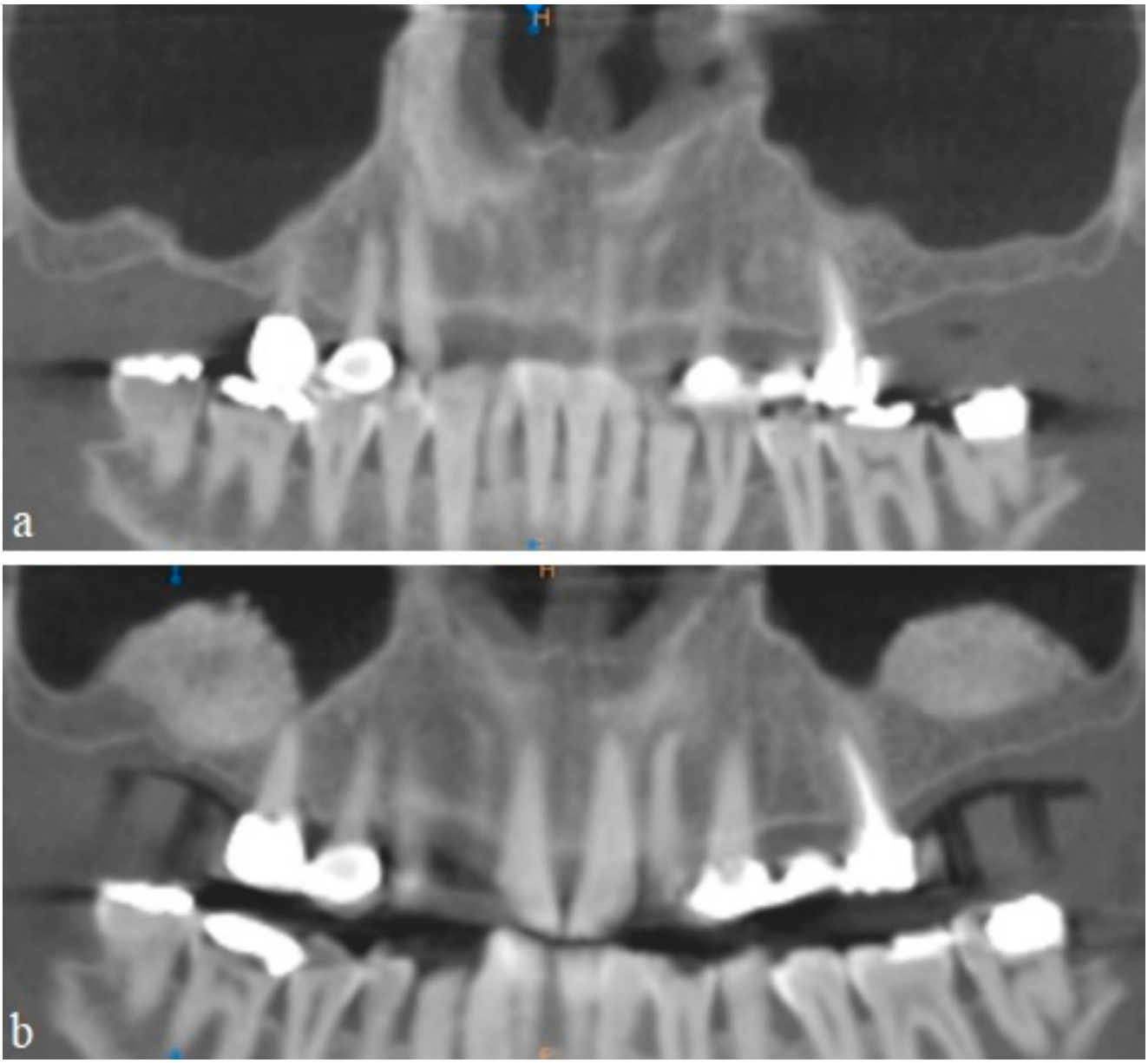

Fig. 4 (**a**) Panoramic CBCT view showing atrophic posterior maxilla on both right and left sides. (**b**) Panoramic CBCT view of the same case showing the 6-month results of a bilateral MSFA procedure

CI 95%: 2.83-13.22%) perforations that were less than 5 mm in diameter, 15 (16.67%. CI 95%: 10.08-25.36%) that were between 5 mm and 10 mm and one perforation (1.11%. CI 95%: 0.12-5.07%) greater than 10 mm (and so the procedure was postponed).

After perforations, the most frequent complications were pain (3.33%. CI 95%: 0.95-8.63%), bleeding (3.33%. CI 95%: 0.95-8.63%), hematoma (3.33%. CI 95%: 0.95-8.63%) and wound dehiscence (3.33%. CI 95%: 0.95-8.63%), followed by inflammation (2.22%. CI 95%: 0.46-6.94%) and, finally, infection (2.22%. CI 95%: 0.46-6.94%) (Fig. 6). Infection was defined as leakage of cystic fluid or purulent exudate through the wound with partial or complete loss of graft [4].

One of the two cases of infection occurred in a procedure in which the membrane was perforated, while the other case occurred in the case of an apparently intact membrane. No statistically significant differences were observed between the groups ($p = 0.431$).

A total of 170 implants were placed: 123 (72.35%. CI 95%: 65.29-78.66%) were placed under intact membranes and 47 (27.65%. CI 95%: 21.34-34.71%) on repaired membranes.

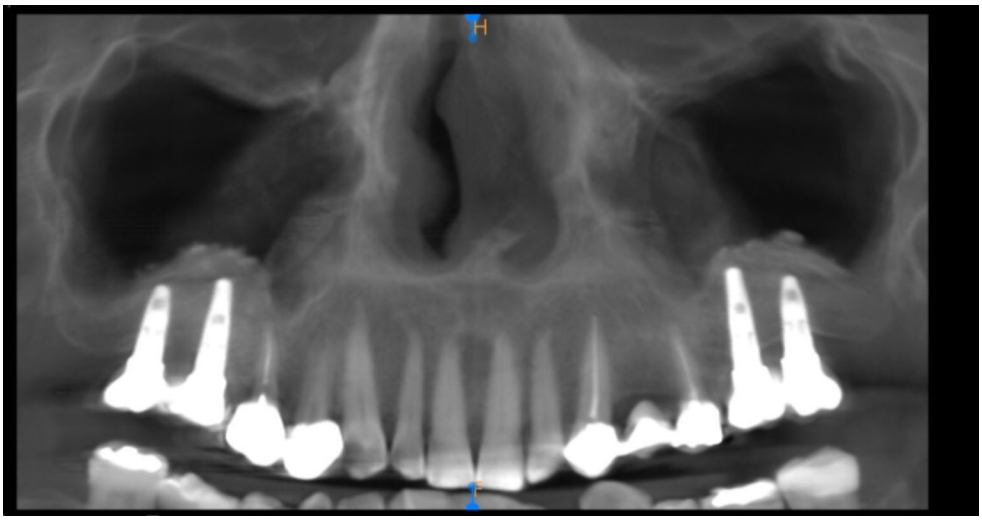

Fig. 5 Panoramic CBCT view of implants placed on regenerated bone and supporting fixed dental prosthesis after 10-year follow-up

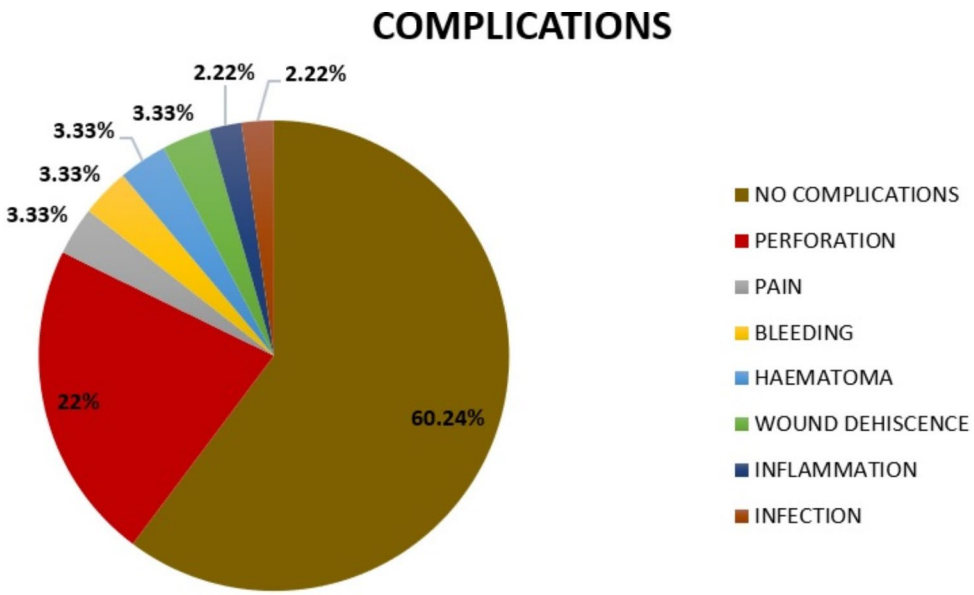

Fig. 6 Diagram showing complications associated with MSFA procedures

The mean implant observation time was 6.73 years (±1.7 years); in MSFA with perforated membranes it was 6.64 years (±2.05 years); and in intact membranes it was 6.76 years (±1.55 years).

Different brands of implants were placed in the regenerative procedures with Nobel BioCare being the most represented with 79 implants (46.47%. CI 95%: 39.09-53.97%), followed by Straumann (37.65%. CI 95%: 30.62-45.09%), Astra (14.12%. CI 95%: 9.50-19.94%), and finally Zimmer (1.76%. CI 95%: 0.50-4.63%). All five failed implants were Straumann.

The overall implant survival rate was 97.06% (CI 95%: 93.67-98.87%); only five implants failed out of the total sample (2.94%. CI 95%: 1.13-6.33%).

The overall implant survival rate in MSFA procedures with intact membranes was 98.37% (CI 95%: 94.89-99.66%) (121 out of 123), while in perforated membranes the survival rate was 93.62% (CI 95%: 83.94-98.17%) (44 out of 47) (Fig. 7).

A logistic regression model was used to associate independent variables; the interpretation was done through odds transformation of the Exp(B) model (Table 1). When passing from the group without perforation to the perforation group, the odds (probability of implant failure) increase by 4.125 times. However, no statistically significant relationship between groups was observed ($p=0.127$).

In terms of perforation size, 15 implants were placed in membranes with small perforations, of which 13 survived (86.67%. CI 95%: 63.66-97.12%); 30 implants were placed in perforations of between 5 and 10 mm with a survival rate of 96.67% (CI 95%: 85.46-99.64%). Finally, the two implants placed in MSFA procedures with a perforation greater than 10 mm, whose approach had to be postponed to a second intervention, both survived (100%) (Table 2). No

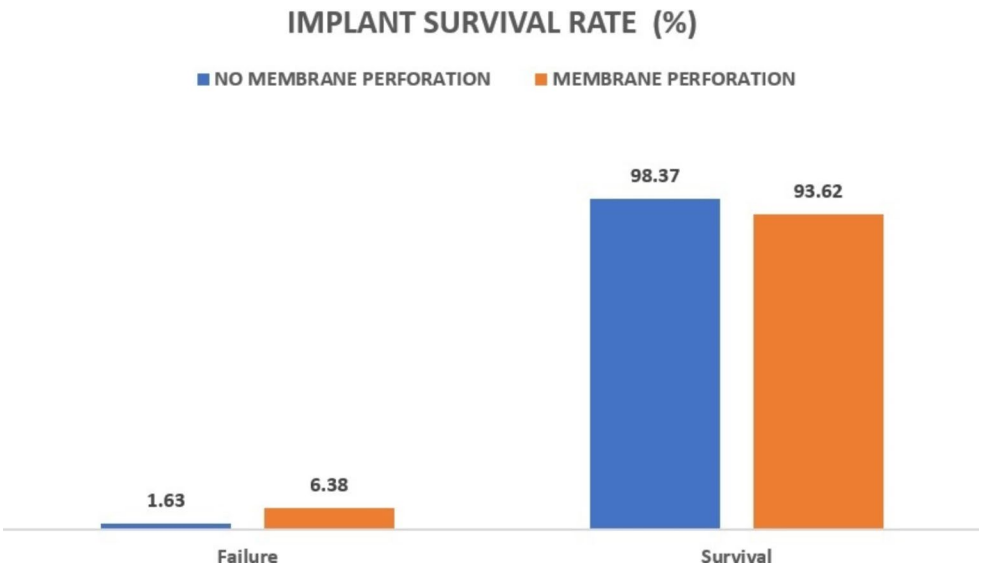

Fig. 7 Diagram showing ISR in patients undergoing MSFA with lateral approach with and without membrane perforation

Table 1 No statistically significant relationship between groups was observed although the odds of implant failure (exp (B)) increased by 4.125 times when perforation occurred

Variables in the equation									
		B	Standard error	Wald	df	Sig.	Exp(B)	95% I.C. to EXP(B)	
								Lower	Upper
Step 1st	MEMBRANE PERFORATION(1)	1,417	0,930	2,323	1	0,127	4,125	0,667	25,514
	Constant	-4,103	0,713	33,116	1	< 0,001	0,017		

a. Variables specified in step 1: MEMBRANE PERFORATION

Table 2 Correlation between perforation size and implant survival rates

Perforation size	Treatment	*N*° of elevations	Nº of implants placed	SURVIVAL
< 5 mm	None (membrane folding itself)	6	15	Yes: 13 (86.67%) No: 2 (13.33%)
5–10 mm	Collagen membrane	15	30	Yes: 29 (96.67%) No: 1 (3.33%)
> 10 mm	Procedure postponed and biomaterial + PRGF	1	2	Yes: 2 (100%) No: 0 (0%)
Total		22	47	Yes: 44 (93.62%) No: 3 (6.38%)

statistically significant relationship was observed between perforation size and implant survival rate ($p = 0.403$).

Discussion

There is still no consensus as to whether or not intraoperative Schneiderian membrane perforation during the maxillary sinus lift procedure provokes an increased risk of implant failure[13]. Although some studies have shown a higher failure rate of implants placed in perforated membranes [22–24], other more recent studies have found no correlation between ISR and membrane perforation [4, 14].

Although MSFA is a well-known and fairly commonplace procedure, no evidenced-based guidelines for perforation closure or clear indications of when to interrupt these procedures have been established [16, 25].

The results of our study showed that implants inserted below repaired membranes (93.62%) had a lower ISR compared with implants inserted below intact membranes (98.37%). However, the difference in ISR between perforated and non-perforated membranes was not statistically significant ($p = 0.127$). Moreover, the odds (probability of implant failure) increase by 4.125 times in perforated membranes.

An intact Schneiderian membrane is crucial to maintain the postoperative osteogenic space [8]. It can be

hypothesized that bacterial penetration through the torn membrane and mucous invasion into the grafted area may be the reasons for this compromised result [22].

Moreover, it has been argued that implant failure might be attributable to the fact that the implant surgeon may find it difficult to assess whether the individual membrane repair is sufficient to withstand the pressure involved in graft packing [13, 26]. When a perforation is of a large size, placing the graft material can provoke local inflammation. This may involve transient or even chronic sinusitis, leading to the failure of the bone graft and so implant loss, even before the implant is loaded. In cases with small perforations, spreading bone particles are predisposed to chronic infection and may limit bone formation or cause severe resorption of the bone graft; these situations can also lead to implant loss although over a much longer time.

Some authors, such as Proussaefs et al. [22] claimed that in MSFA procedures with unperforated membranes more bone formation was observed than with perforated membranes.

In addition, several authors have reported associations between membrane perforation and acute or chronic sinus infection, bacterial invasion, swelling, bleeding, wound dehiscence, or loss of the graft material [6, 13].

In any case it would appear evident that SM perforation is not an absolute indication for abandoning the procedure unless the membrane is largely destroyed [27, 28]. The size of the perforated membrane would appear to be the key factor influencing the implant survival rate [17, 29]. In this sense, several authors have related an increased implant failure rate as the size of the perforations increased [14, 18].

Once the membrane perforation has been made, it is necessary to complete the MSFA without further enlargement of the perforation. When the procedure is terminated, the size of the perforation will determine the treatment needed and the material required. Therefore, knowledge of the exact size of the membrane perforation is essential for deciding on the right treatment plan [16].

In the present study, no statistically significant relationship was observed between perforation size and ISR ($p = 0.403$). However, we observed a higher survival rate of implants in large and medium-sized perforations (100% and 96.67% respectively) than in implants placed in perforations smaller than 5 mm (86.67%). This finding contradicts Hernández-Alfaro et al. [18] who reported an ISR inversely proportional to the perforation size (97–74%); perforations over 10 mm, considered as large, presented the least favorable results (74%). These differences in ISR may be due the present study's small sample size.

In addition, it should be noted, that our results were obtained in the framework of a postgraduate course in implant surgery in which perforations were measured and treated according to their size. For perforations smaller than 5 mm we agree with Testori et al. [30] who postulate that small perforations can self-repair providing that the sinus membrane folds back on itself.

When the perforations were between 5 and 10 mm, the treatment used was a slowly resorbing collagen membrane. Oliveira et al. [31] assert that the resorbable membrane influences the intensity of inflammatory responses leading to a reduction in bone formation, which compromises the primary stability of implants placed simultaneously with MSFA. Nevertheless, most of the studies we reviewed use the collagen membrane technique to repair medium sized perforations (5–10 mm) [14, 25, 27, 32]. One of the exclusion criteria in our study were patients in whom implant placement was performed simultaneously with the MSFA procedure. Moreover, a recent systematic review by Monje et al. [33] to identify a statistically significant association between (primary) mechanical stability of the implant and ISR.

For perforations larger than 10 mm, priority was given to closure and repair of the perforation with a collagen sponge or collagen membrane, and the procedure was postponed [34, 35]; 12–15 weeks later, during re-entry, the biomaterial was mixed with PRGF.

The results of our study revealed a perforation rate of 24.44%, comparable to that obtained by Aldajani [36] in his systematic review that analyzed a total of 1.652 MSFA procedures (23.5%). The low perforation rate in our study is noteworthy, especially considering that the surgeries were performed by residents and these procedures can sometimes be relatively delicate. Our results demonstrate the importance of a thorough preliminary study to detect factors that may increase the risk of intraoperative complications (including general health of the sinus, presence and location of sinus septum, endosseous anastomosis at the osteotomy site, lateral wall thickness, Schneider membrane thickness, and residual bone crest height) [16]. In this way, the surgical approach could vary and even the design of the access window could be altered according to individual case anatomy [37]. Authors such as Manderalis et al. [38] and Goodacre et al. [39] have developed surgical guides in order to minimize these perforations.

The limitations of the present study stem mainly from its retrospective nature and the small number of cases included in each of the groups and subgroups. More studies, especially prospective observational with larger sample sizes, are needed in order to provide clear and reliable results as to which form of treatment is the most effective in relation to the size of the perforation.

Conclusions

Perforation of the Schneiderian membrane during MSFA with lateral approach was observed in 24.44% of the procedures. Within the limitations of this retrospective study, it can be stated that implants inserted below repaired membranes (93.62%) had a lower ISR compared with implants inserted below intact membranes (98.37%) after a mean observation period of 6.73 (± 1.7) years. However, the difference in ISR was not statistically significant. Moreover, no statistically significant relationship was observed between perforation size and ISR. The knowledge of the exact size of the membrane perforation is essential for deciding on the right treatment plan.

Author contributions J.C.B.B.: Conceptualization, Methodology, Validation, Writing Original Draft. C.M.M.P.: Methodology, Validation, Writing-Review & Editing. G.F.N. and L.A.D.O.: Data collection, Formal analysis, Visualization, C.B.D.: Methodology, Writing -Review & Editing, Supervision. I.L.B.: Validation, Formal analysis, Writing Original Draft. J.L.Q.: Conceptualization, Methodology, Writing-Review & Editing, Supervision. All authors gave final approval and agree to be accountable for all aspects of the work.

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Data availability Data is provided within the maniscript or supplementary information files.

Declarations

Ethical approval The study was approved by the Committee for ethics in research at the San Carlos Hospital, Madrid, Spain (Registration Code Nº E23/740-E)C.I. 22/135-E, and followed the ethical guidelines established in the Declaration of Helsinki by the World Medical Association.

Informed consent Informed consent was obtained from al the individual participants included in the study.

Competing interests The authors declare no competing interests.

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