Sinus Floor Bone Failures in Maxillary Sinus Floor Augmentation: A Case-Control Study

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ABSTRACT

Background: Extreme bone resorption in posterior maxilla may lead to absence of part of the sinus floor. This phenomenon has been termed *sinus floor bone failure*, and may compromise sinus floor augmentation.

Purpose: The present article aims to evaluate risk factors related to sinus floor bone failures and to evaluate the influence of these failures in sinus floor augmentation outcomes in patients with severely atrophic posterior maxilla.

Material and Methods: In this case-control study, patients were selected among those referred for sinus floor augmentation. Only patients presenting a ridge bone height of less than 3 mm were included. Cases were defined as presenting sinus floor bone failure, whereas controls did not present any interruption in the sinus floor bone. Information collected included clinical dental records and computed tomographic assessment of sinus width, septa, and schneiderian membrane. Risk estimates for sinus floor bone failures were calculated as adjusted odds ratios (AORs) with 95% confidence intervals (CIs) using conditional logistic regression analyses. A p value under 0.05 was considered statistically significant. In addition, sinus floor augmentation outcomes of both groups were also assessed.

Results: In all, 23 cases and 58 controls were included in the study. Sinus floor bone failures were significantly associated with the number of missing posterior teeth (AOR 3.67; 95% CI 0.86 to 15.63; $p = .046$) and a history of periodontitis (AOR 6.39; 95% CI 1.86 to 21.95; $p = .002$). Of the total, 15 cases and 27 controls underwent sinus floor augmentation. Schneiderian membrane perforation occurred during the surgery of two cases and of one control. No implants were lost during a mean postsurgical follow-up of 20 months.

Conclusion: The number of missing posterior teeth and a history of periodontitis may be considered as risk factors for sinus floor bone failures.

KEY WORDS: schneiderian membrane perforation, severely atrophic maxilla, sinus floor augmentation, sinus floor bone failure

INTRODUCTION

Maxillary sinus augmentation using the lateral window approach is a predictable way of providing sufficient bone height for posterior maxillary implant placement.[1–4] However, intrasurgical and postoperative complications may compromise treatment outcomes and may also lead to implant loss.[5] The most common surgical complication is perforation of the schneiderian membrane, which occurs in 14% to 56% of sinus lift procedures, usually during the preparation of the lateral sinus window or during curette elevation of the membrane.[6–11]

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One of the factors that may act as a primary determinant of sinus floor augmentation outcomes is the residual ridge bone height (RBH).[12,13] Patients with severely atrophic maxilla (RBH < 3 mm) have been found to present higher rates of complications such as sinus membrane perforation.[13–15] However, none of the articles just cited have included cases with RBH of less than 1 mm.

Extreme resorption of the alveolar bone can lead to an absence of bone in some parts of the sinus floor.[12,16,17] This has been defined as *failure of the sinus floor bone*.[17] These failures may represent a risk factor for sinus lift surgeries. One of the main related complications is that direct contact between the schneiderian membrane and the oral mucosa could exist in the failure areas, thus hindering the procedure from elevating the schneiderian membrane, and leading to its perforation.[12,16] However, within the limit of our knowledge, the risk factors associated with sinus floor bone failures remain unknown.

Therefore, the aims of the present study were the following: first, to assess the risk factors associated with the occurrence of sinus floor bone failures in patients with severely atrophic maxilla using a case-control design; and second, to assess the sinus floor augmentation outcomes in patients with and without sinus floor bone failures.

MATERIALS AND METHODS

Ethical approval was obtained from the Ethics Committee of the University of São Paulo. All patients willing to participate in this study signed an informed consent form allowing the researchers to use data obtained during previously performed treatments and the related cone beam computed tomographic (CBCT) images. The guidelines of the Helsinki Declaration were followed in this investigation.

Inclusion and Exclusion Criteria

This case-control study was conducted on patients attending a private dental clinic that partners in research with the School of Dentistry, University of São Paulo. The subjects selected had been diagnosed and indicated for at least one sinus floor augmentation procedure. Only patients presenting RBH of less than 3 mm, measured in cross-sectional CBCT images, were included. All subjects were analyzed consecutively between March 2011 and July 2012.

Any systemic factors interfering with bone or soft tissue healing were considered exclusion criteria. Patients with a recent tooth extraction (less than 6 months of follow-up) were also excluded to avoid consideration of the socket-remodeling period. Patients with metabolic disorders, such as diabetes or osteoporosis, or with any history of diseases affecting systemic bone turnover were also excluded from the study.

Case and Control Definitions

Sinuses presenting sinus floor bone failure, that is, an absence of part of the sinus floor bone as detected in CBCT coronal images, were defined as cases. Sinuses that presented no interruption in the sinus floor bone were treated as controls.

Presurgical Assessment

Demographic parameters were recorded for all patients, including age, gender, and smoking habits. Dental parameters were also recorded, including number of missing posterior teeth, length of time since last extraction, and history of periodontitis. Patients were recorded as having a history of periodontitis if at least one of the missing teeth was lost owing to periodontitis in the ridge area indicated for sinus floor augmentation. The ridge area assessed in this study extended from the first premolar site to the second molar site, as these are the sites usually rehabilitated with sinus floor augmentation and dental implants. Additionally, radiographic parameters were measured in this same area using the preoperative coronal CBCT images and were recorded, including presence of sinus septum, minimum RBH, sinus membrane thickness (measured at the site with the minimum RBH), and presence of narrow sinus antrum (>10.0 mm in width).

Treatment Timetable

Patients who underwent sinus floor augmentation were instructed to use amoxicillin 2.0 g an hour before the procedure as prophylaxis. Patients were treated by the same surgeon, using the same surgical procedure. Under local anesthesia, a crestal incision was performed slightly palatal to the crest midline, and the mucogingival flap was elevated. A lateral antrostomy was then created by outlining the borders of the lateral window using a piezoelectric unit (Piezosonic, Driller®, São Paulo, Brazil) with a grinding tip, according to the manufacturer's instructions. Cooling was carried out with saline solution cooled at 3°C and applied at a flow rate of 40 ml/minute.

Elevation of the schneiderian membrane was performed by initially exposing and mobilizing the

membrane using the piezoelectric handpiece with a blunt tip, followed by further elevation of the membrane along the medial wall of the sinus with a curette. In sinuses with a small sinus membrane perforation (less than 5 mm), another resorbable collagen membrane was placed to close the membrane perforation at this stage. A large membrane perforation (greater than 1 cm) was considered grounds to abort the procedure.

In sinuses with sinus floor bone failure, a resorbable collagen membrane (CollaCote®, Zimmer Dental, Carlsbad, CA, USA) was then placed over the sinus floor bone to close the failure prior to graft insertion. A particulate graft material composed of biphasic calcium phosphate (Straumann BoneCeramic®, Institut Straumann AG, Basel, Switzerland) was inserted to enable sinus floor augmentation, followed by the placement of a resorbable collagen membrane (CollaCote) to close the fenestrated lateral wall of the sinus. Flaps were secured using monofilament suture with primary closure.

After a graft maturation period of 6 months, tapered dental implants were inserted into the augmented areas to rehabilitate the compromised sites. In sites with thick flap tissue (>2 mm, measured with a 1-mm marked periodontal probe), soft-tissue-level implants (SLA; Institut Straumann AG, Basel, Switzerland) were placed, whereas in sites with thin flap tissue (<2 mm), bone-level implants (XiVE plus, DENTSPLY-Friadent, Mannheim, Germany) were placed. Following 3 months of uneventful healing, implants were restored and followed up.

Postsurgical Assessment

Different parameters were recorded for patients who underwent sinus floor augmentation, including occurrence of sinus membrane perforation, final RBH (as measured on a postoperative CBCT, taken 6 months after the intervention), number of implants placed in the sinus area, and follow-up period.

Radiographic Analysis

Digital CBCT images from all the analyzed patients were provided in the Digital Imaging Communications in Medicine (DICOM) format and analyzed and measured using the OsiriX imaging software (open-source; OsiriX DICOM Viewer version 3.9.4, Pixmeo, Geneva, Switzerland; http://www.osirix-viewer.com) installed on a Mac OS 10.7 Apple computer (Apple Inc., Cupertino, CA, USA). All images were obtained with the same CBCT scan unit (i-CAT Classic, Image Sciences International, Hatfield, PA, USA), which was configured with a diagnostic protocol used for dental implants (0.25-mm voxel, 120 kVp, 8 mA, field of view 16 cm in diameter and 6 cm in height). All CBCT measurements (in millimeters) in this study were recorded separately in random order by two trained independent observers. Measurement reliability assessment of replicate measurements was made using the concordance correlation coefficient (CCC). One observer served as the main observer, and intraobserver reliability was assessed between measurements performed 2 weeks apart to eliminate memory bias. All subjects were reassessed to ascertain the interobserver reliability. Systematic differences between observers were evaluated using the weighted kappa index.

Statistical Analysis

Conditional logistic regression analyses were performed using the SPSS 17 software (IBM Corp., Armonk, NY, USA). Risk estimates were presented as odds ratios (ORs) with 95% confidence intervals (CIs). The ORs were adjusted for the potential confounders of age, gender, smoking habit, presence of sinus septum, sinus mucosal thickness, number of missing posterior teeth, length of time since last extraction, and history of periodontitis. In addition, Pearson's correlation test was used to compare data from the analyzed variables (age, minimum RBH, number of missing posterior teeth, and time since last extraction). Finally, Student's *t*-test was also used to compare the mean minimum RBH in cases with and without a history of periodontitis. A p value under .05 was considered statistically significant.

RESULTS

A total of 23 cases and 58 controls were included in the study (Figure 1). The demographic characteristics of the case and control groups are presented in Table 1. The case group had a mean age of 60.6 ± 9.8 years, whereas the control group had a mean age of 55.8 ± 11.9 years. Additionally, controls had a mean minimum RBH of 1.6 ± 0.8 mm. The mean length of time since last extraction was 12.6 ± 10.1 years for cases and 10.4 ± 8.7 years for controls.

Intraobserver reproducibility was confirmed for the CBCT measurements, insofar as the CCC ranged between 0.78 and 0.90. Interobserver reliability was also confirmed, according to the weighted kappa index result (0.81, $p = .03$).

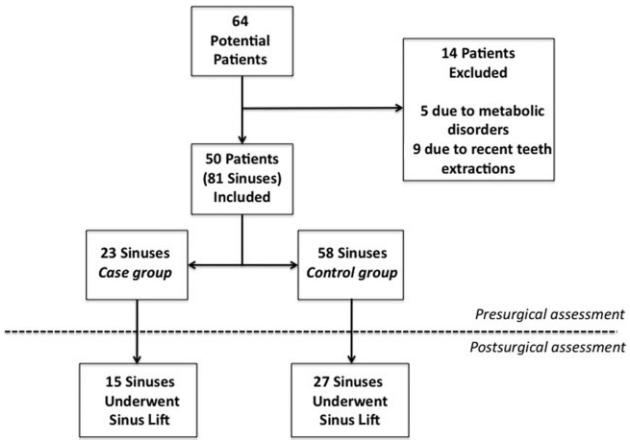

Figure 1 Main flowchart of the study.

Statistical analysis showed that the number of missing posterior teeth (AOR 3.95; 95% CI 1.03 to 16.86; $p = .044$) and a history of periodontitis (AOR 6.83; 95% CI 1.76 to 18.19; $p = .002$) were significantly associated with sinus floor bone failures (Table 1). All other factors were not significantly associated with sinus floor bone failures ($p > .05$). Regarding correlation analysis, there was a weak but significant inverse correlation between minimum RBH and age ($r = -0.23$, $p = .033$) and a significant inverse correlation between minimum RBH and number of missing teeth ($r = -0.41$, $p = .003$) (Figure 2). No other correlations were significant ($p > .05$). In addition, a statistically significant

TABLE 1 Associations between Presence of Sinus Floor Bone Failure and Patients' Characteristics

	Sinus Floor Bone Failure				
Variables	No	Yes	OR (95% CI)	AOR (95% CI)	*p* Value
Age					
≤60 years	36	11	1	1	
>60 years	22	12	1.78 (0.67–4.73)	1.17 (0.37–3.66)	.783
Gender					
Female	33	8	1	1	
Male	25	15	0.40 (0.15–1.10)	0.53 (0.13–2.27)	.401
Smoking habit					
Nonsmokers	30	11	1	1	
Smokers	28	12	1.17 (0.44–3.07)	0.54 (0.14–2.11)	.377
Presence of sinus septum					
No	35	16	1	1	
Yes	23	7	0.67 (0.23–1.87)	1.02 (0.28–3.56)	.891
Sinus membrane thickness					
≤2 mm	36	10	1	1	
>2 mm	22	13	2.12 (0.79–5.67)	1.18 (0.31–4.47)	.806
Sinus antrum					
Wide	43	15	1	1	
Narrow	15	8	1.68 (0.59–4.78)	1.97 (0.49–7.91)	.337
Number of missing posterior teeth					
1–3 (partially edentulous)	28	4	1	1	
4 (totally edentulous)	30	19	4.43 (1.32–14.64)*	3.67 (0.86–15.63)	.046
Length of time since last extraction					
≤10 years	35	8	1	1	
>10 years	23	15	2.85 (1.04–7.81)*	2.64 (0.69–10.18)	.156
History of periodontitis					
No	45	9	1	1	
Yes	13	14	5.48 (1.93–15.92)*	6.39 (1.86–21.95)	.003

*Statistically significant ($p < 0.05$).

OR, odds ratio; AOR, adjusted odds ratio, adjusted for confounders (age, gender, smoking habit, presence of sinus septum, sinus membrane thickness, sinus antrum, number of missing posterior teeth, length of time since last extraction, and history of periodontitis); CI, confidence interval.

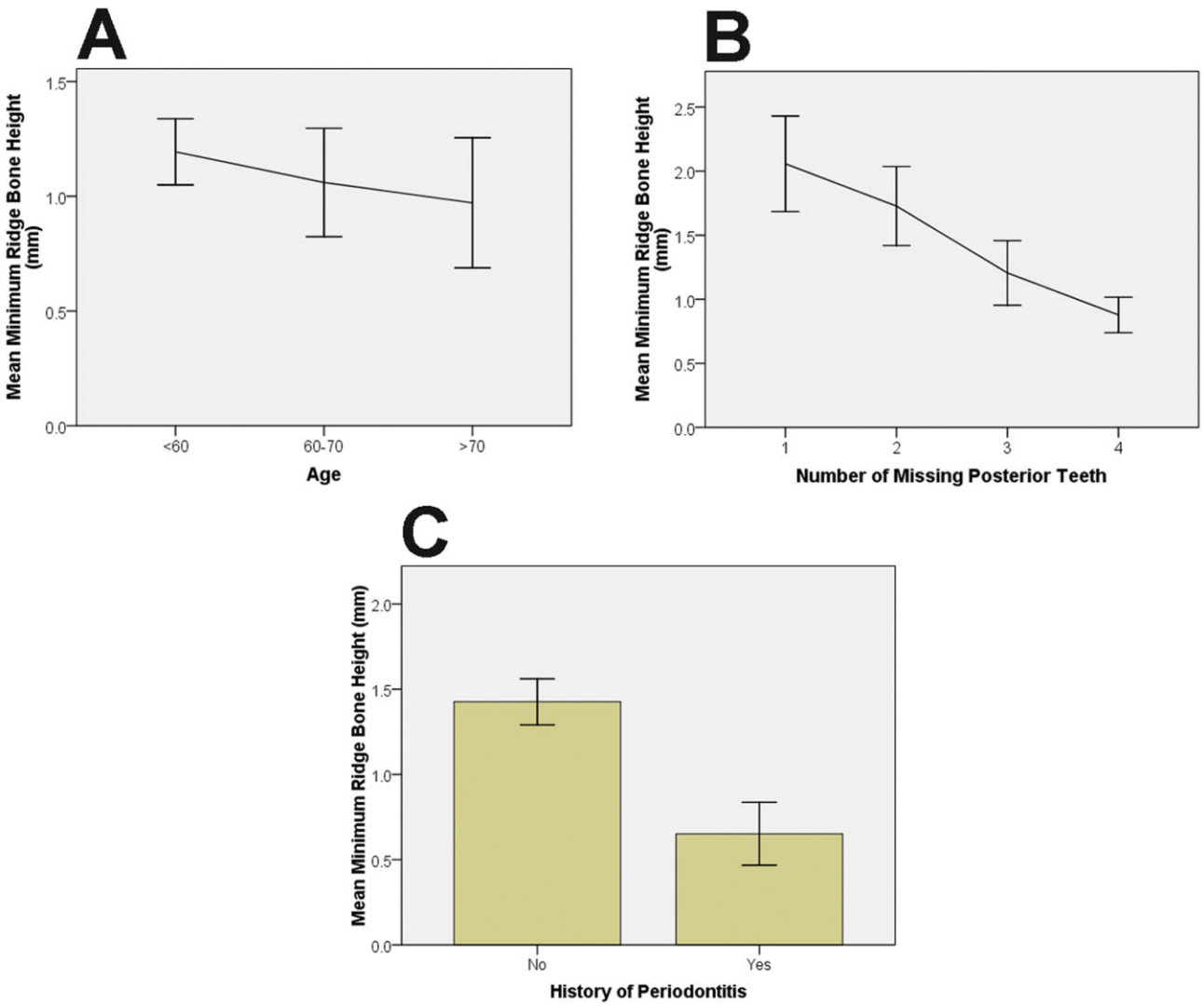

Figure 2 Distribution of mean minimum ridge bone height as a function of age (A) ($r = -0.23$, $p = .033$), of number of missing posterior teeth (B) ($r = -0.41$, $p = .003$), and of history of periodontitis (C) ($p = .001$).

difference was found in minimum RBH between patients with and without a history of periodontitis, according to the Student's *t*-test result ($p = .001$).

Sinus floor augmentation was performed in 15 cases and in 27 controls (Figure 1). Data regarding the surgical outcomes are shown in Table 2. All sinus floor bone failures observed in the CBCT images (Figure 3) were also detected during the respective sinus floor augmentation surgeries. Likewise, no sinus floor bone failures were clinically detected during the surgeries of the control group. Sinus membrane perforation occurred in 3 (7.1%) treated sinuses. One small and one large perforation were observed in the case group. Only one small perforation was observed in the control group. Small perforations occurred during the curette elevation of the

TABLE 2 Characteristics of Each Group of Patients Who Underwent Sinus Floor Augmentation

	Sinus Floor Bone Failure	
Variable	No	Yes
Number of sinuses	27	15
Sinus membrane perforations	1	2
Total implants placed	53	38
Final bone height (mm), mean ± SD	10.7 ± 1.2	10.4 ± 1.4
Implants per procedure, mean ± SD	1.9 ± 0.7	2.5 ± 0.8
Follow-up (months), mean ± SD	19.4 ± 7.1	20.4 ± 12.2

SD, standard deviation.

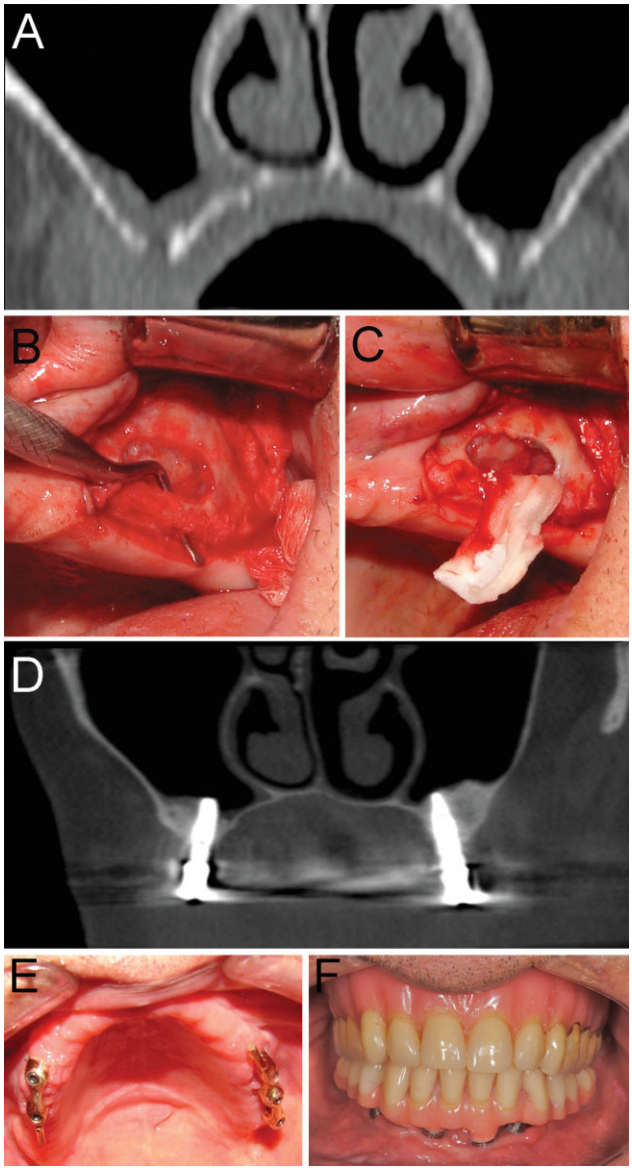

Figure 3 Diagnosis and treatment of bilateral sinus floor bone failures. *A*, Initial coronal CBCT image showing the sinus floor bone failures. *B*, Clinical evidence of the bone failure in the left sinus floor. *C*, A resorbable collagen membrane was placed to close the bone failure prior to graft insertion. *D*, Final coronal CBCT image taken after a 40-month follow-up. *E*, Clinical follow-up image of the overdenture bar attachments after a 40-month follow-up. *F*, Clinical follow-up image of the final overdenture after a 40-month follow-up. CBCT image, cone beam computed tomographic image.

sinus membrane and could be closed with resorbable collagen membranes prior to immediate graft insertion. The large perforation observed in the case group occurred during the flap opening owing to the close contact between the schneiderian membrane and the oral mucosa, causing the procedure to be aborted (Figure 4). No other procedure-related complications were observed in this study. The study implant cumulative success rate was 100% with a mean 20-month follow-up (range of 8–47 months).

DISCUSSION

Anatomical sinus variations may increase the risk of complications related to sinus floor augmentation.[12,16–20] As observed in the present study, CBCT images can be useful for obtaining detailed information on the anatomy of the maxillary sinus for surgical planning and postoperative evaluation.[16,17,21]

Anatomical alterations of the sinus floor such as convolutions and root-shape expressions, commonly observed in patients with recent tooth extraction, may render the procedure of elevating the sinus membrane more difficult.[12,16] However, as the objective of the present study was to assess risk factors for the occurrence of sinus floor bone failures due to extreme bone resorption, patients with recent extractions were identified as potential confounders and were therefore excluded from the study in order to minimize the relevance of tooth extraction as a factor in sinus floor bone failures.

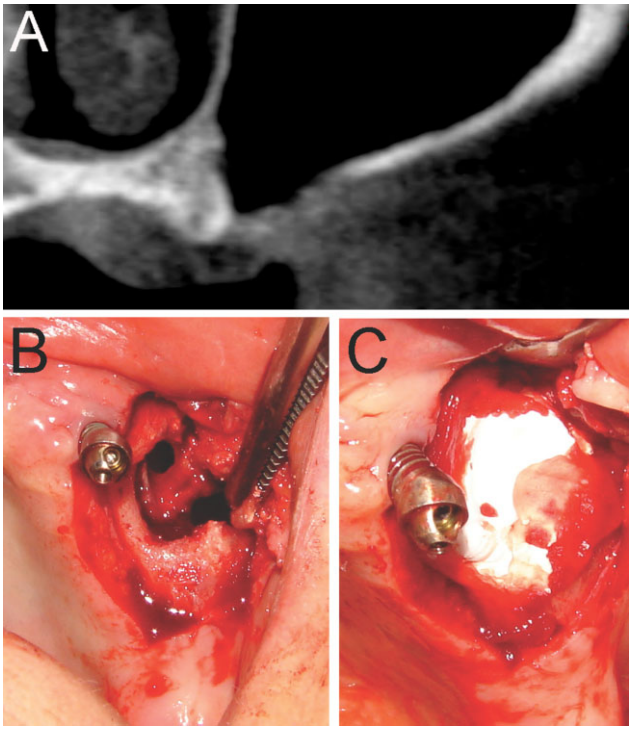

Figure 4 Diagnosis and treatment of a large sinus floor bone failure. *A*, Initial coronal CBCT image showing the buccal-lingual extension of the failure. *B*, Clinical view of a sinus membrane perforation due to close contact between this membrane and the oral mucosa. *C*, A membrane was placed to close the failure, and the procedure was aborted.

Sinus floor bone failures were significantly associated with the number of missing posterior teeth and a history of periodontitis, which are factors known to induce bone loss. However, no significant association was found between failures and length of time since last extraction, which is another factor described as directly related to maxillary alveolar bone loss.[22] Furthermore, minimum RBH was significantly correlated inversely with the number of missing posterior teeth but not with the length of time since last extraction. These findings suggest that the extension of the edentulous area has more impact on bone loss than the duration of edentulousness. This is the first study addressing the risk factors for the occurrence of this type of sinus floor alteration, which was observed in 23 of 81 sinuses included. This finding contrasts with those from other studies on severely resorbed maxillae, which did not present cases with RBH of less than 1 mm.[13–15]

In this study, minimum RBH was also significantly correlated inversely with the patients' age. This finding supports the influence of age-related bone turnover alterations on maxillary alveolar bone loss.[23] However, there was no significant correlation between number of missing teeth and age, suggesting that both factors act independently in causing ridge bone loss.

The present study also strove to assess the impact of the analyzed sinus floor bone failures on the sinus floor augmentation outcomes. All the sinuses with failures could be treated with a resorbable collagen membrane to close the failure prior to graft insertion without compromising the outcomes. This finding is supported by studies on the treatment of oroantral communications, which have demonstrated success in closing sinus floor bone defects by using the same type of membrane.[24,25]

In this study, all sinus floor augmentation surgeries were performed with the lateral window approach by using a piezoelectric surgical device. This method has been regarded as useful to avoid sinus membrane perforation and other surgical complications insofar as piezoelectric surgery is able to cut through hard tissue while sparing soft tissue.[26] Regarding the 42 sinuses that underwent surgery, only three sinus membrane perforations were observed, resulting in a study perforation rate of 7.1%. This finding is in agreement with those of other studies that used piezoelectric surgery to perform sinus floor augmentation and that observed similar perforation rates.[17,27] On the other hand, controls had a perforation rate of 3.7%, whereas cases had a perforation rate of 13.3%. These findings indicate the absence of part of the sinus floor bone as a factor that may increase the risk of sinus membrane perforation, as suggested by other studies.[12,16] However, a limitation of this study was that the size of the sample undergoing sinus floor augmentation was not statistically large enough to rule out the possibility of a significant difference between the surgical outcomes of the case and control groups. Bearing in mind the limitations of our case-control design, future cohort studies will be needed to determine the causality of sinus floor bone failure and the complications associated with it.

CONCLUSION

Totally edentulous posterior maxilla and a history of periodontitis could be considered risk factors associated with the presence of sinus floor bone failures. There were significant inverse correlations between minimum RBH and the patients' age and between minimum RBH and the number of missing teeth. In addition, there was a significant difference between mean minimum RBH in cases with and without a history of periodontitis. Finally, failures could be successfully treated with resorbable collagen membranes.

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