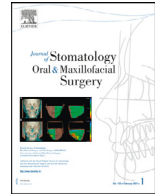




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Original Article

Single-tooth prosthetic rehabilitation of the atrophic posterior maxilla following maxillary sinus floor augmentation utilizing the lateral window technique. A European multicenter retrospective chart review



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ABSTRACT

This retrospective multicenter chart review assessed single-tooth rehabilitation following maxillary sinus floor augmentation (MSFA) utilizing the lateral window technique across eight European departments between January 1st, 2018, until December 31st, 2023. Intraoperative, early- and late postoperative data from 224 patients (mean age: 53.1 years; mean residual ridge height: 4.4 mm) were analyzed using a standardized computer-assisted database. Implants were placed simultaneously ($n = 124$) or staged ($n = 100$) after a mean healing period of 7.9 months. Coagulum or autogenous bone mixed with xenograft were the most used grafting materials. The incidence of Schneiderian membrane perforation was 17.4%. The implant survival was 96.9% and radiographic peri-implant marginal bone loss was diminutive after a mean period of 25.4 months. There were no predictive parameters for Schneiderian membrane perforation or implant loss, while peri-implant marginal bone loss was significantly correlated to smoking, omission of pre-operative antibiotics, and grafting materials without autogenous bone ($P > 0.05$). In conclusion, MSFA utilizing the lateral window technique is a highly predictable surgical procedure for prosthetic rehabilitation of the atrophic posterior maxilla. However, meticulous preoperative assessment of patient-related factors, anatomical variations, sinus pathologies, and surgical risk factors is mandatory to improve the long-term implant outcome.

1. Introduction

The lateral window technique for maxillary sinus floor augmentation (MSFA) with application of a grafting material underneath the elevated Schneiderian membrane (SM) is the standard surgical procedure for vertical alveolar ridge augmentation of the partially or totally edentulous atrophic posterior maxilla. Autogenous bone, allografts, or various bone substitutes or a combination thereof has been used as grafting material

demonstrating satisfying long-term implant treatment outcome, regardless of the grafting material used [1–40]. Autogenous bone graft is considered as the most appropriate grafting material due to its osteogenic, osteoinductive, and osteoconductive properties [3–5]. Harvesting of autogenous bone is, however, associated with a supplementary surgical procedure and risk of donor site morbidity [6,7,40–46]. Bone substitutes are, therefore, used increasingly to avoid donor site morbidity and simplifying the surgical procedure. However, allografts and xenografts

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Table 1
Inclusion and exclusion criteria.

Inclusion criteria:
• ≥ 20 years.
• Missing posterior maxillary tooth/teeth.
• Width of the alveolar process ≥ 6.5 mm.
• Indication for implant-supported single-tooth rehabilitation.
Exclusion criteria
• Insufficient chart information.
• Cancer in past medical history
• Age lower than 20 years
• Previous maxillofacial fractures involving maxilla and zygoma

contain a minimal risk of immunologic rejection or disease transmission [8,9], while alloplasts are characterized by unpredictable resorption and inadequate mechanical stability [10]. Thus, the ideal grafting material for vertical alveolar ridge augmentation of the partially edentulous atrophic posterior maxilla in conjunction with MSFA remains a topic of debate from both a professional and patient-centered perspective.

MSFA is associated with risk of surgical, biological, and technical complications, but patient-related factors, anatomical variations, maxillary sinus pathologies, and specific surgical risk factors affect the frequency of complications and long-term implant treatment outcome [11,12,40]. However, the generalizability of these findings remains limited, as most studies assessing predictive parameters in conjunction with MSFA involve small patient cohorts, single-surgeon designs, or a specific type of grafting material.

The aim of this European multicenter retrospective chart review is, therefore, to evaluate single-tooth prosthetic rehabilitation following MSFA utilizing the lateral window technique in a large patient cohort including an analysis of potential parameters influencing the long-term implant treatment outcome.

2. Material and methods

2.1. Study design

The present retrospective multicenter chart review was conducted at eight European departments of maxillofacial and oral surgery. Patients consecutively treated by MSFA utilizing the lateral window between January 1st, 2018, until December 31st, 2023, were included. Ethical approval was obtained by each individual center, if needed, according to local laws and regulations. The study was performed according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) for observational studies.

2.2. Eligibility criteria

Inclusion and exclusion criteria are outlined in Table 1.

2.3. Surgical procedure and prosthetic rehabilitation

The surgical procedures were performed under local or general anesthesia by multiple surgeons across participating departments. A crestal incision was initially made in the posterior maxilla, supplemented by an anterior releasing incision. A full-thickness mucoperiosteal flap was raised to expose the lateral sinus wall. The osteotomy for the maxillary sinus lateral window was performed utilizing either a bone scraper, rotary burs, or piezoelectric surgery prior to SM elevation. SM perforations, regardless of size, were managed in accordance with department-specific guidelines. Implants were placed either simultaneously or using a delayed, two-stage approach. Autogenous bone graft, allograft, bone substitutes, blood coagulum, advanced platelet-rich fibrin clots, or a mixture of the different grafting materials were applied beneath the elevated SM. For simultaneous implant placements, either a cover screw or a healing abutment was mounted. The lateral window was either left

uncovered or protected by a collagen barrier membrane, bone lid, or advanced platelet-rich fibrin membrane in accordance with department-specific guidelines, followed by tension-free suturing of the periosteum and mucosa. Prosthetic rehabilitation was subsequently completed using either cement- or screw-retained single-crown restoration.

2.4. Data collection

Data collection was conducted by an appointed investigator at each department and registered in a standardized excel sheet ensuring systematic recording of all data. In each department, patients included were assigned a confidential number, so that anonymity was maintained, and collected data was stored in a systematic computer-assisted database.

The following pre-operative data were recorded: gender, age, voluptuary habits, psychological stress, medication, systemic diseases, implant location, type of radiograph, residual alveolar ridge height at implant site, asymptomatic sinus pathology, sinus septum, pre-operative prescription of antibiotic, analgetic, and corticosteroids.

The following intraoperative data were recorded: local or general anesthesia, type of grafting material, autogenous bone harvesting, donor site, simultaneous versus delayed implant placement, implant diameter and length, SM perforation, handling of SM perforation, prescription of antibiotic in case of SM perforation, intraoperative complications, membrane coverage of the lateral window, cover screw or healing abutment.

The following early postoperative data were recorded: prescription of analgetic, antibiotic or corticosteroids, and complications.

The following late postoperative data were recorded: implant loss and reason, radiographic peri-implant marginal bone loss (PIMBL), complications, and length of follow-up period.

2.5. Data management and statistical analysis

Data was recorded in Microsoft Excel (Microsoft Inc., Redmond, WA, USA). Statistical analysis was performed using SPSS software version 23 (IBM Corp., Armonk, New York, US). Descriptive statistics were reported by mean, standard deviation, and range. Categorical variables were analyzed using standard statistical methods such as count, frequency tables, and proportion analyses. Statistical significance for categorical variables was determined using the chi-square test or, if the sample was too small, the Fisher exact test. The Mann–Whitney U test was used to compare continuous variables, and $p < 0.05$ was considered statistically significant.

A propensity score matching with logistic regression (decay rate, 0.9; alpha, 10) was performed to investigate potential bias in the statistical outcomes depending on covariates (voluptuary habits, comorbidities).

3. Results

3.1. Preoperative

A total of 224 patients, including 88 males (39.3%) and 136 females (60.7%) with a mean age of 53.1 ± 9.5 years (range, 21–79; median, 52) were included. Most of the patients were between 50 and 59 years (Fig. 1.). Forty-two patients (18.8%) reported voluptuary habits including alcohol consumption (3 patients, 1.3%), smoking <10 cigarettes daily (18 patients, 8.0%), smoking >10 cigarettes daily (12 patients, 5.4%), smokeless tobacco (1 patient, 0.5%), alcohol and smoking (2 patients, 0.9%), or other voluptuary habits (5 patients, 2%). Forty-one patients (19 males and 22 females, 18.3%) reported psychological stress. Eight-four patients (37.5%) suffered from a systemic disease including hypertension (33 patients, 14.7%), diabetes (22 patients, 9.8%), cardiovascular disease (18 patients, 8.0%), and asthma (8 patients, 3.6%). Eighty-seven patients (38.9%) received daily prescription medication including antihypertensive medication (33 patients, 14.7%), Insulin (10 patients, 4.5%), Beta blockers (10 patients, 4.5%), Statins (9 patients,

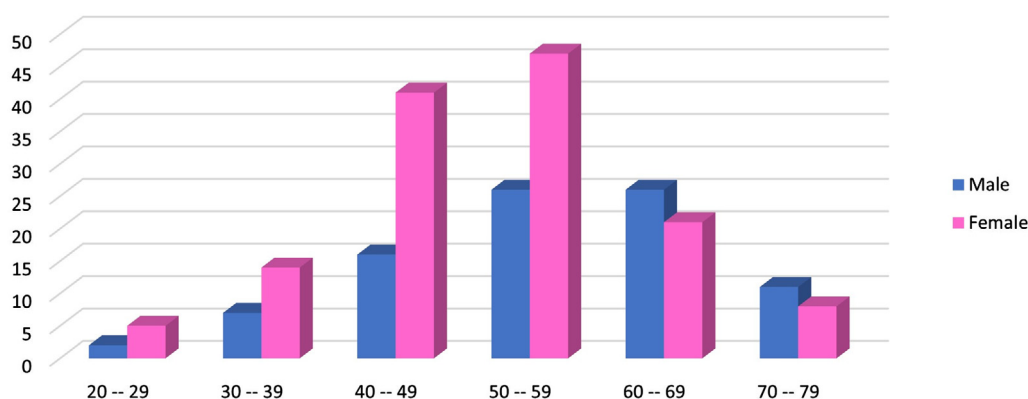


Fig. 1.

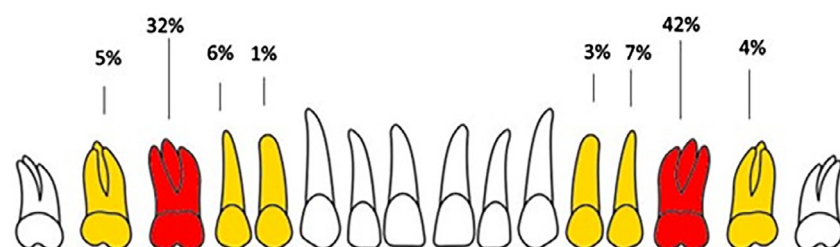


Fig. 2.

Table 2

Distribution of pre-operative radiographs.

Radiographic method:	No. patients	%
• Intraoral	6	2.7
• Panoramic	31	13.8
• CBCT-scan	65	29.0
• CT-scan	36	16.1
• Intraoral, panoramic	4	1.8
• Intraoral, panoramic, CBCT-scan	81	36.2
• Panoramic, CBCT-scan	1	0.5

CBCT, cone beam computed tomography; CT, computed tomography, No, number.

Table 3

Radiographic asymptomatic pathology of the maxillary sinus.

	No. patients	%
Minor mucosal thickening of the SM (< 3 mm)	38	17.0
Moderate mucosal thickening of the SM (3–10 mm)	19	8.5
Severe mucosal thickening of the SM (> 10 mm)	8	3.6
Mucous retention cyst	11	4.9
Polypoidal-mucosal thickening of the SM	1	0.4
Polyps	2	0.9
Foreign body	1	0.4
Partial and total opacification	6	2.7

SM, Schneiderian membrane.

4.4%), metformin (Glucophage), NOAC (5 patients, 2.2%), or antidepressive medication (4 patients, 1.8%).

The first maxillary molar was the most common implant location in the present cohort (Fig. 2). Cone Beam Computed Tomography (CBCT) was the most frequently used pre-operative radiograph among the centers included in this study (Table 2). Fifty-nine patients (26.3%) had at least one sinus septum. Eighty patients (35.7%) had radiographic asymptomatic maxillary sinus pathology (Table 3). The mean pre-operative alveolar ridge height was 4.4 ± 1.5 mm (range, 1.0–9.5; median, 4).

The most common pre-operative medication in the present cohort included paracetamol combined with NASID (89 patients, 39.7%), and Amoxicillin (179 patients, 79.9%) (Table 4). Pre-operative corticosteroids were prescribed in two patients (0.9%).

3.2. Intraoperative

MSFA was primarily performed in local anesthesia (219 patients, 97.8%) compared with general anesthesia (5 patients, 2.2%). Simultaneous implant placement was performed in 124 patients (55.4%) with an average residual alveolar ridge height of 4.5 mm. Delayed implant placement was performed in 100 patients (44.6%) with an average residual ridge height of 4.2 mm. Delayed implant placement was performed after an average of 7.9 ± 2.4 months (range, 2–12; median, 9). The average implant length was 11.6 ± 0.5 mm (range, 6–15; median 11.5). The

Table 4

Distribution of pre-operative analgetic and antibiotic.

Analgetic	No. patients	%
• Paracetamol	40	17.9
• NASID	9	4.0
• Paracetamol, NASID	89	39.7
None	86	38.4
Antibiotic		
• Amoxicillin	179	79.9
• Clindamycin	6	2.7
• Amoxicillin, Clavulanic acid	13	5.8
• None	26	11.6

No, number; NSAID, Nonsteroidal anti-inflammatory drugs.

average implant diameter was 4.4 ± 0.4 mm (range, 3.5–5.5; median, 5). Blood coagulum was the most frequently used grafting material (74 patients, 33.0%) followed by mixture of autogenous bone and xenograft (52 patients, 23.2%) (Table 5). Blood coagulum was applied as blood aspirated from the surgical site or by formation of a blood clot underneath the elevated SM. Autogenous bone graft was harvested in 76 patients (33.9%), and the zygomatic buttress was the most frequent used donor site (73.7%) (Table 6). SM perforation occurred in 39 patients

Table 5
Type of grafting material.

Type of grafting material:	No. of patients	%
• Blood coagulum	74	33.0
• Autogenous bone graft and xenograft	52	23.2
• Xenograft and advanced platelet-rich fibrin	26	11.6
• Xenograft	22	9.8
• Autogenous bone graft	16	7.1
• Autogenous bone graft and alloplast	11	4.9
• Advanced platelet-rich fibrin	10	4.4
• Allograft and xenograft	8	3.6
• Allograft	3	1.3
• Alloplast	1	0.4
• Autogenous bone graft and allograft	1	0.4

No, number.

Table 6
Donor site for harvesting autogenous bone graft.

Donor site:	No. of patients	%
• Zygomatic buttress/lateral window	56	73.7
• Mandibular ramus as a block graft	7	9.2
• Mandibular ramus with safe scraper, bone traps, piezoelectric surgery	12	15.8
• Iliac crest	1	1.3

Table 7
Distribution of post-operative analgetic and antibiotic.

Analgetic	No. patients	%
• Paracetamol	1	0.5
• NASID	60	26.8
• Paracetamol, NASID	106	47.3
• Paracetamol, NSAID, opioids	1	0.5
• None	56	25.0
Antibiotic		
• Amoxicillin	60	26.8
• Clindamycin	5	2.2
• Amoxicillin, Clavulanic acid	18	8.0
• Penicillin G, Metronidazole	5	2.2
• None	136	60.7

No, number; NSAID, Nonsteroidal anti-inflammatory drugs.

(17.4%) and was handled by resorbable barrier membrane coverage (29 patients, 74.3%), resorbable hemostatic agent (2 patients, 5.1%), or no treatment (8 patients, 20.5%). Antibiotic was prescribed in 18 patients (46.2%) with SM perforation. Other complications included bleeding (9 patients; 4.0%), implant displacement to the maxillary sinus (1 patient, 0.4%), while no intraoperative complications occurred in 212 patients (94.6%). The lateral window was covered by a resorbable barrier membrane without fixation (159 patients, 71.0%), bone lid (55 patients, 24.6%), advanced platelet-rich fibrin membrane (3 patients, 1.3%), or no coverage (7 patients, 3.1%). The inserted implants were mounted with a cover screw in 202 patients (90.2%) and healing abutment in 22 patients (9.8%).

3.3. Immediate postoperative

The most common post-operative medication included paracetamol combined with NASID (106 patients, 47.3%), and no antibiotic (136 patients, 60.7%) (Table 7). Pre-operative corticosteroids were prescribed in ten patients (4.5%). No complications besides expected discomfort were registered in 204 patients (91.1%). Postoperative infection, facial swelling, wound dehiscence, persisting pain and swelling, maxillary

Table 8
Postoperative complications.

Complication:	No. of patients	%
• Infection	6	2.7
• Continuous severe bleeding	4	1.8
• Severe facial swelling	4	1.8
• Wound dehiscence	2	0.9
• Severe epistaxis	1	0.5
• Maxillary sinus congestion	1	0.5
• Persisting pain	1	0.5
• Persisting swelling	1	0.5
• None	204	91.1

No, number.

Table 9
Late postoperative complications.

Complication:	No. of patients	%
• Implant fracture	2	0.9
• Numbness of gingiva	2	0.9
• Retraction of gingiva	3	1.3
• Maxillary sinusitis	1	0.5
• Continuous loosening of suprastructure	4	1.8
• Maxillary sinus congestion	1	0.5
• Other	1	0.5
• None	210	93.7

No, number.

sinus congestion, epistaxis or continuous bleeding were rarely reported (Table 8).

3.4. Late postoperative

The implant survival rate after functional implant loading was 96.9% with a mean follow-up period of 25.4 ± 24.2 months (Range 3–151; median, 36). Seven implants were lost due to lack of osseointegration (2 patients, 0.9%), peri-implantitis (1 patient, 0.5%), implant fracture (2 patients, 0.9%), sinusitis (1 patients, 0.5%), and other reasons (1 patient, 0.5%).

The mean radiographic peri-implant marginal bone loss at the mesial implant surface was 0.4 ± 0.7 mm (range, 0–7, median 0). The mean radiographic peri-implant marginal bone loss at the distal implant surface was 0.5 ± 0.8 mm (range, 0–5, median 8).

No long-term complications were registered in 210 patients (93.7%). Implant fracture, numbness of the gingiva, retraction of the gingiva, maxillary sinusitis, and continuous loosening of the suprastructure were rarely reported (Table 9).

3.5. Correlation analysis

3.5.1. Intraoperative

There was no significant correlation between SM perforation and smoking ($P > 0.05$), pre-operative alveolar ridge height ($P > 0.05$), presence of sinus septum ($P > 0.05$), or asymptomatic maxillary sinus pathology ($P > 0.05$).

3.5.2. Late postoperative

There was no significant correlation between implant loss and smoking ($P > 0.05$), pre-operative alveolar ridge height ($P > 0.05$), grafting material without autogenous bone ($P > 0.05$), simultaneous versus delayed implant placement ($P > 0.05$), or SM perforation ($P > 0.05$).

There was a significant correlation between radiographic PIMBL at the mesial implant surface and smoking (RR, 2.9; 95% CI, 1.2–6.9, $P = 0.01$), omission of pre-operative antibiotic (RR, 10.5; 95% CI, 3.7–33.7, $P = 0.000001$), grafting material without autogenous bone (RR, 2.9; 95% CI, 1.4–6.5, $P = 0.002$). There was no significant correlation between radiographic PIMBL at the mesial implant surface and

pre-operative alveolar ridge height ($P > 0.05$), simultaneous versus delayed implant placement ($P > 0.05$), or SM perforation ($P > 0.05$).

There was a significant correlation between radiographic PIMBL at the distal implant surface and omission of pre-operative antibiotic (RR, 6.3; 95% CI, 2.4–17.8, $P = 0.00006$), grafting material without autogenous bone (RR, 2.8; 95% CI, 1.4–6.0, $P = 0.003$). There was no significant correlation between radiographic PIMBL at the distal implant surface and smoking ($P > 0.05$), pre-operative alveolar ridge height ($P > 0.05$), simultaneous versus delayed implant placement ($P > 0.05$), or SM perforation ($P > 0.05$).

The propensity score matching considering covariates revealed a non-significant very small difference between subgroups according to the covariates “voluptuary habits” and “comorbidities” ($M = 0.01$ and 0.04 ; $SD = 0.1$ and 0.2 ; $t(77) = 1$; $p = .320$; $b_0, -0.6774$; Minimum Alpha: $1.092e-7$).

4. Discussion

The present European multicenter retrospective chart review demonstrates that single-tooth prosthetic rehabilitation following MSFA utilizing the lateral window technique is associated with high long-term implant survival rate and limited PIMBL. Few biological, surgical, and technical complications were registered, but patient-related factors and surgical risk factors such as smoking, omission of pre-operative antibiotics, and use of grafting materials without autogenous bone seem to significantly negatively influence the long-term implant outcome following MSFA.

Numerous systematic reviews have demonstrated that MSFA is a predictable surgical procedure, yielding high cumulative implant survival rates irrespective of the applied grafting material [1,2,40]. However, the appropriated grafting material from a professional and patient-centered perspective is presently unknown as well as the required length and implant diameter to adequately support the final prosthetic solution. Moreover, the majority of previous studies assessing prognostic parameters associated with MSFA are hindered by methodological limitations, notably restricted sample sizes, single-center or single-surgeon study designs, and inadequate comparative heterogeneity concerning type of grafting materials. To address these limitations, the objective of this European multicenter retrospective chart review was, therefore, to assess the correlation between long-term implant treatment outcome and potential multivariate predictive parameters.

Implant diameters of 4.0–5.0 mm, and lengths of 8.0–12.0 mm are generally recommended for prosthetic rehabilitation of the atrophic partially edentulous maxilla, depending upon whether a premolar or a molar is being restored [13]. The implant dimensions used in the present study adhere to these recommendations and no correlation between implant loss and implant diameter or implant length were observed.

The optimal radiographic imaging prior to MSFA is controversial. CBCT-scan has been advocated compared with two-dimensional radiographic imaging due to better visualization of the dimension of the alveolar ridge, sinus septa, intrasinus pathologies, and anatomical structures [14]. Moreover, a recently published systematic review concluded that a detailed CBCT examination and careful surgical planning significantly reduce the risk of possible complications [15]. In the present study, CBCT-scan was the most frequently used pre-operative radiograph. However, no correlation between SM perforation and pre-operative alveolar ridge height, presence of sinus septum, or asymptomatic maxillary sinus pathology was observed.

Application of a grafting material underneath the elevated SM is intended to repair the vertical bone deficit, facilitate bone regeneration, and provide mechanical support for the inserted implants. Historically, autogenous bone has been the most used grafting material, although comparable long-term implant outcomes have been reported, regardless of the applied grafting material [1,2,40]. In the present study, blood coagulum was the most used grafting material demonstrating implant treatment outcome equivalent to those achieved with alternative

grafting materials. This finding aligns with the conclusions of a previous long-term study [16] and systematic reviews indicating that blood coagulum can be utilized as grafting material in conjunction with MSFA [17,18]. However, blood coagulum generates less radiographic endosinus bone gain and bone density as compared with autogenous bone mixed with deproteinized porcine bone mineral [19].

The primary implant treatment outcome is, usually, defined as the most critical parameter for evaluating treatment efficacy or therapeutic failure. Consequently, implant survival and PIMBL generally serve as the primary outcome for assessment of long-term implant treatment outcome following MSFA [20]. The high implant survival revealed in the present study aligns with previous long-term systematic reviews [1,2,40]. However, in contrast to previous systematic reviews indicating that long-term implant survival following MSFA is independent of the applied grafting material, the present study identified a significant correlation between implant loss and use of grafting materials without autogenous bone [1,2,40]. Autogenous bone graft is widely considered as the golden standard for MSFA [3–5]. However, an experimental study demonstrated that combining a small quantity of autogenous bone with a non-resorbable bone substitute generates equivalent bone-to-implant contact compared with autogenous bone alone following MSFA [5]. Moreover, a retrospective study assessing various predictors of implant failure following MSFA revealed a higher implant survival with autogenous bone compared with bone substitutes [21]. These findings suggest that incorporating autogenous bone within the grafting material may improve the long-term implant survival, although long-term randomized controlled trials are required to confirm this statement.

Radiographic PIMBL of <1.0 to 1.5 mm during the first year of functional implant loading, followed by an annual bone loss of <0.2 mm, has been established as a criterion for successful implant treatment outcome [22,36]. Adhering to these criteria, a cumulative PIMBL below 1.7 mm after 24 months of functional implant loading signifies a successful implant treatment outcome. In the present study, the mean radiographic PIMBL at the mesial and distal implant surface was 0.4 mm and 0.5 mm, respectively, after a mean follow-up period of 25 months, indicating a successful long-term implant treatment outcome. While a recent study concluded that PIMBL is associated with smoking habits, history of periodontitis, and uncontrolled diabetes [23], our study demonstrated a correlation between radiographic PIMBL and smoking, omission pre-operative antibiotic, and use of grafting material without autogenous bone. Thus, various factors appear to influence the long-term implant treatment outcome following MSFA.

The incidence of surgical, biological, and technical complications as well as long-term implant treatment outcome are influenced by patient-related factors, anatomical variations, maxillary sinus pathologies, and specific surgical risk factors [11,12,40]. Patient-related factors include smoking habits, polypharmacy, uncontrolled diabetes, immunosuppressive therapy, ASA status, chronic rhinosinusitis, and high-dose bisphosphonates or denosumab [21,24–26]. In the present study, no correlation between implant loss and smoking habits or diabetes were observed, which are inconsistent with the literature [24,27]. However, smoking was associated with increased PIMBL at the mesial side, which may lead to implant loss with a longer follow-up period.

Anatomical variations include residual alveolar ridge height, sinus septa, sinus wall thickness, thickness of the SM, and sinus morphology [21,25]. While previous studies indicate that residual alveolar ridge height <3.5 mm, sinus septa, and a thin SM predispose for a higher perforation rate of the SM membrane [11], the present study found no correlation between SM perforation and residual alveolar ridge height or presence of sinus septum. Notably, although the mediolateral width of the maxillary sinus has been implicated in compromised bone regeneration and increased risks of intraoperative SM perforation, this specific morphological dimension was not assessed in the present study.

Maxillary sinus pathologies include symptomatic and asymptomatic mucosal thickening, mucosal retention cysts, and odontogenic sinusitis. Asymptomatic manifestations, such as minimal localized mucosal

thickening, and benign mucous retention cysts are associated with minimal additional risk of SM perforation, while severe mucosal thickening, acute sinusitis, or large retentions cysts increase the risk of complications and compromising long-term implant treatment outcome [28]. In the present study, no correlation between SM perforation and asymptomatic maxillary sinus pathology was observed.

Surgical risk factors include prescription of pre- and postoperative antibiotics, SM perforation, type of grafting material, simultaneous versus delayed implant placement, and implant dimension. Systematic antibiotic prophylaxis is recommended following MSFA, though the clinical efficacy of a single preoperative dose compared with extended postoperative regimens is controversial. In the present study, various antibiotic protocols were used, none of which demonstrated a beneficial effect on long-term implant treatment outcome. These findings corroborate with the conclusions of a recent systematic review suggesting that antibiotic prophylaxis may only be beneficial in specific high-risk scenarios, whereas routine use appears unwarranted in uncomplicated MSFA [29]. Perforation of the SM is the most common surgical complication and been correlated with a higher risk of postoperative sinusitis, infection, graft or implant failure, and reduced bone regeneration [30,45]. The need for prescription of postoperative antibiotics to manage secondary sinusitis has been significantly higher, when the SM was perforated compared with non-perforated [36,40–43,45]. In contrast, a recent systematic review concluded that when a SM perforation is intraoperatively repaired, it does not appear to adversely affect long-term implant treatment outcome [42]. In the present study, the incidence of SM perforation was 17.4% and managed predominately by barrier membrane coverage or hemostatic agent. There was no correlation between SM perforation and implant loss. Postoperative antibiotics were prescribed in 46.2%, when the SM was perforated, but administration of postoperative antibiotics did not influence implant treatment outcome. Thus, administration of systemic antibiotics following SM perforation remains debatable, suggesting that prophylactic prescription should be critically evaluated on an individualized basis.

5. Conclusions

Within the limitations of this European multicenter retrospective chart review, it seems that MSFA utilizing the lateral window technique is associated with high long-term implant treatment outcome and limited PIMBL. However, the risk of surgical, biological, and technical complications as well as long-term implant outcomes is generally influenced by various patient-related factors, anatomical variations, maxillary sinus pathologies, and specific surgical risk factors. In the present study, there were no predictive parameters for Schneiderian membrane perforation or implant loss, while peri-implant marginal bone loss was significantly correlated to smoking, omission of pre-operative antibiotics, and grafting materials without autogenous bone. Meticulous preoperative assessment of patient-related factors, anatomical variations, sinus pathologies, and surgical risk factors is, therefore, mandatory to improve the long-term implant outcome following MSFA.

Declarations section

Ethical Approval and Consent to participate
Not relevant.

Consent for publication

Not relevant.

Availability of supporting data

Study protocol and all data are available from the corresponding author on reasonable request.

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Clinical trial number

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

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