

Single-tooth Rehabilitation of the Atrophic Posterior Maxilla following Osteotome-Mediated Sinus Floor Elevation. A European Multicentre Retrospective Chart Review

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ABSTRACT

Objectives: This retrospective multicentre chart review assessed single-tooth rehabilitation following osteotome-mediated sinus floor elevation across six European departments between January 1, 2018, until December 31, 2023.

Material and Methods: The study was performed according to Strengthening the Reporting of Observational Studies in Epidemiology. Intraoperative, early- and late postoperative data were registered in a standardized excel sheet and analysed using a standardized computer-assisted database. Parametric data was presented as mean and standard deviation. Level of significance was $P < 0.05$.

Results: Ninety-five patients with a mean age of 48.9 (SD 11.3) years were included. Mean preoperative alveolar ridge height was 6.4 (SD 1.2) mm. Mean implant length and diameter were 10.8 (SD 2.1) mm and 4.3 (SD 0.4) mm, respectively. Xenograft was the most used grafting material followed by coagulum. High implant survival (93.7%), limited peri-implant marginal bone loss at the mesial (0.5 [SD 0.9] mm) and distal implant surface (0.7 [SD 1.0] mm), and low incidence of complications were observed after 38 (SD 27.2) months. Schneiderian membrane perforation occurred in 6.3%. Peri-implant marginal bone loss was statistically significantly correlated with omission of preoperative antibiotics ($P = 0.001$, $P = 0.00002$), preoperative alveolar ridge height (≤ 6 mm) ($P = 0.049$), and utilization of calibrated osteotomes alone ($P = 0.02$).

Conclusions: Osteotome-mediated sinus floor elevation is a highly predictable method for single-tooth rehabilitation of the atrophic posterior maxilla. However, meticulous preoperative assessment of patient-related parameters, anatomical factors, or surgical risk factors is mandatory to improve the long-term implant outcome.

Keywords: alveolar ridge augmentation; dental implants; maxillary sinus; multicentre study; oral surgical procedures; retrospective study.

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INTRODUCTION

Implant-supported prosthetic rehabilitation of the partially edentulous posterior maxilla is frequently compromised by dimensional changes of the alveolar ridge and pneumatization of the maxillary sinus following tooth loss [1]. Maxillary sinus floor augmentation applying the lateral window technique with application of a grafting material underneath the elevated Schneiderian membrane is generally recommended when the residual alveolar ridge height is below 5 mm and several teeth need to be replaced [2-5]. Conversely, osteotome-mediated sinus floor elevation (OMSFE) combined with simultaneous placement of standard-length implants is indicated for single-tooth prosthetic rehabilitation, when the residual alveolar ridge height is between 5 mm and 8 mm [2-5].

The osteotome-mediated transcrestal sinus lift approach was introduced by Tatum in 1986 [6]. In 1994, Summers [7] suggested a modification of the technique utilizing a series of tapered osteotomes with increasing diameters designed to compress the trabecular bone and induce an up-fracture of the maxillary sinus floor with the attached Schneiderian membrane. More recently, alternative treatment modalities for Schneiderian membrane elevation in conjunction with OMSFE have emerged including piezoelectric surgery, hydraulic pressure technique, gel pressure elevation, reamer mediators, osseodensification drills, or membrane balloon elevation technique [8-11]. Systematic reviews and meta-analysis have demonstrated high long-term survival of suprastructures and implants, limited peri-implant marginal bone loss (PIMBL), endo-sinus bone gain, low frequency of complications, and improvement of oral-health-related quality following OMSFE regardless of the specific surgical technique used [4,9]. Traditionally, a grafting material has been applied underneath the elevated Schneiderian membrane to promote endo-sinus bone gain, prevent collapse of the Schneiderian membrane, and provide mechanical support for the inserted implant [4,9]. However, the necessity of a grafting material underneath the elevated Schneiderian membrane has been questionable as comparable long-term implant treatment outcome have been reported following OMSFE without the use of a grafting material [4,12,13]. It has also been emphasized that successful long-term implant treatment outcome following OMSFE is influenced by patient-related parameters, anatomical factors, and surgical risk factors [14-17]. However, the existing literature assessing OMSFE

is generally limited by small patient cohorts and single-surgeon designs, thereby compromising the generalizability of the results. Consequently, the objective of this European multicentre retrospective chart review is to assess single-tooth prosthetic rehabilitation following osteotome-mediated sinus floor elevation in a large patient cohort including an analysis of potential parameters influencing the long-term implant treatment outcome.

MATERIAL AND METHODS

Study design

The present retrospective multicentre chart review was conducted at six European departments of maxillofacial and oral surgery including: 1) Department of Health Sciences, University of Eastern Piedmont, Novara, Italy, 2) University of Novi Sad, Faculty of Medicine, Dental Clinic of Vojvodina, Novi Sad, Serbia, 3) Department of Maxillofacial Surgery, Faculty of Medicine, Medical University of Gdansk, Gdansk, Poland, 4) Department of Dental, Oral and Maxillofacial Surgery, Faculty of Dental Medicine, Medical University of Plovdiv, Bulgaria, 5) First General Hospital of Athens K.A.T., Athens, Greece, 6) Department of Oral and Maxillofacial Surgery, Aalborg University Hospital, Aalborg, Denmark. Patients consecutively treated by OMSFE between January 1, 2018, until December 31, 2023, were included. Ethical approval was obtained by each individual centre, 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 (<https://www.strobe-statement.org/>) (Figure 1).

Eligibility 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 were - insufficient chart information.

Surgical procedure and prosthetic rehabilitation

The surgical procedures were conducted under local anaesthesia or general anaesthesia by multiple surgeons across participating departments. An intraoral marginal incision was performed at the

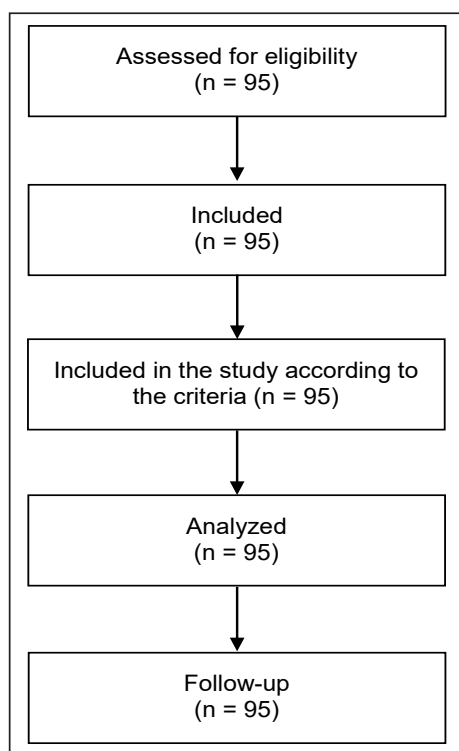


Figure 1. STROBE flowchart. Ninety-five patients were assessed for eligibility, and all met the inclusion criteria and were analysed.

implant site continuing into the gingival sulcus of the adjacent teeth. Mucoperiosteum was reflected to expose the alveolar process. An implant bed was successively prepared on the top of the alveolar crest according to the implant manufacturer's drilling protocol. The original maxillary sinus floor with the attached Schneiderian membrane was elevated to the planned implant length using calibrated osteotomes alone or combined with alternative methods. The integrity of the Schneiderian membrane was checked by Valsalva maneuver. Schneiderian membrane perforations, regardless of size, were managed in accordance with department-specific guidelines. When a grafting material was used, it was applied through the implant bed. The implants were placed simultaneously before a cover screw, or a healing abutment was mounted. Prosthetic rehabilitation was subsequently completed using either cement- or screw-retained single-crown restoration.

Data collection

Data collection was conducted by an appointed investigator at each department including 1) Department of Health Sciences, University of Eastern Piedmont, Novara, Italy, 2) University of Novi Sad, Faculty of Medicine, Dental Clinic of Vojvodina, Novi Sad, Serbia, 3) Department of Maxillofacial

Surgery, Faculty of Medicine, Medical University of Gdansk, Gdansk, Poland, 4) Department of Dental, Oral and Maxillofacial Surgery, Faculty of Dental Medicine, Medical University of Plovdiv, Bulgaria, 5) First General Hospital of Athens K.A.T, Athens, Greece, 6) Department of Oral and Maxillofacial Surgery, Aalborg University Hospital, Aalborg, Denmark, 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 preoperative 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, preoperative prescription of antibiotic, analgetic, and corticosteroids.

The following intraoperative data were recorded: local or general anaesthesia, type of grafting material, autogenous bone harvesting, donor site, simultaneous versus delayed implant placement, implant diameter and length, Schneiderian membrane perforation, handling of Schneiderian membrane perforation, prescription of antibiotic in case of Schneiderian membrane perforation, intraoperative complications, and 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 PIMBL, complications, and length of follow-up period.

Statistical analysis

Data management and analysis was conducted using SPSS statistical software version 26 (SPS Inc., US). Parametric data expressed as mean and standard deviation (M [SD]). Descriptive statistics were reported by mean, standard deviation, and range. Categorical variables were analysed 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 logistic regression analysis was performed among different factors and PIMBL.

RESULTS

Preoperative

A total of 95 patients, including 49 males (51.6%) and 46 females (48.4%) with a mean age of 48.9 (SD 11.3) years (range 24 to 75; median, 49) were included (Table 1). Most of the patients were between 40 to 59 years (Figure 2). Twenty-six patients (27.4%) reported voluptuary habits including alcohol consumption (9 patients, 9.5%), smoking less than 10 cigarettes daily (5 patients, 5.3%), smoking more than 10 cigarettes daily (6 patients, 6.3%), vaping (3 patient, 3.2%), alcohol and smoking (3 patients, 3.2%). Twenty-nine patients (18.3%) reported psychological stress. Thirty-nine patients (41.1%) suffered from a systemic disease including hypertension (15 patients, 15.8%), diabetes (4 patients, 4.2%), cardiovascular disease (12 patients, 12.6%), and asthma (8 patients, 8.4%). Thirty-four patients (35.8%) received daily prescription medication including antihypertensive medication (15 patients, 15.8%), Insulin (2 patients, 2.1%), Beta blockers (11 patients, 11.6%), Metformin (2 patients, 2.1%), or Methotrexate (3 patients, 3.2%).

The first maxillary molar was the most common implant location followed by the second premolar (Figure 3). Cone-beam computed tomography (CBCT) was the most frequently used preoperative radiograph (Table 2). Twenty-two patients (23.2%) had at least one sinus septum. Forty patients (42.1%) had radiographic asymptomatic maxillary sinus pathology (Table 3). The mean preoperative alveolar ridge height was 6.4 (SD 1.2) mm (range 2.7 to 9; median 6).

The most common preoperative medication included paracetamol combined with NASID (40 patients, 42.1%), and Amoxicillin (40 patients, 42.1%) (Table 4). Preoperative corticosteroids were not prescribed in any patients.

Table 1. A total of 95 patients, including 49 males and 46 females with a mean age of 48.9 (SD 11.3) years were included

Years decades	Total	Male	Female
20 - 29	5	2	3
30 - 39	12	5	7
40 - 49	32	16	16
50 - 59	29	13	16
60 - 69	11	9	2
70 - 79	6	4	2
-	95	49	46

Table 2. Distribution of preoperative radiographs

Radiographic method	Number of patients	%
Intraoral	10	10.5
Panoramic	1	1.1
CBCT-scan	43	45.6
Computed tomography-scan	0	0.0
Intraoral, panoramic	1	1.1
Intraoral, panoramic, CBCT-scan	40	42.1
Panoramic, CBCT-scan	0	0.0

CBCT = cone-beam computed tomography.

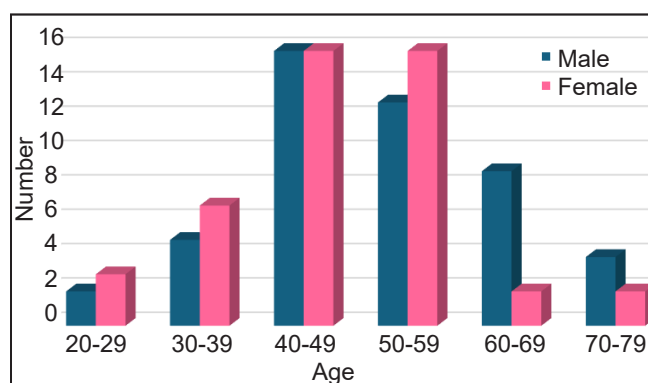


Figure 2. Age and gender distribution. A total of 95 patients, including 49 males and 46 females with a mean age of 48.9 (SD 11.3) years (range 24 to 75; median, 49) were included.

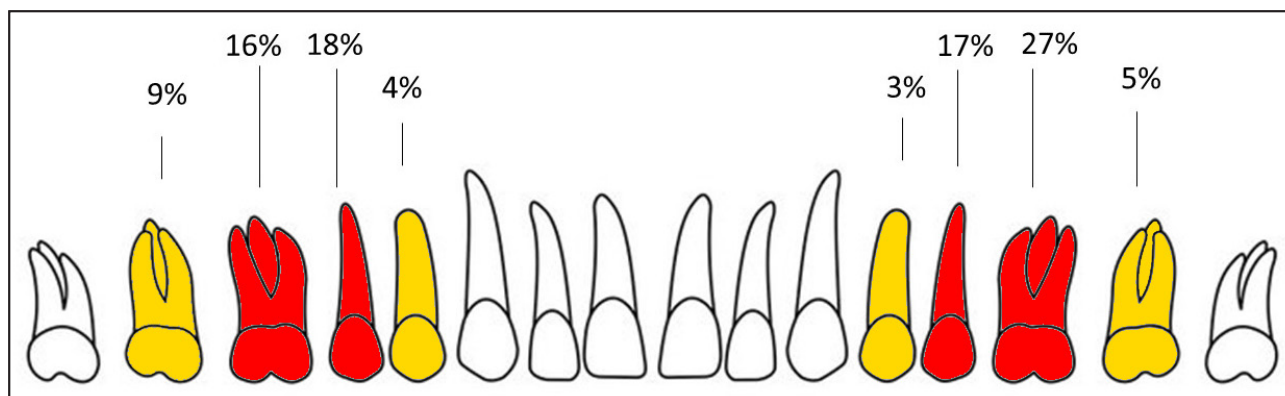


Figure 3. Implant location. The first maxillary molar was the most common implant location followed by the second premolar.

Table 3. Radiographic asymptomatic pathology of the maxillary sinus

	Number of patients	%
None	55	57.9
Minor mucosal thickening of the Schneiderian membrane (< 3 mm)	21	22.1
Moderate mucosal thickening of the Schneiderian membrane (3 to 10 mm)	6	6.3
Severe mucosal thickening of the Schneiderian membrane (> 10 mm)	1	1.1
Mucous retention cyst	6	6.3
Polypoidal-mucosal thickening of the Schneiderian membrane	0	0.0
Polyps	2	2.1
Foreign body	1	1.1
Partial or total opacification	0	0.0
Moderate mucosal thickening of the Schneiderian membrane (3 to 10 mm) including partial or total opacification	1	1.1
Severe mucosal thickening of the Schneiderian membrane (> 10 mm) including partial or total opacification	2	2.1

Intraoperative

OMSFE was primarily performed in local anaesthesia (94 patients, 99.0%) compared with general anaesthesia (1 patients, 1.1%). Simultaneous implant placement was performed in all patients, and the average implant length was 10.8 (SD 2.1) mm (range 6 to 13; median 11.5). The average implant diameter was 4.3 (SD 0.4) mm (range 3.5 to 5; median, 4.2). OMSFE was performed using calibrated osteotomes (55 patients, 57.9%) or by calibrated osteotomes combined with hydraulic pressure technique (40 patients, 42.1%). Xenograft was the most frequently used grafting material (49 patients, 51.6%) followed by no grafting material (coagulum) (23 patients, 24.2%) (Table 5). Schneiderian membrane perforation occurred in 6 patients (6.3%) and was handled by resorbable barrier membrane coverage (5 patients, 83.3%), or no treatment (1 patients, 16.7%). Antibiotic was prescribed in 5 patients (83.3%) with Schneiderian membrane perforation. Other complications included bleeding (6 patients; 6.3%), while no intraoperative complications occurred in 83 patients (87.4%). The inserted implants were mounted with a cover screw in 82 patients (86.3%) or healing abutment in 13 patients (13.7%).

Immediate postoperative

The most common postoperative medication included

Table 4. Distribution of preoperative analgetic and antibiotic

		Number of patients	%
Analgetic	None	55	57.9
	Paracetamol, NSAID	40	42.1
Antibiotic	None	28	29.5
	Amoxicillin	40	42.1
	Clindamycin	5	5.3
	Amoxicillin, Clavulanic acid	22	23.2

No = number; NSAID = nonsteroidal anti-inflammatory drugs.

Table 5. Type of grafting material

Complication	Number of patients	%
None (coagulum)	23	24.2
Xenograft	49	51.6
Advanced platelet-rich fibrin	21	22.1
Allograft	2	2.1

Table 6. Distribution of postoperative analgetic and antibiotic

		Number of patients	%
Analgetic	None	15	15.8
	Paracetamol	2	2.1
	NASID	34	35.8
	Paracetamol, NASID	44	46.3
Antibiotic	None	40	42.1
	Amoxicillin	23	24.2
	Clindamycin	3	3.2
	Amoxicillin, Clavulanic acid	29	30.5

No = number; NSAID = nonsteroidal anti-inflammatory drugs.

Table 7. Postoperative complications

Complication	Number of patients	%
None	88	92.6
Infection	3	3.2
Wound dehiscence	2	2.1
Severe epistaxis	1	1.1
Maxillary sinusitis	1	1.1

paracetamol combined with NASID (44 patients, 46.3%), and no antibiotic (40 patients, 42.1%) (Table 6). Postoperative corticosteroids were not prescribed in any patients. No complications besides expected discomfort were registered in 88 patients (92.6%). Postoperative infection, wound dehiscence, severe epistaxis or maxillary sinusitis were rarely reported (Table 7).

Late postoperative

The implant survival rate after functional implant loading was 93.7% with a mean follow-up period of 38 (SD 27.2) months (range 4 to 176; median, 48). Seven implants were lost due to lack of osseointegration (3 patients, 3.2%), peri-implantitis (1 patient, 1.1%), implant fracture (1 patients, 1.1%), or sinusitis (1 patients, 1.1%).

The mean radiographic PIMBL at the mesial implant surface was 0.5 (SD 0.9) mm (range 0 to 4, median 0.2). The mean radiographic PIMBL at the distal implant surface was 0.7 (SD 1) mm (range 0 to 5, median 0.3).

No long-term complications were registered in 87 patients (91.6%). Implant fracture, numbness of the gingiva, retraction of the gingiva, or other complications were rarely reported (Table 8).

Correlation analysis

There was a significant correlation between radiographic PIMBL at the mesial implant surface and preoperative alveolar ridge height (≤ 6 mm) (RR = 2.83, 95% CI = 1.004 to 8.484, $P = 0.049$), omission of preoperative antibiotic (RR = 5.29, 95% CI = 1.797 to 15.591, $P = 0.001$), and use of calibrated osteotomes compared with calibrated osteotomes combined with hydraulic technique (RR = 3.5, 95% CI = 1.2 to 11.8, $P = 0.02$). There was no significant correlation between radiographic PIMBL at the mesial implant surface and smoking ($P > 0.05$), or Schneiderian membrane ($P > 0.05$).

There was a significant correlation between radiographic PIMBL at the distal implant surface and omission of preoperative antibiotic (RR = 8.67, 95% CI = 2.88 to 27.02, $P = 0.00002$), and use of calibrated osteotomes compared with calibrated osteotomes combined with hydraulic technique (RR = 3.09, 95% CI = 1.15 to 8.71, $P = 0.02$). There was no significant correlation between radiographic PIMBL at the distal implant surface and smoking ($P > 0.05$), preoperative

Table 8. Late postoperative complications

Complication	Number of patients	%
None	87	91.6
Implant fracture	1	1.1
Numbness of gingiva	5	5.3
Retraction of gingiva	1	1.1
Other	1	1.1

alveolar ridge height ($P > 0.05$), or Schneiderian membrane perforation ($P > 0.05$) (Table 9).

DISCUSSION

The present European multicentre retrospective chart review revealed an implant survival rate of 93.7% and radiographic PIMBL of 0.5 mm and 0.7 mm following single-tooth prosthetic rehabilitation in conjunction with OMSFE after a mean observation period of 38 months. Few biological, surgical, and technical complications were registered, whereas a significant correlation between radiographic PIMBL and preoperative alveolar ridge height (≤ 6 mm), omission of preoperative antibiotic, and the use of calibrated osteotomes compared with calibrated osteotomes combined with hydraulic technique was observed. This European multicentre retrospective chart review revealed that selection of preoperative radiograph, surgical technique, type of pre- and postoperative medication, the necessity of a grafting material, and handling of biological, surgical, and technical complications varied significantly across the participating departments.

Implant survival or PIMBL are usually selected as the primary outcome for long-term assessment of implant treatment outcome following OMSFE. The high implant survival revealed in the present study aligns with previous long-term systematic reviews [4,5]. An implant survival rate of 47.6% have been reported following OMSFE with simultaneous placement of 6 mm implants [18].

Table 9. Logistic regression statistical analysis

PIMBL	Risk factors		
	Preoperative ridge height (< 6 mm)	Omission of preoperative antibiotic	Calibrated osteotomes compared with calibrated osteotomes combined with hydraulic technique
Mesial implant surface	$P = 0.049$, RR = 2.83, 95% CI = 1.004 to 8.484, coefficient = 0.32	$P = 0.001$, RR = 5.29, 95% CI = 1.797 to 15.591, coefficient = 0.36	$P = 0.02$, RR = 3.5, 95% CI = 1.16 to 11.81, coefficient = 0.29
Distal implant surface	-	$P = 0.00002$, RR = 8.67, 95% CI = 2.88 to 27.02, coefficient = 0.47	$P = 0.02$, RR = 3.09, 95% CI = 1.15 to 8.71, coefficient = 0.52

An implant length of 8 mm to 12 mm with a diameter of 4 mm to 5 mm are, therefore, generally recommended for single-tooth prosthetic rehabilitation of the atrophic partially edentulous maxilla, depending upon whether a premolar or a molar is being restored [5]. The implant dimensions utilized in the present study adhered to these recommendations and no statistically significant correlation was observed between implant failure and implant diameter or length.

The ideal preoperative radiographic imaging prior to OMSFE remains debateable. CBCT has been advocated for diagnostics, treatment planning, and monitoring of the maxillary sinus floor elevation compared with two-dimensional radiographic imaging due to its superior visualization of the dimensions of the alveolar ridge, sinus septa, intrasinus pathologies, augmented area, and vital anatomical structures [19]. Furthermore, a recent systematic review concluded that a comprehensive CBCT examination and meticulous surgical planning significantly reduce the risk of possible complications [20]. In the present study, CBCT-scan was the most frequently used preoperative radiograph. However, the current literature has not demonstrated a statistically significant decrease in implant failure rates when using three-dimensional CBCT scans compared with conventional two-dimensional radiographs.

Application of a grafting material underneath the elevated Schneiderian membrane during OMSFE is intended to promote endo-sinus bone gain, prevent Schneiderian membrane collapse, and provide mechanical support for the inserted implant [4,9]. However, application of a grafting material underneath the elevated Schneiderian membrane introduces risk of surgical and biological complications such as Schneiderian membrane perforation, infections, and displacement of the grafting material [17]. Moreover, an altered long-term dimensional behaviour of grafting material has been described following OMSFE with or without a grafting material involving volumetric shrinkage of the augmented area, when a grafting material was applied compared with slight increase, when no grafting material was applied [21,22]. In the present study, xenograft was the most frequently used grafting material followed by no grafting material (coagulum) demonstrating comparable successful implant treatment outcome. This finding aligns with the conclusions of previous systematic reviews disclosing that OMSFE is associated with high implant survival rate irrespectively of the applied grafting material [4,5,12-14]. Thus, the high predictability of OMSFE indicates that the long-term implant success is

primarily influenced not by the choice of preoperative radiographic or application of a grafting material, but rather by patient-related parameters, anatomical factors, and surgical risk factors.

Patient-related parameters such as smoking habits, polypharmacy, uncontrolled diabetes, immunosuppressive therapy, American Society of Anesthesiologists (ASA) classification (<https://www.asahq.org/>), chronic rhinosinusitis, or high-dose bisphosphonates or denosumab may predispose for decreased implant survival rate as well as increased risk of Schneiderian membrane perforation and PIMBL following OMSFE [23-25]. In the present study, no correlation between implant loss and smoking habits, polypharmacy, or diabetes were observed, which are inconsistent with the literature [26-28]. However, a comprehensive statistical analysis was not feasible in the present study due to a relatively small patient sample combined with limited implant losses and low frequency of Schneiderian membrane perforations. Consequently, studies involving larger patient samples are required to definitively determine the association between patient-related parameters and implant survival rate, PIMBL, and frequency of biological, surgical, and technical complications following OMSFE.

Anatomical factors such as residual alveolar ridge height, sinus septa, oblique maxillary sinus floor, and morphology of the maxillary sinus may predispose for increased risk of Schneiderian membrane perforation and decreased implant survival rate following OMSFE [18,29]. Previous studies have demonstrated that a residual alveolar ridge height of less than 5 mm predispose for higher risk of implant loss following OMSFE [28], while presence of maxillary sinus septa or root apices penetrating into the maxillary sinus increases the risk of Schneiderian membrane perforation [29]. Furthermore, increased width and angle of the maxillary sinus compromises bone regeneration and induce a higher resorption rate of the applied grafting material [15]. In the present study, the mean preoperative alveolar ridge height was 6.4 mm, and a statistically significant correlation was found between radiographic PIMBL at the mesial implant surface and a preoperative alveolar ridge height of ≤ 6 mm. The causal relationship between diminished alveolar ridge height and PIMBL observed in this study has not been previously described; however, it may be secondary to undersized surgical implant bed preparation.

Maxillary sinus pathologies including symptomatic and asymptomatic mucosal thickening, mucosal retention cysts, or odontogenic sinusitis may predispose to an increased risk of Schneiderian

membrane perforation and subsequently early implant failure following OMSFE [30,31]. In the present study, asymptomatic maxillary sinus pathology was radiographically identified in 42.1% of the patients, which aligns with previous studies [32,33]. The high prevalences of maxillary sinus pathologies emphasizes the critical importance of meticulous preoperative radiographic evaluation to optimize implant treatment planning and minimize intraoperative complications. However, a comprehensive statistical analysis of the association between maxillary sinus pathologies and intraoperative complications was not feasible in the present study due to a relatively small sample size, combined with limited number of implant losses and low frequency of Schneiderian membrane perforation. Consequently, studies involving larger patient samples are required to definitively determine the association between maxillary sinus pathologies and frequency of Schneiderian membrane perforation and early implant losses following OMSFE.

Surgical risk factors involve the instrumentation and surgical technique applied, prescription of pre- and postoperative antibiotics, and intraoperative Schneiderian membrane perforation. Perforation of the Schneiderian membrane is the most common intraoperative complication following OMSFE and has been correlated with a higher risk of postoperative infection, sinusitis, implant loss, displacement of the grafting material, and reduced bone regeneration [31,34]. It has, therefore, been recommended to use an atraumatic malleating technique to preserve the integrity of the Schneiderian membrane perforation or combine the use of osteotomes with other techniques for gently elevation of the Schneiderian membrane [5,8-10,11]. Moreover, biomechanical evidence has revealed that vertical displacement of the maxillary sinus floor should be strictly restricted to a threshold of 3 mm to 4 mm to avoid compromising the physiological stretching capacity of the Schneiderian membrane [5]. In the present study, Schneiderian membrane perforation occurred in 6.3%, which aligns with previous studies [4,5]. The Schneiderian membrane perforation was covered by a resorbable barrier membrane or left untreated, and antibiotic was prescribed in most of the patients with Schneiderian membrane perforation. A recent systematic review concluded that routine antibiotic yields negligible clinical benefit in uncomplicated

OMSFE and should instead be selectively reserved for high-risk scenarios [35]. However, in the present study, a statistically significant correlation was found between radiographic PIMBL and omission of preoperative antibiotic and elevation of the Schneiderian membrane solely by using calibrated osteotomes. The causal relationship between PIMBL and omission of preoperative antibiotic as observed in the present study has not been previously described, whereas the higher prevalence of Schneiderian membrane perforation following OMSFE with solely calibrated osteotomes aligns with previous clinical and experimental studies assessing OMSFE using alternative other techniques for elevation of the Schneiderian membrane [36,37].

CONCLUSIONS

The present European multicentre retrospective chart review demonstrated that osteotome-mediated sinus floor elevation with or without a grafting material yields high implant survival rate, limited peri-implant marginal bone loss, and low incidence of biological, surgical, and technical complications over a mean observation period of 38 months. However, peri-implant marginal bone loss was statistically significantly correlated with the omission of preoperative antibiotics and utilization of calibrated osteotomes alone indicating that calibrate osteotomes should be combined with hydraulic techniques and prescription of prophylactic antibiotic is compulsory to achieve successful long-term implant treatment outcome. Hence, a personalized approach is crucial when selecting preoperative radiographic, determine the surgical technique including application of a grafting material underneath the elevated Schneiderian membrane, and prescription of peri-operative pharmacological interventions, taking patient-related parameters, anatomical factors, and surgical risk factors into account.

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The authors declare that there are no financial or other conflicts of interest related to this publication.

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