Lateral Displacement of Maxillary Sinus Palatal Wall: A 1-Year Retrospective Computerized Tomography Study

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Purpose: To examine the short-term outcomes of maxillary sinus augmentations consisting of laterally and apically displacing the palatal wall through a transcresal approach. Materials and Methods: The maxillary sinus floor was fractured in its palatal aspect by allowing a displacement in the buccal and apical direction with a magnetoelectric system. A medial displacement of the alveolar crest in its palatal bony plate was performed at the same time. Crestal bone change was investigated using superimposed preoperative and postsurgical computed tomography scans. Clinical and radiologic outcomes over 1 year were evaluated. Results: A total of 18 implants were selected for retrospective volumetric and linear analyses. Sinus floor and alveolar bone augmentation surgery led to a significant increase in the bone volume ($P = .0002)$ from $0.134 \pm 0.060 \text{ cm}^3$ to $0.639 \pm 0.166 \text{ cm}^3$, with an overall gain of $+0.504 \pm 0.139 \text{ cm}^3$. No part of the implant apices appeared to protrude into the maxillary sinus at the 1-year follow-up. The width of the alveolar crest changed from $5.1 \pm 0.5 \text{ mm}$ to $6.5 \pm 0.7 \text{ mm}$, with a significant increase of $+1.4 \pm 0.6 \text{ mm}$ registered at 1 year. However, a marginal bone loss of $1.0 \pm 0.8 \text{ mm}$ was observed. When tooth positions were investigated, no significant differences between the two groups (premolars versus molars) were found. Conclusion: Significant and effective bone gains allowed proper placement of the dental implants but with a minimal loss of peri-implant bone volume. Int J Oral Maxillofac Implants 2022;37:920–928. doi: 10.11607/jomi.9594

Keywords: bone displacement, computerized tomography image, dental implants, infracture technique, maxillary sinus

The maxillary sinus is a bilateral and symmetric cavity largely enclosed within the maxillary bone. A primary antral sinus septum is a bone ingrowth coming from the sinus floor that extends to the inside of the maxillary sinus, which shows its extension from the floor to the vault, generally splitting the sinus into two or more compartments.1 In the case of tooth loss, this vacuum volume can hyperexpand up to the area of the alveolar ridge coupled with a large pneumatized sinus requiring a grafting procedure for the correction of both the alveolar crest7 and the pristine sinus floor.6 The first suggested procedure, the lateral approach for sinus floor augmentation described by Boyne and James, involves the bone volume augmentation procedures for any dental implant–supported rehabilitation strategies.2 The extent of postextraction loss in the vertical dimension seems to be highly dependent on the individual anatomical preconditions, such as a superiorly curving sinus floor, a wide sinus transversal space, and the type and position of the extracted tooth; ie, multiple adjacent tooth extractions in the posterior maxilla (mainly in second molars).1,3 But beyond that, if the bone loss was so extensive as to involve both the width and height of the alveolar ridge beneath the sinus floor, lifting and grafting procedures were usually needed for successful implant placement. Even if some maxillary sinus augmentation techniques were considered safe and predictable, the treated areas could suffer side effects from the time-consuming and very demanding surgical augmentation strategies.4,5 Among conventional surgeries to increase available bone for implant placement, there are two options: to approach the alveolar bone either laterally or crestally to reach and raise the sinus membrane.6 A severe bone height deficiency could easily be solved by modifying the internal aspect of the maxillary sinus floor in cases of excessive sinus hyperpneumatization; however, a narrow alveolar ridge coupled with a large pneumatized sinus requires a grafting procedure for the correction of both the alveolar crest7 and the pristine sinus floor.6 The first suggested procedure, the lateral approach for sinus floor augmentation described by Boyne and James, involves the

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The use of a bony window for a laterally opened sinus elevation in which cancellous bone from the iliac crest is immediately grafted in the site needing augmentation.8 Dental implant placement could be a concomitant treatment with the sinus augmentation when primary stability was achievable; when primary stability would not be possible, delayed implant placement would be the choice.9 The reports of a consensus conference and systematic review suggest that a delayed implant positioning is necessary to achieve success for prosthetic rehabilitation, especially in cases in which the residual crest had a bone height less than 4 mm.9,10 Hence, to reduce postsurgical side effects, transcrestal sinus floor elevation (TSFE) was outlined in different studies.11–13 They described a floor elevation technique with a crestal approach by using osteotomes or other minimally invasive tools. Moreover, the transcrestal approach appeared to be a minimally invasive procedure that, in its new proposals (flapless, no use of any bone substitutes, immediate implantation, immediate provisionalization), intended to make the surgical option available for less experienced surgeons.14,15

The primary aim of this retrospective study was to test volumetric and linear modifications after a sinus floor fracture and lateral displacement of the fragment in the buccal and apical directions, and a medial displacement of the alveolar crest in its palatal bony plate at the same time. A secondary aim was to record the number of negative side effects after surgery and the implant survival rate.

**MATERIALS AND METHODS**

**Patient Selection**

A set of patients operated on in the Tuscan Dental Institute from 2016 to 2018 were selected for this data analysis. Follow-up was conducted 1 year postsurgery (December 2019) and was carried out at the Maxillofacial Surgery Department of the Hospital and University of Pisa. Patients’ information was gathered and collected.

All surgeries in studies involving humans followed the ethics and standards of the institutional and/or national research committee and the 1964 Helsinki Declaration and its later amendments.

**Inclusion and Exclusion Criteria**

Patients were included if they underwent:

- Sinus augmentation with lateral displacement of the palatal wall
- Dental implant immediately placed in the augmented sinus
- Three-dimensional CT scans acquired preoperatively and postoperatively (1 year postsurgery)

Patients were excluded if their data showed:

- No loaded implant within the 3 months of follow-up
- File corruption or loss of scans data
- Chronic systemic diseases
- Excessive smoking habits (10 cigarettes/day)
- Alcohol or drug abuse
- Neither inclination to cooperate for hygiene nor to follow medical advice

During treatment planning, the clinician fulfilled the following indications, even if each rehabilitation strategy was defined individually, as the maxillary sinus anatomy varied very much from subject to subject:

- Long-standing healed edentulous areas
- Residual bone height beneath sinus floor greater than or equal to 3 mm
Residual alveolar width beneath sinus floor from 3 to 5 mm
Thickness of the palatal wall greater than or equal to 2 mm

U.C. was the only surgeon, and R.C. was the only prosthodontist.

### Surgical Procedures

One hour before surgery, patients underwent administration of 2 g of amoxicillin, after which 1 g was administered twice daily for 6 days. Local anesthesia was attained by injection of optocaine 20 mg/mL with epi-nephrine 1:80,000 (Molteni Dental).

Raising the partial-thickness flap saved the periosteum. The present soft tissue mobilization was central to maintaining the blood supply and promoting the healing phase by secondary intention.16

The primary incision was beveled and slightly palatal to favor the final buccal displacement of the keratinized residual tissue. Preservation of the papillae was then accomplished by making releasing incisions a few millimeters from the residual teeth. A slot wedged inside the alveolar bone was created according to the direction of the palatal wall of the sinus floor by using a fixed tip on a magnetoelectric system (Magnetic Mallet, Os- seotouch),17,18 which penetrated the crestal ridge to the palatal wall of the maxillary sinus (Fig 1a). Tip penetration through the palatal wall depended on the amount of required bone height augmentation (the more bone required, the deeper the penetration); careful attention might furthermore be paid to ensure that the split slot did not exceed the safety threshold of 3 mm from the boundaries of the nasal cavity. Nontraumatic tips were used to displace the fractured bone mass within the sinus in the lateral direction, allowing clinicians to laterally push the free palatal bony sinus floor above the pristine palatal vault (Figs 1b and 1c).

The apical implant bed was created against the pre-existing and newly created lateral sinus floor, apically moving up and compressing bone marrow with bone expanders (Figs 1d and 1e). A medial shift of the palatal aspect of the crestal bone helped to actively reorient implants toward an ideal prosthetic axis. The final cavity should remain underdimensioned, with a dental implant acting as a final plug and space maintainer (Fig 2).

The same brand and type of implant (Pro-Link Outlink, Sweden & Martina) was positioned. The implant had the following features: external hexagon, cylindrical-shaped body, flat-grooved apex, sandblasted and acid-etched surface, and pure grade 4 titanium.

Surgical flaps were firmly sutured in their original position to both the mucosa and periosteum. Absorbable hemostatic collagen spongy dressing (Gingistat, Acteon Pharma) was positioned over the wound to cover both the implant and the surrounding tissues, and then held with sutures. After about 3 months, the implant was loaded.

### Clinical Variables

Case information was gathered, and negative events and complications, including pain or any reported signs and symptoms of infection, were collected and
An implant was considered surviving when placed and stable; it was considered a failure upon the occurrence of fracture, mobility, pain/discomfort/neurologic disorder, inflammation or chronic suppuration, and apparent radiographic bone loss (greater than 80% in depth along implant direction). Survival rate, performed according to Anusavice, was calculated as per Romeo et al.

Radiographic Measurements and Outcomes
Preoperative (preop) and postsurgical (after 1 year) computerized tomography scans were investigated. Three-dimensional data were superimposed as per Crespi et al (Fig 3). Then data were saved as new DICOM (Digital Imaging and Communications in Medicine) files. Volumes were calculated as per Sbordone et al using a volume of interest (VOI) within which all measurements were performed. The VOIs had the following boundaries: 6 mm mesial and 6 mm distal to the center of implant shoulder, full width from buccal to palatal aspect, and upper limit to 2 mm beyond the implant apex.

A set of primary anatomical variables was introduced:

- ARV, or alveolar ridge volume, describes the volume between the upper limit of the VOI and the overall external contour of the alveolar ridge.
- ESV, or empty sinus volume, describes the volume of the empty space between the upper limit of the VOI and the lower limit, ie, the sinus floor.

A tomography cross-section passing through the entire length of the implant was acquired. Alveolar width (W), measured in the image, was the distance from the most protruding facial point to the most palatal, 1 mm below the implant neck platform. All measurements were acquired before sinus surgery (preop) and 1 year postsurgery (1y).

Secondary outcome variables were calculated as algebraic manipulations of the primary ones:

\[ \Delta \text{ARV} = \text{ARV}_{1y} - \text{ARV}_{\text{preop}} \]
\[ \Delta \text{ESV} = \text{ESV}_{1y} - \text{ESV}_{\text{preop}} \]
\[ \Delta V = \Delta \text{ARV} - \Delta \text{ESV} \]
\[ \Delta W = \Delta W_{1y} - \Delta W_{\text{preop}} \]

For all the above-mentioned outcome variables, with the exception of ESV, a positive value represented a gain and a negative value a loss. Obviously, a reduction in ESV was a gain.

Fig 3 Palatal sinus wall displacement for implant-supported rehabilitation in one of the patients: (left) preoperative, (right) postoperative, and (center) superimposed (cross-sectional views within the volumes of interests (VOIs). Minor ticks at the bottom of each image are millimeters. External contour: preoperative in yellow and postoperative in red. Sinus floor contour: preoperative in light blue and postoperative in green. ARV = bone volume of the whole alveolar ridge and ESV = volume of the empty maxillary sinus, with related outcome variables from baseline to 1 year (\( \Delta \text{ARV} \) and \( \Delta \text{ESV} \)). \( \Delta V = \Delta \text{ARV} - \Delta \text{ESV} \) denotes the change in bone volume useful for implant placement.
of the empty sinus produced an increase of the effective bone volume for dental implant placement.

Peri-implant marginal bone loss (MBL), measured in the cross-section passing through the entire length of the implant, was the distance from the implant platform and the most apical point of the marginal bone level (mean between the mesial and the distal sites).

Statistical Analysis
A matrix laboratory performed all the statistics (Statistics Toolbox, MatLab 7.11; The MathWorks). Brown-Forsythe analysis of homogeneity was used to test for variance among all the time points; Gaussian distribution was tested by the Shapiro-Wilk analysis. Neither normality nor homoscedasticity was met. Therefore, for a more conservative analysis, matched data and independent data were pair-compared by the Wilcoxon signed rank and rank sum tests, respectively. Mean ± standard deviation was used for description of variables. The level of significance was \( P = .01 \).

RESULTS
Following the inclusion and exclusion criteria, this analysis included 18 subjects (11 females, 7 males), with a mean age of 52.2 ± 9.3 years (Table 1).

**Surgical and Prosthetic Findings**
At the 1-year follow-up, there was a 100% implant survival rate. No sinus perforation of the membrane was observed during surgery. Minor swelling of the healing sites occurred during the same-day surgery, but there were no episodes of flap dehiscence, mucositis, or suppurative. Implants were provisionally loaded within about 3 months after the first surgery.

**Radiologic Evaluation**
Radiographic primary and secondary outcomes are described in Table 1 and Fig 4. Differences were found between times, indicating positive effects on bone volume gain for both the alveolar ridge and the
The gain in bone volume useful for implant placement, ranging from \(0.134 \pm 0.060\) to \(0.639 \pm 0.166\) cm\(^3\), resulted from both the empty sinus reduction \((0.621 \pm 0.113\) to \(0.339 \pm 0.111\) cm\(^3\)) and the external contour increase \((0.756 \pm 0.128\) to \(0.978 \pm 0.176\) cm\(^3\)). Therefore, the net bone volume augmentation of \(+0.504 \pm 0.139\) cm\(^3\) resulted from the additive effect of the change in the whole alveolar ridge \((+0.223 \pm 0.084\) cm\(^3\)) with the reduction of the empty sinus \((-0.282 \pm 0.099\) cm\(^3\)), as shown in Table 1.

The preoperative width of the alveolar crest was \(5.1 \pm 0.5\) mm with a significant \((P = .0002)\) increase of \(+1.4 \pm 0.6\) mm at 1 year. However, a marginal bone loss of \(1.0 \pm 0.8\) mm was measured.

When tooth positions were investigated, no significant differences in volumetric outcomes between the two groups (premolars versus molars) were encountered. The only significant difference \((P = .0003)\) was encountered in the preoperative width \((4.8 \pm 0.3\) mm and \(5.5 \pm 0.3\) mm for premolars and molars, respectively). However, this significance disappeared after 1 year.

Correlation analyses performed among outcomes and primary variables showed a positive correlation between augmentation of the useful bone \((\Delta V)\) and the marginal bone loss \((\text{MBL})\), but only for premolars \((r = .7778; P = .0008)\). Again, a negative correlation was found between \(\Delta \text{ARV}\) and \(\Delta \text{ESV}\) \((r = -0.9605; P < .0001)\) just for premolar teeth. All the other correlation data are shown in Table 2.

**DISCUSSION**

The present research was conducted to report 1-year outcomes after lateral displacement of the palatal bony wall by a magnetoelectrical device for sinus elevation in patients with a need for bone augmentation in height and width for successful dental implant placement surgeries. Effectiveness of the technique in terms of negative side effects and implant survival was also reported.

If it could be shown that there were alternative surgical procedures without bone augmentation (eg, tilted or short/ultrashort implants), such equivalent rehabilitation strategies might be used when the height and width of the alveolar crest were not considered adequate.\(^{26}\) However, the trend nowadays is to augment the bone without demanding surgeries.\(^{27,28}\) More conservative approaches include no-flap surgery or minimally elevated flap margins, indirect single\(^{26}\) or double sinus elevation procedures,\(^{29}\) and split crest of the ridge beneath the maxillary sinus.\(^{30}\) Since the concept of “greenstick” fracture of the maxillary anterior sinus wall had already been developed in a previous paper,\(^{31}\) the present study focused on resolving clinical problems due to the lack of height and width for both narrow and pneumatized implantation sites not as close to the anterior wall. The present technique combined the advantages of indirect sinus elevation and ridge splitting followed by immediate implant insertion. The clinician laterally displaced an intrasinus portion of the palatal...
wall, carving and shaping the pristine maxillary sinus floor and compressing the cancellous bone within the osteotomy site while simultaneously displacing the fractured palatal aspect of the crest palatally to obtain an increase in width.

All of the 3D measurements showed that the present augmentation technique, in the rough analysis of ΔARV, increased available bone for implant placement by +0.223 cm³; however, an in-depth analysis of the external contour and maxillary sinus floor 1 year postsurgery suggested that the aforementioned augmentation might be increased by an empty space reduction within the maxillary sinus (ΔESV of –0.282 cm³ at floor level); that is, an overall gain of bone useful for dental implant placement was +0.504 cm³.

Results concerning the volume estimation around dental implants suggested that at 1 year postsurgery, the overall increase of available bone was higher than that obtained by distal displacement of the sinus anterior wall at 3 years (0.36 cm³) and less than the amount of bone gain obtained by lifting and grafting the sinus with xenogeneic bone and lateral access (0.71 cm³). A possible explanation is that the procedure was a more localized displacement than that of the other more demanding techniques, in which the delayed implantation strategy forced the clinician to aspire to more significant bone augmentation. The electromagnetic system (perfect for breaking through the external and internal plates of the palatal sinus wall) fractured the sinus floor and detached it from the pristine palate toward empty sinus space. Moreover, lateral displacement of the palatal wall seemed to be free from any postsurgical complication.

Among different papers describing the bone volume remodeling, Bensaha and El Mjabber reported a transcrestal maxillary sinus infiltration technique for sinus floor elevation in patients with a reduced vertical height. Even if the effect of the solution used on the volume of new bone had not been fully investigated, they found a significant bone gain (3.40 cm³) even though the procedure had to be used only for extended edentulous areas. When sites were limited in extension, ie, a single edentulous site, conventional osteotome sinus floor elevation

### Table 2

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</table>

Anatomical and outcome variables before (preop) and 1 year postsurgery (1y). ARV = overall volume in the volume of interest below the alveolar ridge, ESV = volume of the empty maxillary sinus, and V = volume useful for implant placement, with ΔARV, ΔESV, and ΔV their change at 1 y, respectively. W and ΔW = linear measurements at crestal width and their change, respectively. MBL = marginal bone loss. Significance (in bold) set at P < .01 (two-tailed).
techniques with or without grafting materials had to be applied. In all the aforementioned studies, significant bone gains were registered: volume increase of 1.13 cm³, and vertical bone augmentation from 2.3 to 5.84 mm in sites with a residual bone height from 2 to 4 mm. These results were in line with those obtained by the present study (Fig 4). Even if no modification in width reduction was described, Zheng et al attested to the influence of the mediolateral dimension (whole sinus width) on the amount of change in sinus graft. Similarly, the external contour of the alveolar crest could be affected by this surgical procedure. The surgical technique gave the clinicians the possibility of obtaining an extra 2 mm of width for conventional-diameter implant placement; resorption phenomenon implied that the alveolar crest could have a loss in height of 1 mm. This was not a problem because the dental implants could be easily placed in a subcrestal position in advance.

Even if no significant differences were found between premolars and molars, correlation analyses suggested that the present surgical technique seemed to mostly influence premolar sites.

The present implant survival rate was 100%; because of the short-term follow-up (1 year), the survival was higher than that of the other osteotome sinus floor elevation procedures (in the range of 87.5% to 98.7% with up to 3 years of follow-up). However, such a conclusion is premature; in fact, there was neither a sufficiently large sample nor an adequate clinical period of observation.

As discussed above, if an implant-supported fixed rehabilitation in the posterior maxillary areas was needed, clinicians could laterally displace the palatal wall of the spongy bone. The displacement produced a lift of the pristine alveolar ridge in width. The only limitation was palatal bone thickness being too low; the tips of the electromagnetic system had to wedge between the plates of cortical bone within the spongious bone.

Given the nature of the study, the small sample and the localized site of bone augmentation were points of weakness, whereas the ability to measure both the external and internal modifications of the alveolar crest, use of dental implants of the same manufacturer/model, and a standard surgical technique were strengths of this study.

CONCLUSIONS

Clinical and radiographic outcomes showed no adverse effects for the present surgery; moreover, outcomes revealed a 1-year bone gain around implants as the result of a lateral displacement of the palatal wall without any bone substitute material. The displacement technique had a high 1-year implant survival rate and led to sufficient bone to place an implant of conventional diameter and length.

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