Among several techniques for management of edentulous sites in the posterior maxilla via a sinus elevation procedure, the two that had been most successful at maximizing their great beneficial outcomes and minimizing the side effects of the surgery were broadly discussed under the crestal and lateral approaches.1

A window in the lateral wall of the maxillary sinus provided access through the buccal area for sinus elevation and grafting with bone substitutes.2 There were some alternatives to lateral access for sinus floor augmentation surgery, according to different biologic, anatomical, and surgical aspects, and to various techniques and grafted materials.3,4

Before dental implant placement, the piece of carved bone obtained from the crestal atraumatic osteotomy was very slowly pushed up to reduce the risk of perforation of the mucosa lining the sinus. Gained space was then filled with different grafting materials along a predetermined direction, in order to facilitate immediate or delayed implant placement.3,5

Purpose: This study aimed to report a practicable and noninvasive two-stage technique for sinus elevation and delayed implant insertion in the augmented site with residual bone height down to 3 mm or even lower. Materials and Methods: The surgical technique employed a two-stage process for rehabilitation of posterior maxillary single-tooth edentulous areas, involving, in the first step, transcrestal maxillary sinus floor augmentation with a collagen sponge to fill the intrabony cavity resulting from the detachment of the sinus membrane; the second step consisted of another indirect sinus floor elevation using magnetoelectric surgery with immediate implant placement and no grafting material. Changes in bone height were evaluated by a comparison of the computed tomography scans acquired before treatment and after surgery (at 3 months and 5 years of the survey). Statistically significant differences between the times and the tooth sites were evaluated by nonparametric statistics (matched and independent), with \( P < .01 \).

Results: Forty patients were retrospectively selected. The preoperative height of the available alveolar bone was 2.9 ± 0.6 mm. A significant increase in bone height \( (P < .01) \) was found for both the first and the second surgery (3.1 ± 0.6 mm and 4.4 ± 0.6 mm, respectively). The overall bone height was measured at 3 years after the first surgery (10.3 ± 0.6 mm). Measurements of the bone height ranked for tooth positions showed no significant difference between premolars and molars. None of the selected patients registered an implant failure.

Conclusion: Two-stage osteotome-mediated sinus elevation appeared to be a predictable technique that enabled practitioners to increase the bone height and to obtain successful outcomes even if the amount of bone was approximately 3 mm in height. Int J Oral Maxillofac Implants 2021;36:553–560. doi: 10.11607/jomi.8573

Keywords: CBCT, dental implant, osteotome sinus elevation, single crown, two-step technique

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Submitted May 1, 2020; accepted December 11, 2020. ©2021 by Quintessence Publishing Co Inc.
Furthermore, the use of the osteotome-assisted maxillary sinus bone augmentation technique resulted in high density at the osteotomy area due to the specific work of the osteotomy devices (compacting and condensing). Some authors advocated manual osteotomes rather than automatic systems because of the excellent tactile sensitivity, the better control of movement, the lower heat generation, and the lower cost. Some clinical studies attested that the maxillary sinus floor elevation with a lateral approach reported survival rates ranging from 82.4% to 96%, with a long-term observation period, whereas transesternal surgery reported techniques acting to increase available bone height, with very good results regarding the long-term implant survival rates (between 93.5% and 98.3%).

Further authors proposed extension of the use of indirect sinus elevation procedures even if the amount of bone height for implant placement was < 4 mm because of their reliability and predictability.

The technique described here looked like the procedure of Summers, despite having been reformed; the amendment suggested that the surgeons could elevate the sinus with the height of the residual bone ≤ 3 mm, avoiding the lateral approach and bone substitutes. It was shown that thisatraumatic surgery allowed bone height toward the sinus floor to be increased in an apical implant direction. The osteotomes were gently malleted to apically expand the alveolar ridge into the location in which the dental implant had to be placed. Different osteotomes could be tapped toward the sinus floor and used for fracturing the cortical plate with an electromagnetic mallet. This newly revised method is based primarily on the biologic principles of the elasticity and repair mechanism of the bone tissue and the sinus physiology.

The present study aimed to report a practicable and noninvasive double-step technique for a sinus elevation procedure and delayed implant insertion beneath the sinus floor with residual bone height down to 3 mm or even lower.

**MATERIALS AND METHODS**

**Patient Selection**

Between April 2014 and October 2016, subjects requiring implant-supported rehabilitation in the posterior alveolar crests below hyperpneumatized maxillary sinuses were retrospectively selected.

Selected subjects matched the following inclusion criteria:

- Osteotome-mediated sinus elevation with delayed implant insertion in combination with a second localized indirect sinus elevation
- Height of the maxillary sinus floor of approximately 3 mm or less
- Each implant supporting a fixed single-crown restoration
- Radiologic survey (CBCT) of at least 3 years from the first surgery

Subjects were excluded from data analysis if in the medical record, it was documented that they were treated with any other surgery close to the selected site.

As generalized practice, clinicians fulfilled the following contraindication guidelines, even if patients' treatments were decided on a case-by-case basis.

Absolute contraindications were as follows: chronic systemic disease (report of immunocompromised condition, uncompensated/uncontrolled diabetes, coagulation disorders); intravenous and/or oral bisphosphonate therapy, chemotherapy, or radiotherapy.

Relative contraindications were as follows: heavy smoker habit (> 10 cigarettes/day), and misuse of hard alcohol or substances.

One clinician and prosthetic specialist treated all the subjects at Tuscan Dental Institute.

Patients had to sign a routine informed consent form regarding surgical treatment, and additional informed consent for analysis of their data, as requested by the ethical committee according to the Helsinki Declaration (1975) and further revisions.

**Surgical Procedure**

All patients were treated with a local anesthetic at the first surgery (Xylocaine, Astra). All sites were treated with a premedication with a nonsteroidal anti-inflammatory drug (Naprosyn, 1.5 g; Recordati) and an antimicrobial agent (Ciproxin, 1 g; Bayer) 1 hour before surgery. Antimicrobial and anti-inflammatory medications continued for 5 days.

The alveolar crestal bone in which the dental implant had to be placed was denuded with a modified partial-thickness flap. The first incision went from the palatal masticatory mucosa to the fornix and passed through the buccal suprabony connective tissue and edentulous ridge crest. The second incision was complementary to the first one. It began on the buccal border and continued within the connective tissue toward the palatal aspect of the ridge so that the preserved suprabony connective tissue and the underlying periosteum covered the edentulous site. A rectangular window of adequate size was created on the occlusal side of the edentulous bone crest with the free end of the working tip insert 83 (KaVo SONICflex, KaVo Italia), avoiding sinus membrane perforation.
The rectangular-shaped trapdoor of carved bone was gently tapped with osteotomes mounted on an electromagnetic device (Magnetic Mallet, Osseotouch Total Control)\textsuperscript{15–18} to push it inside the sinus cavity (Fig 1). The sinus membrane was carefully detached all around the trapdoor through a proper curette (number 2 De Marco curette, Hu-Friedy PGF-GFS, Hu-Friedy) to create a space from the lateral to the mesiodistal walls (Fig 1). Once the space achieved as a result of the sinus elevation was sufficient, a collagen sheet was placed inside the elevated sinus to maintain the apically displaced trapdoor. A primary wound closure by sutures was performed and removed after 7 days.

During the second stage, the same surgical procedure was repeated within 3 months. The sinus floor was pushed up so that the ridge height was increased by 3 to 4 mm along the implant direction (Fig 1). The implant site was prepared, and the bone achieved at stage 1 was newly expanded, both laterally against the pre-existing lateral walls and apically moving up and compressing it with bone expanders. A titanium plasma spray with an external connection, 0.8-mm machined neck, rough surface, and body with a progressive thread design (Outlink, Sweden & Martina) was placed in each site. The buccal flap was repositioned and stabilized with sutures tied to the margin of the lingual/palatal flap. To increase the size of keratinized mucosa, the gap between the superficial margin of tissue was buccally displaced, and the lower part of the palatal tissue was healed by secondary intention. A collagen sheet covered the resulting gap. The collagen was placed under the buccal flap and covered the bone crest to stabilize the coagulum (Fig 2).

The definitive prosthetic restorations were cemented 5 months after implant placement.

**Follow-up and Variable**

Planning and follow-up were done radiographically using a CBCT scanner (Gendex GXCB-500, Gendex Dental Systems) with the following setting: 120 kV, 30.89 mAs, isotropic voxel size of 200 mm, and 8.72-cm diameter of reconstruction.

Preoperative and postoperative scans were modified to appear superimposable according to Crespi et al and were saved as DICOM files.\textsuperscript{19} A single examiner (T.P.) performed all the measurements. CBCT cross-sectional images were extrapolated from each set of the three scans that were superimposable in the space, and measurements of alveolar crestal height (ACH), that is, the distance from the most apical bone-to-implant contact (palatal/buccal side) to the level of the implant-abutment interface, were measured at 1 mm from the implant surface and parallel to it (Fig 3). The alveolar crest height change (\(\Delta ACH\)) was the difference between the postoperative measurements (3 years after implant placement) and the preoperative measurements (before first surgery), following equation 1:

\[
\Delta ACH_{\text{preop}} - \text{postop} = ACH_{\text{postop}} - ACH_{\text{preop}} \quad \text{equation 1}
\]

A positive value of \(\Delta ACH\) represented a net gain in the bone height within the sinus. Postoperative \(ACH\), which was less than the implant length, was going to mean a variable amount of implant protrusion into the maxillary sinus.
Clinical Outcomes

The following clinical parameters were gathered from patients’ case sheets: report of pain, surgical complication, implant, and prosthesis outcome. The following were considered as the implant failing criteria: the presence of implant mobility, a radiolucent area close to the implant surface, suppurative mucosa, and pain associated with implant movement.

Statistical Analysis

A statistician performed all the analyses with specialized software (Statistics Toolbox, MatLab 7.11; MathWorks). The unit of the analysis was the patient. In the case of a bilateral procedure, only one surgical site per patient was randomly selected. Normal distributions of the sample data were not confirmed for each group and subgroup. Nonparametric tests were used (matched and unpaired Wilcoxon tests). Data were described as mean ± SD and given to one decimal place. The level of significance was set at .01.

RESULTS

Forty patients were selected for the present analysis. The subjects were 25 women and 15 men (age 60.0 ± 4.9 years, with values varying from 49 to 71 years).

Minor swelling could be present for a day, with residual swelling lasting another few days after surgery. Neither mucositis nor dehiscence was observed. After both surgeries, neither pain nor final mobility of the definitive prosthesis was recorded. After sinus elevation, patients experienced neither minor nasal bleeding nor vertigo syndrome.
Different radiographic outcomes are reported in Table 1 and Fig 4. Preoperative heights of the overall sites had a mean of 2.9 ± 0.6 mm. After surgical procedures, significant increases in the bone height were respectively reported for first (3.1 ± 0.6 mm) and second surgeries (4.4 ± 0.6 mm), with $P < .01$. The overall bone height, measured 3 years after the first surgery, was 10.3 ± 0.6 mm.

All linear measurements were ranked for tooth sites; however, no significant difference was registered between premolars and molars as reported in Table 1. None of the selected patients experienced implant failure.

**DISCUSSION**

The surgical procedure employed a two-stage approach involving transcrestal maxillary sinus floor augmentation with the use of a collagen sponge to fill the intrabony cavity resulting from floor elevation and detachment of the sinus membrane; the second step consisted of another indirect sinus elevation without grafting material by a magnetoelastic device, which allowed contextual implant insertion.

It was suggested that a malleting approach for sinus elevation could reduce the impact of surgery on the patient by minimizing trauma to the craniofacial region and potential occurrence of benign paroxysmal positional vertigo.\(^{18,20,21}\) The explanation might be the fact that there was high control of the axial and radial movements of the tip of the osteotome, with a limited number of calibrated shock waves resulting in better condensation, especially in softer bone.\(^ {22}\)

Although the osteotome-mediated sinus elevation technique was a predictable procedure with minimal discomfort for patients suffering from pneumatization of the maxillary sinus, some authors reported that the lower the available bone height, the larger the number of failures.\(^ {23–25}\)

Rosen et al\(^ {23}\) attested that the available bone height from the maxillary sinus floor to the alveolar crest mostly affected survival outcomes of the osteotome-mediated sinus elevation technique. Survival was 96% if the residual bone height was higher than 5 mm, whereas it dropped to 85.7% if the residual bone height was ≤ 4 mm. Difficulties in achieving optimum primary stability with decreased bone height were mainly responsible for these results.\(^ {26}\) On the contrary, the study of Soydan et al seemed to prove that exactly the opposite

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**Table 1  Mean and SD of Alveolar Crestal Height (ACH)**

<table>
<thead>
<tr>
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<th>ACH (mm)</th>
<th>Significance</th>
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<th>ACH (mm)</th>
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<tbody>
<tr>
<td></td>
<td>Preop</td>
<td>3 mo</td>
<td>3 y</td>
<td>Preop vs 3 mo</td>
<td>3 mo vs 3 y</td>
</tr>
<tr>
<td>Overall n = 40</td>
<td>2.9 ± 0.6</td>
<td>6.0 ± 0.6</td>
<td>10.3 ± 0.6</td>
<td>&lt; .00001a</td>
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<td>∆ACH</td>
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<td></td>
<td>Preop to 3 mo</td>
<td>3 mo to 3 y</td>
<td>Preop to 3 y</td>
<td>Preop to 3 mo vs 3 mo to 3 y</td>
<td>3 mo to 3 y vs Preop to 3 y</td>
</tr>
<tr>
<td>Overall n = 40 (mm)</td>
<td>3.1 ± 0.6</td>
<td>4.4 ± 0.6</td>
<td>7.5 ± 0.6</td>
<td>&lt; .00001a</td>
<td>&lt; .00001a</td>
</tr>
<tr>
<td>Premolar n = 10 (mm)</td>
<td>3.1 ± 0.4</td>
<td>4.6 ± 0.6</td>
<td>7.7 ± 0.7</td>
<td>.00195a</td>
<td>.00195a</td>
</tr>
<tr>
<td>Molar n = 30 (mm)</td>
<td>3.1 ± 0.7</td>
<td>4.3 ± 0.6</td>
<td>7.4 ± 0.6</td>
<td>.00004a</td>
<td>&lt; .00001a</td>
</tr>
<tr>
<td>Premolar vs molar</td>
<td>0.75458b</td>
<td>0.15068b</td>
<td>0.26723b</td>
<td></td>
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</tr>
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</table>

Preoperative (preop), at 3 months (3 mo), and at 3-year survey (3 y) at augmented site, with related changes; ∆ACH from preoperative to 3-month survey (preop to 3 mo), from 3-month to 3-year survey (3 mo to 3 y) and from preoperative to 3-year survey (preop to 3 y).

Statistical comparisons: aWilcoxon signed-rank test; bWilcoxon rank-sum test.
was true. The implant survival was 94.2% in subjects with a residual bone height between 1 and 4.9 mm and 95.8% when bone height ranged from 5 to 8 mm. However, the present results showed a 100% success rate up to 3 years.

There was evidence of the influence of the size of the maxillary sinus on outcomes of the floor elevation. Zheng et al found a correlation between the stability of augmented bone and the distance between the medial and the lateral walls; moreover, Cheng et al verified that the width of the maxillary sinus might have a positive correlation with the new bone formation after sinus elevation without grafting material.

Primary stability appeared to be difficult to gain in patients with atrophic alveolar bone beneath the sinus because of the limited bone height and the low bone density. A recent review of literature suggested that there was a 5-year bone gain of 3.61 ± 0.34 mm during the analysis of 371 implants. A deeper implant placement than equicrestal implant positioning allowed good-quality bone to be rested against the flared neck of the implant.

Radiographic image analysis in this study attested an increase of 7.5 ± 0.6 mm in the height of available bone from the baseline to 3-year follow-up. The present increase was higher than that in the aforementioned literature because the present augmentation technique was a double-stage approach.

Even if some very recent studies attested that the height of the available bone seemed to affect neither short-nor medium-term outcomes of implant-supported restorations, useful data of meta-regression analysis about long-term success were very poor or could lead to false conclusions. To avoid the reduction of successful rates, just in case, the present clinical study described a two-stage procedure for transcristal maxillary sinus floor augmentation if the amount of bone was approximately 3 mm in height.

One of the main uses of the present two-stage approach was to let the edentulous site, which had undergone displacement of both the transcristal trapdoor cortical bone and sinus membrane, have favorable remodeling in the pristine alveolar bone and formation of bone in the newly created vertical space.

As suggested by Beaudry et al, a venous coagulum under the elevated sinus membrane could be used as filling material in sinus elevation and grafting surgical technique and increase bone formation in surgical-induced bone defects in the sub sinus cavity as well.

Shreds of evidence about the aforementioned considerations were given by the histologic analysis of Palma et al, who proposed that new bone arose in close contact with the sinus membrane in a coagulum-alone site after sinus floor augmentation in primates and without adjunctive use of grafting material. Moreover, the observation that new formation of bone occurred as a natural repair mechanism demonstrated that bone fillers might not be required to support the healing after the time necessary.

That is why over the last 15 years, clinicians published their evidence-based results with regard to sinus elevation without bone substitute materials, and irrespective of the technique used. There was also the fact, of course, that the sinus membrane is a very interesting membranous lining with particular biologic properties (mesenchymal and osteogenic activities that could promote natural healing). Furthermore, tissues with high regeneration potential could create the conditions for better healing of the bone-to-implant surface.

In addition to those features, available alveolar bone in the posterior zones of the maxilla could be considered as “low-quality bone,” mostly of spongiosa with very thin layers of cortical bone, and therefore, withstood compressive stress better than dense bone. Lozada et al first described adapted devices to access the maxillary sinus, and further, a recent review paper sorted the transcristal sinus elevation techniques by approach and employed device (modified osteotomes, safe-cutting drills, hydraulic and piezoelectric devices, and displacement balloons).

While some authors advocated the use of osteotomes just in cases of bone height > 6 mm, this procedure showed that in the case of bone from 2 to 4 mm, it was still a safe way to elevate the sinus floor as long as primary stability was achieved, albeit by a much longer time for rehabilitation. The results of the present two-stage osteotome protocol showed that adequate primary stability was achieved when the available bone was approximately 3 mm in height. The main strengths of the present study were the non-use of bone substitute materials; in fact, neither recovery autogenous bone substitute, nor allogeneic grafting material, nor a mixture of them had been used. Just a blood clot was entrapped within the elevated space. Two-stage osteotome-mediated sinus elevation techniques appeared to be less invasive than the standard sinus elevation procedures performed via a lateral approach in which the residual lateral bone defect had to be covered with soft tissue and induced encleftation and scarring in cases of wide access and large flap mobilization. The two-stage approach seemed to produce fewer side effects compared with the single-stage approaches; the transalveolar approach yielded the most common post-operative complication of sinus floor elevation, that is, the perforation of the sinus membrane. Single-stage crestal sinus floor elevation was useful to rehabilitate the edentulous area with a bone height ranging from 2 to 4 mm, but only when associated with simultaneous placement of short-length implants. Otherwise, lateral sinus floor elevation was recommended when the
edentulous site was not fully flattened or completely healed, and when the two bony plates were fused together or missing. However, a two-stage technique should be used instead of single-stage procedures because primary stability might be achieved.

The limitations of this study were represented by the delayed implant placement and the small size of the sample. Moreover, the retrospective nature of the analysis might be a bias influencing the results. The osteotome-mediated sinus elevation approach, although it seemed to simplify the rehabilitation, was highly affected by surgical skills, and therefore, more long-term cases are required to confirm the present conclusions.

CONCLUSIONS

Two-stage osteotome-mediated sinus elevation appeared to be a predictable technique that enabled practitioners to increase the bone height and to obtain successful outcomes even if the amount of bone was approximately 3 mm in height.

ACKNOWLEDGMENTS

The authors reported no conflicts of interest related to this study.

REFERENCES


