Influence of the Height of the Antrostomy in Sinus Floor Elevation Assessed by Cone Beam Computed Tomography: A Randomized Clinical Trial

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Purpose: To evaluate the influence of the height of the antrostomy on dimensional variations of the elevated space after sinus floor elevation. Materials and Methods: Twenty-four healthy volunteers planned for sinus floor elevation were included in the study. An antrostomy of either 4 mm (group A) or 8 mm (group B) in height was prepared in the lateral wall of the sinus. Cone beam computed tomography scans (CBCTs) were taken before surgery (T0) and after 1 week (T1) and 9 months (T2). Dimensional variation analyses were performed. Results: The CBCTs of 10 patients per group were evaluated. After 1 week (T1), the sinus floor was found elevated in the middle region by 12.0 ± 2.3 mm in group A, while in group B, the height was 11.8 ± 2.1 mm. After 9 months (T2), the respective heights were 9.9 ± 2.4 mm and 8.9 ± 2.7 mm, with a reduction of −2.1 ± 2.2 mm in group A and −3.0 ± 2.6 mm in group B. The area in a central position was reduced by 25.5% to 34.2%, showing a slightly higher shrinkage in group B compared with group A. However, no statistically significant differences were found between the two groups. Conclusion: In maxillary sinus floor elevations performed by the lateral approach, the size of the antrostomy did not affect the clinical and radiographic outcomes. Int J Oral Maxillofac Implants 2019;34:223–232. doi: 10.11607/jomi.7112

Keywords: antrostomy size, biomaterial, cone beam tomography, maxillary sinus, sinus augmentation, sinus dimension, sinus height
The resorptive properties of the biomaterial affecting the healing have to be considered as well. A resorbable biomaterial resulted in higher osteoclastic activities during the early phases of healing, while DBBM allowed the formation of dense tissue surrounding the particles. This tissue was substituted by new bone over time.

It was demonstrated that the bone was forming from the parent bone of the sinus walls and from the sinus floor. This, in turn, meant that the integrity of the sinus bony walls was of fundamental importance for new bone formation. This statement is also corroborated by the results from a clinical study in which 24 sinus floor elevations were performed in 21 patients. The area of the antrostomy was assessed, and biopsy specimens were harvested after 5 months of healing. It was concluded that vital bone formation was inversely proportional to the area of the antrostomy. These data suggest that position and size of the antrostomy may be of significance for the outcome when a lateral access is prepared, as the window will remove a part of the source for new bone formation. Antrostomies of 10 × 8 or 6 × 6 dimensions were compared in a randomized clinical study. At a CBCT analysis, no differences were found in dimensions of the augmented volumes. Nevertheless, higher technical difficulties were reported when small access windows were used.

When the antrostomy is prepared, the position of the intraosseous anastomosis (IA), connecting the posterior superior alveolar artery to the infraorbital artery, should be taken into consideration. The mean distance between the IA and the alveolar crest has been reported to be 19 mm, with a minimum distance of 14 mm. Moreover, the diameter of such an artery may be of a size to require a ligature if included in the antrostomy.

Considering the importance of the integrity of the sinus bony walls and the position of the IA, it seems of interest to evaluate possible effects of the height of the antrostomy on the dimensional variations. Hence, the aim of the present study was to evaluate the effect of the antrostomy height on the dimension and on dimensional changes over time of the augmented space after sinus floor elevation using a lateral approach.

The hypothesis was that the height of the antrostomy might influence the dimensional changes of the augmented space over time.

**MATERIALS AND METHODS**

The protocol was approved by the study Ethical Committee of the Corporación Universitaria Rafael Núñez, Cartagena de Indias, Colombia (protocol #01-2015; May 19, 2015). The study was performed following the Declaration of Helsinki on medical protocols and ethics. The protocol comprised two different studies on sinus floor elevation that evaluated different variables in different groups of patients. The present article reports data from the study on antrostomy dimensions. After having comprehensively explained all procedures and possible complications to the patient, informed consent was subsequently obtained. The present study followed the CONSORT statement for the reporting of randomized controlled trials (http://www.consort-statement.org/).

**Study Population**

Twenty-four healthy volunteers, who desired to receive fixed oral rehabilitation and were in need of sinus floor elevation, were recruited in the present randomized controlled trial (RCT). All the volunteers received definitive implants free of charge at the end of the study. The patients had to fulfill the following inclusion criteria: (1) ≥ 21 years of age; (2) presence of an edentulous zone in the posterior segment of the maxilla; (3) height of the sinus floor ~4 mm or less; (4) desiring a prosthetic restoration using a fixed prosthesis supported by implants; (5) good general health; (6) no contraindications for oral surgical procedures; and (7) not being pregnant. The patients were not admitted to the study if they: (1) were affected by a systemic disorder; (2) received chemotherapeutic or radiotherapeutic treatment; (3) were smokers of > 10 cigarettes/day; (4) referred with an acute or chronic sinusitis; (5) were treated for bone augmentation in the region of interest.

The recruitment of the patients, the surgeries, and the follow-ups were performed at the Corporación Universitaria Rafael Núñez, Cartagena de Indias (Colombia).

The power calculation was performed using the outcomes from a radiographic evaluation of the changes in the height of augmented sinus floors. A minimum n = 10 was obtained. An author (M.F.) not involved in the surgical procedures performed electronically the randomization (randomization.com). Sealed opaque envelopes containing the assignments of the treatment were prepared and opened at the time of surgery, when the surgeon (D.B.) was informed about the randomly allocated treatment.

**Clinical Procedures**

Local anesthesia was provided, and crestal and releasing incisions were performed. Full-thickness muco-periosteal flaps were elevated, the lateral sinus wall was exposed, and an antrostomy was randomly prepared either 4 mm (group A) or 8 mm (group B) in height, according to the treatment assignment (Figs 1a and 1b). The access window was prepared,
Grinding the bone with a diamond insert (SFS 109 029, Komet-Brasseler) mounted on a sonic-air surgical instrument (Sonosurgery TKD). The sinus mucosa was elevated approximately 5 mm above the upper margin of the antrostomy and close to the nasal-palatal sulcus. The height of the antrostomy was adjusted to the standardized protocol, while the length was prepared as needed. The depth of the balcony and the size of the access window were measured using an UNC 15 probe (Hu-Friedy). A collagenated cortico-cancellous porcine bone (OsteoBiol Gen-Os, 250 to 1,000 µm, Tecnoss) was used to fill the elevated space and softly condensed (Fig 1b). A collagen membrane (OsteoBiol Evolution, 0.3 mm, Tecnoss) was placed to cover the antrostomy. The flaps were secured with single silk sutures. Antibiotics (amoxicillin 875 mg and clavulanic acid 125 mg twice per day for 6 days), non-steroidal anti-inflammatory drug (ibuprofen 400 mg three times per day for 3 days), and mouthrinses with 0.12% chlorhexidine three times a day for 10 days were prescribed. The patients were also suggested to avoid blowing the nose as well as to open the mouth when sneezing. The sutures were removed after 7 days. The patients were included in a maintenance care system for the full extent of the study. The visits included inspection and cleaning of the wounds after 2 and 4 weeks from surgery and then monthly afterward. The oral hygiene conditions were monitored.

Six months after the surgery, through a small crestal incision, an experimental implant (Sweden & Martina) was placed in a position corresponding to that of a definitive implant. This represented a second step of the present study, and the related results are illustrated elsewhere.

**CBCT Imaging Procedures**

Three cone beam computed tomography scans (CBCTs) were taken for each patient at three different periods: (T0) before sinus floor elevation aiming to evaluate sinus and bone dimensions, presence of septa, and possible sinus pathologies; (T1) 1 week after the surgery evaluating dimensional changes compared with the T0 and T2 tomography scans; and (T2) 9 months after sinus floor elevation comparing dimensional changes with T0 and T1.

All tomography scans were taken in a specialist radiologic clinic using a 3D Accuitomo 170 Tomograph (J Morita Corporation). A voxel size of 0.125 mm, with a set of the parameters to 8.0 mA, 80 kV, and an exposure time of 12 to 18 seconds were applied. An effective dose irradiation to the patient of 18 to 66 µSv was reported using a 3D Accuitomo 170 Tomograph. The total irradiation for the three CBCTs was 54 to 198 µSv. This dose was lower than that recommended for an annual maximum dose (< 50 mSv) by the Health Physics Society.

**CBCT Imaging Analyses**

The software i-Dixel 2.0 (J. Morita Corporation) was used to perform measurements. The floor of the nose was chosen as the horizontal reference line both for the coronal (axis X; Fig 2) and lateral views (axis Z; Fig 3). A vertical line crossing the anterior nasal spine and the septum was used as vertical reference axis in the coronal view. In the 1-week tomography, the center of the antrostomy was identified, and the distance from the anterior nasal spine was evaluated. This distance was reported on the graduate scale on the CBCTs of T0 and T2. The section representing the center of the antrostomy was used for measurements in the coronal view, while the section crossing the center of the alveolar bone crest was used for the measurement in the lateral view.

**Landmarks Identified in the Coronal View**

The landmarks identified in the coronal view were as follows:

- T0 (Fig 2): center of the bony crest (C) and base of the sinus floor (F); base of the infraosseous anastomosis (A)
- T1 (Fig 4): upper margin (UM) and the lower margin (LM) of the antrostomy
- T1 and T2 (Figs 4 and 5): the highest position of the bony tissue/xenograft at the medial, middle, and lateral aspects

**Parameters Reported for the Coronal View**

The parameters reported for the coronal view were as follows:

- T0 (Fig 2): center of the bony crest (C) and base of the sinus floor (F); base of the infraosseous anastomosis (A)
- T1 (Fig 4): upper margin (UM) and the lower margin (LM) of the antrostomy
- T1 and T2 (Figs 4 and 5): the highest position of the bony tissue/xenograft at the medial, middle, and lateral aspects
- T0 (Fig 2): mucosa thickness (MT), bone crest height (distance C-F), nasal floor height (distance X-F), anastomosis height (distance A-C, evaluated following the plane of the lateral sinus wall) and its diameter (AD), sinus width (XW; distance evaluated on the line X between the two intersection points with the medial and lateral sinus bone walls); T0 X-area = area delimited by the sinus bone walls and the line X.

- T1 (Fig 4): balcony height (distance between LM-F) and window height (distance LM-UM)

- T1 and T2 (Figs 4 and 5): mucosa thickness (MT), floor augmentation heights at the medial, middle, and lateral aspects. The axis X was used as reference at the various periods evaluated. T1 X-area and T2 X-area were obtained subtracting the areas from T0 X-area not filled with biomaterial/bony tissue (residual area) below the axis X and adding the area above the axis X filled with biomaterial/bony tissue (exceeding area; Figs 3 and 5).
Parameters Reported for the Lateral View
The parameters reported for the lateral view were as follows:

- T0 (Fig 3): sinus length (distance between the two intersection points with the mesial and distal sinus bone walls on the axis Z; ZW)
- T1 and T2: the largest length of the xenograft/bony tissue (ZE). T1 Z-area and T2 Z-area were obtained subtracting the areas from T0 Z-area not filled with biomaterial/bony tissues located below the axis Z (residual area), and adding the area filled with xenograft/bony tissue above the axis Z (exceeding area)

Data Analysis
The primary outcome measure was the gain in height of the elevated sinus space evaluated in the coronal view. The evaluations were performed in the medial, middle, and lateral aspects. The secondary outcome measure was the area of the elevated zone. All clinical measurements were performed twice by the surgeon (D.B.), and a mean value was used. All radiographic measurements were performed twice by a well-trained researcher (K.A.A.A.), blinded about the aim in the protocols at the time of measurements. Mean values were obtained between the two measurements and used for analysis. Mean values and standard deviations (SD) were calculated for each outcome variable. Differences between groups A and B were analyzed with the IBM SPSS Statistics software (IBM) using the Mann-Whitney test. The level of significance was set at $\alpha = .05$.

RESULTS
The study started in August 2015 and ended in March 2017. Twenty-four patients were included in the study. Four perforations occurred during surgery, two in group A and two in group B. In one patient of group B, the perforation was too large, so the treatment was interrupted and postponed. One perforation of approximately $3 \times 4$ mm occurred in one patient in group A. The perforation was covered with a collagen membrane. Two small perforations ($< 1$ mm) were seen, one in each group, and small pieces of collagen membrane were used to protect them. These three patients with small perforations were maintained in the study. Three other patients did not comply with the timetable of the CBCT planning within the limits provided. These three patients and the patient with the treatment interrupted during surgery were excluded from the radiographic analyses. No further dropouts were registered during the follow-up, so the CBCTs of 20 patients were available, 10 for each group (n = 10; Fig 6).

No complications were reported after any surgery or during the following periods of observation. An asterisk was added to the data within the text and tables to indicate that the difference between group A and group B was statistically significant ($P < .05$).

Clinical Measurements
The mean height of the antrostomy was $4.1 \pm 0.2^* \text{ mm}$ and $7.9 \pm 0.2^* \text{ mm}$ for groups A and B, respectively. The mean quantity of biomaterial applied was $0.8 \pm 0.2 \text{ g}$ and $1.0 \pm 0.1 \text{ g}$ in groups A and B, respectively (Table 1).
Table 1  Anagraphic and Clinical Data

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age (y)</th>
<th>Smokers</th>
<th>Side</th>
<th>Window height (mm)</th>
<th>Window length (mm)</th>
<th>Window area (mm²)</th>
<th>Balcony (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>4 males; 6 females</td>
<td>57.8 ± 9.6</td>
<td>None</td>
<td>7 right; 3 left</td>
<td>4.1 ± 0.2*</td>
<td>11.8 ± 3.2</td>
<td>48.7 ± 14.7*</td>
</tr>
<tr>
<td>Group B</td>
<td>4 males; 6 females</td>
<td>55.4 ± 9.8</td>
<td>None</td>
<td>6 right; 4 left</td>
<td>7.9 ± 0.2*</td>
<td>12.5 ± 3.3</td>
<td>98.3 ± 27.1*</td>
</tr>
</tbody>
</table>

*P < .05.

Table 2  Radiographic Anatomical Data in the Coronal View Taken at Different Periods

<table>
<thead>
<tr>
<th>Bone crest height (C-F) at T0</th>
<th>Sinus height (X-F) at T0</th>
<th>Sinus width (XW) at T0</th>
<th>IA height (A-C) at T0</th>
<th>IA diameter at T0</th>
<th>X-area at T0</th>
<th>Balcony height (LM-F) at T1</th>
<th>Window height (LM-UM) at T1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>3.5 ± 1.5</td>
<td>8.5 ± 3.4</td>
<td>14.0 ± 2.8</td>
<td>16.8 ± 3.5</td>
<td>1.1 ± 0.4</td>
<td>82.1 ± 45.4</td>
<td>4.0 ± 0.7</td>
</tr>
<tr>
<td>Group B</td>
<td>3.6 ± 1.3</td>
<td>9.3 ± 2.3</td>
<td>14.8 ± 3.4</td>
<td>18.1 ± 3.0</td>
<td>1.2 ± 0.5</td>
<td>94.2 ± 38.9</td>
<td>3.7 ± 0.5</td>
</tr>
</tbody>
</table>

*P < .05. Data in millimeters or square millimeters (only the Area X).
IA = intra-osseous anastomosis; T0 = before surgery; T1 = 1 week; T2 = 9 months.

Table 3  Floor Augmentation Heights in the Coronal View Evaluated at Medial, Middle, and Lateral Aspects of Sinus at Various Periods of Observation

<table>
<thead>
<tr>
<th></th>
<th>Medial wall</th>
<th>Middle aspect</th>
<th>Lateral wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Δ T1 – T2</td>
<td>T1</td>
<td>Δ T1 – T2</td>
</tr>
<tr>
<td>Group A</td>
<td>6.7 ± 2.2</td>
<td>6.6 ± 1.5</td>
<td>0.0 ± 1.9</td>
</tr>
<tr>
<td>Group B</td>
<td>6.7 ± 2.0</td>
<td>6.2 ± 2.1</td>
<td>−0.5 ± 1.8</td>
</tr>
</tbody>
</table>

T1 = 1 week; T2 = 9 months; Δ = difference. Data in millimeters. P < .05.

CBCT Imaging Evaluation
Coronal View. Table 2 reports the anatomical data in the coronal view related to bone crest height (C-F), the sinus height (X-F), and the sinus width (XW) at T0, balcony, and antrostomy heights at T1. Moreover, intraosseous anastomosis position and diameter are also indicated.

At T1, the sinus floor was augmented in the middle aspect by 12.0 ± 2.3 mm in group A and 11.8 ± 2.1 mm in group B (Table 3; Fig 7). At the T2 period (Fig 5), a reduction of −2.1 ± 2.2 mm in group A and of −3.0 ± 2.6 mm in group B was observed resulting in a sinus floor augmentation of 9.9 ± 2.4 mm and 8.9 ± 2.7 mm in the middle aspect, respectively. In the three patients with a small perforation of the sinus mucosa, which was treated with collagen membranes, a mean loss of −0.1 mm was observed in the middle aspect.

At the analyses after 1 week, the sinus was elevated from the floor at the medial and lateral aspects of the sinus by 6.7 ± 2.2 mm and 8.6 ± 1.5 mm in group A and by 6.7 ± 2.0 mm and 8.8 ± 2.4 mm in group B, respectively. After 9 months, the respective measurements were 6.6 ± 1.5 mm and 7.7 ± 1.7 mm at group A and 6.2 ± 2.1 mm and 8.5 ± 2.2 mm in group B.

A reduction of the augmented area of 25.5% ± 18.3% in group A and of 28.1% ± 19.8% in group B was observed (Table 4).

No statistically significant differences for any of the parameters were revealed between the two groups.

Table 5 reports the dimensional variation of the sinus mucosa width among the periods T0, T1, and T2 (Fig 5) for both groups.

A partial/total corticalization of the new sinus floor was visible in nine cases in group A and five cases in group B. The antrostomy was closed in all cases. However, it was found to be partially or totally corticalized in eight cases in group A and six cases in group B.
Lateral View. Table 6 reports the data in the lateral view related to sinus length and the largest length of the xenograft. The horizontal reduction of the hard tissue (bone/xenograft) was 1.5 ± 1.1 mm and 2.7 ± 2.6 mm, for groups A and B, respectively.

At T2, a total reduction of area in percentage was 25.4% ± 20.1% at group A and 34.2% ± 23.5% at group B (Table 4).

DISCUSSION

The present study illustrated the anatomical dimensional changes evaluated by CBCT after sinus floor elevation applying a collagenated cortico-cancellous porcine bone and a lateral access antrostomy with either approximately 4 or 8 mm of height. No major statistically significant differences were seen in changes of the hard tissues between the two groups evaluated.

In the present study, the base of the nose was used as reference plane both in the coronal and lateral views in the CBCT analyses. Lines were drawn that, in the coronal view, were crossing the medial and lateral walls of the sinus (axis X), and in the lateral view were crossing the mesial and distal walls of the sinus (axis Z). These well-defined and stable references over time allowed calculating at T0 the area included between these axes and the sinus bony walls as well as the distance from the axes to the floor of the sinus. At the subsequent periods of evaluation, the dimensional changes were also evaluated, subtracting the areas not occupied by biomaterial/bone tissues below axes X and Z, and adding the areas occupied by biomaterial/hard tissues above the two axes.

The biomaterial applied in the present study was also used in an experiment for sinus augmentation in rabbits.20 Mainly due to the osteoclastic activity, a resorption up to 50% was observed after 8 weeks of healing. Nevertheless, a loss of biomaterial through the antrostomy was seen. This might have contributed to the shrinkage of volume. In the present clinical study, the amount of biomaterial placed within the elevated space exceeded the dimensions of T0 X-area and T0 Z-area in both groups. After 9 months of healing, a shrinkage of 25% to 34% of the elevated area was found in the two groups with no statistically significant differences. This shrinkage of the elevated space may be attributed to the osteoclastic resorption of the biomaterial used.14 However, other factors may influence the volumetric reduction of the elevated space due to the pressure balance within the sinus cavity. The soft condensation used to place the biomaterial in the present study may have contributed to the reduction of volume for a consolidation of the graft. Moreover,

### Table 4

| Areas (in mm²) in the X and Z Planes at Various Periods Evaluated and Shrinkage (in mm²) and Percentages (%) of Elevated Space Between 1 Week and 9 Months in the Coronal and Lateral Planes |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| Coronal view | Coronal view | Coronal view | Coronal view | Coronal view | Coronal view |
| T0 X-area and T0 Z-area | T1 X-area and T1 Z-area | T2 X-area and T2 Z-area | Δ T1 - T2 (mm²) | Δ T1 – T2 (%) |
| Group A | 82.1 ± 45.4 | 103.8 ± 25.5 | 74.7 ± 19.2 | –29.0 ± 20.3 | –25.5 ± 18.3 |
| Group B | 94.2 ± 38.9 | 107.8 ± 15.5 | 79.3 ± 32.2 | –28.5 ± 21.1 | –28.1 ± 19.8 |
| Lateral view | Lateral view | Lateral view | Lateral view | Lateral view | Lateral view |
| T0 X-area and T0 Z-area | T1 X-area and T1 Z-area | T2 X-area and T2 Z-area | Δ T1 - T2 (mm²) | Δ T1 – T2 (%) |
| Group A | 163.9 ± 97.4 | 171.5 ± 50.0 | 126.6 ± 49.9 | –44.9 ± 34.4 | –25.4 ± 20.1 |
| Group B | 163.6 ± 66.9 | 167.5 ± 36.9 | 113.0 ± 48.6 | –54.5 ± 36.2 | –34.2 ± 23.5 |

P < .05. T0 = before surgery; T1 = 1 week; T2 = 9 months; Δ = difference.

### Table 5

<table>
<thead>
<tr>
<th>Sinus Mucosa Thickness at Various Periods of Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>T0</td>
</tr>
<tr>
<td>Group A</td>
</tr>
<tr>
<td>Group B</td>
</tr>
</tbody>
</table>

*P < .05; none of the differences was statistically significant between group A and group B. T0 = before surgery; T1 = 1 week; T2 = 9 months; Δ = difference. Data in millimeters.

### Table 6

<table>
<thead>
<tr>
<th>Sinus Width and Length of Grafted Zone in Lateral View at 1 Week (T1) and 9 Months (T2) Periods and Reduction of Length Between the Two Periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinus width ZW at T0</td>
</tr>
<tr>
<td>Group A</td>
</tr>
<tr>
<td>Group B</td>
</tr>
</tbody>
</table>

Data in millimeters. P < .05; none of the differences was statistically significant between group A and group B. T0 = before surgery; T1 = 1 week; T2 = 9 months; Δ = difference.
the sinus pressure might generate extrusion of biomaterial through the antrostomy.\textsuperscript{33} The reduction in dimension observed in the present study was lower at the small compared with the large antrostomy, even though the differences did not reach statistical significance. This difference may be due to a higher displacement of the biomaterial outside the larger antrostomy compared with the smaller antrostomy, as shown in some of the CBCTs analyzed (eg, Fig 4).

The shrinkage in dimensions registered in the present study is in agreement with the data of a systematic review that reported a reduction of 18\% to 22\% for bone substitutes or composite grafts between 6 months and 2 years.\textsuperscript{19}

The height of the elevated region was evaluated after 1 week (T1) at three different sites that were close to the medial sinus wall (medial aspect), in a central location (middle aspect), and close to the lateral wall (lateral aspect). This latter measurement was obviously affected by the presence of the antrostomy. The gain in height in the middle aspect after 1 week (T1) was approximately 12 mm in both groups, again evaluated using axis X as reference line. Including the sinus floor height, the total available height was approximately 16 mm. After 9 months of healing, the augmented height was of 9.9 mm and 8.9 mm in groups A and B, respectively. No statistically significant differences were found either. These results are in agreement with those reported in other clinical studies. In a randomized controlled clinical study,\textsuperscript{26} a gain of approximately 8.5 to 8.7 mm was reported after 6 months of healing using a DBBM xenograft. In a retrospective clinical study, no statistically significant differences between antrostomies with vertical height 3 to 5 mm or 6 to 8 mm were found.\textsuperscript{34} A gain in height of 8.5 mm at the test group and 9.7 mm in the control group after 1 year from sinus floor elevation was reported.

In another clinical study, the elevated space was filled with beta-tricalcium phosphate with or without platelet-rich plasma.\textsuperscript{35} A gain of 11.6 to 13.2 mm was achieved after 6 months of healing. In another clinical study,\textsuperscript{36} autogenous bone alone, or an inorganic bovine bone or a mixture of the two biomaterials were used. A gain in height of the sinus floor of 11.0 to 13.2 mm was obtained after 1 to 5 years.

Considering the initial height of the sinus floor, the total available height was approximately 12 to 14 mm in the present study. This height may be considered sufficient for the placement of an implant. The biomaterial used in the present study had a density and a mineral content similar to that of natural human bone (2.43 g/cm\textsuperscript{3} and 64.6\% for Gen-Os and 2.30 g/cm\textsuperscript{3} and 65.0\% for human bone), so a high resorption rate may be expected.\textsuperscript{37} This has to be taken into consideration when such materials are used. In fact, in the present study, 2 to 3 mm in height was lost during the first 9 months of healing.

At the medial aspect, a height of 6.7 mm was seen in both groups at T1. The mean height of the sinus floor at the level of axis X was 8.5 mm and 9.3 mm in groups A and B, respectively. This, in turn, means that after 1 week of healing, the biomaterial was located approximately 2 mm below axis X and below the nasal-palatal sulcus despite the effort applied to elevate the sinus mucosa up to that level. This may have been due to an imperfect elevation of the sinus mucosa or a deficiency in the placement of the biomaterial in that region. However, a displacement of the biomaterial during the first week of healing may have to be considered as well, owing to the hydrostatic pressure within the sinus cavity. This is supported by the detection of biomaterial outside the antrostomy in some cases, a fact that did not exclude the dislocation toward other directions within the sinus.

The height at which the biomaterial was found close to the lateral wall after 1 week of healing was 8.6 mm in group A and 8.8 mm in group B. Considering balcony and antrostomy heights, the upper margin of the antrostomy was located at approximately 8.3 mm in group A and at 11.6 mm in group B from the sinus floor. This, in turn, means that the biomaterial in group B was located as a mean value a few millimeters below the upper margin of the antrostomy. During surgery, the sinus mucosa was always detached and displaced above the upper margin of the antrostomy. Obviously, the biomaterial was dislocated during the first week of healing, again owing to the sinus pressure and the edema/bleeding of the sinus mucosa/submucosa. After 9 months of healing, the heights at the medial and lateral aspects remained stable (0 to 0.9 mm) in both groups and the antrostomy appeared to be corticalized in most cases (14 out of 20).

The middle aspect of the elevated sinus floor was higher compared with the medial and lateral aspects at T1, thus producing a dome effect of the elevated space. The higher reduction in dimension in the middle aspect compared with the other aspects resulted in a flatter top of the elevated zone. A partial corticalization of the new sinus floor at the top of the elevated zone was seen in most cases in both groups (15 out of 20).

The sinus mucosa had a width of approximately 1.7 to 1.9 mm before surgery. After 1 week following sinus floor elevation, the width increased 2 to 3 times in groups A and B, respectively.

The swelling of the sinus mucosa after sinus floor elevation has been reported in various clinical studies,\textsuperscript{33,38} and it has been reported as early as 1 day after surgery.\textsuperscript{39}
In the present study, an air-sonic device was used to prepare the antrostomy. This instrument has been shown to reduce the incidence of soft tissue injuries and of perforations of the sinus mucosa. In the present study, this tendency was confirmed with four perforations out of 24 sites.

Limitations of the present study that should be considered include the reduced sample size. Moreover, the time frame of 9 months allowed for a tomographic evaluation may not be sufficient for conclusive statements about the healing of the biomaterial used and the influence of the antrostomy dimensions.

CONCLUSIONS

This study has demonstrated that in maxillary sinus floor elevations performed by the lateral approach, the size of the antrostomy did not affect the clinical and radiographic outcomes in terms of obtained sinus floor height.

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