Influence of Lateral Sinus Floor Elevation Procedures on the Pulpal and Periapical Status of Adjacent Vital Teeth

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Featured Application: The aim of lateral sinus floor elevation (LSFE) is to increase the residual alveolar bone volume at the posterior maxillary area for implant-supported restoration. However, due to the restricted surgical access, mainly to the anterior sinus wall, this procedure becomes more challenging and difficult to perform in cases where adjacent proximal vital teeth are present. The present study proves that through a strict surgical protocol and careful tissue management, LSFE is a predictable and safe procedure presenting no risk of vitality loss and periapical pathology for adjacent vital teeth.

Abstract: The aim of the present study was to evaluate the pulpal and periapical status of vital teeth within the area of a lateral sinus floor elevation (LSFE). The files of patients treated by LSFE between 2009 and 2015 were retrospectively evaluated. The radiographic bone measurements and the periapical status of the teeth adjacent to the LSFE area were evaluated preoperatively and 6 months following the surgery by CBCT. The pulpal status of the adjacent teeth was clinically evaluated using thermal pulp vitality testing. Vital teeth within the sinus floor elevation area were the main inclusion criteria for this study. A total of 158 LSFE procedures were evaluated; 18 cases fulfilled the inclusion criteria, and 20 adjacent teeth were vital. There were no cases of periapical pathology or loss of pulp vitality. There was a statistically significant difference in the ridge height between the baseline and 6 months postoperatively and in the distance from the apex to the sinus floor between pre- and 6 months postoperatively (p < 0.01). The pulpal and periapical status of vital teeth was not affected following LSFE.

Keywords: tooth vitality; maxillary sinus; bone augmentation; dental diseases; oral diseases; dentistry; diagnosis; prognosis

1. Introduction

The maxillary posterior edentulous region presents a challenge when planning for restoring missing teeth with a dental implant [1]. The lateral sinus floor elevation (LSFE) approach is performed to increase the height of the residual alveolar bone at the posterior maxilla. Although LSFE is considered
a predictable procedure, several complications may occur, affecting the outcome and viability of the graft and hence that of the implants and oral reconstruction [1–6].

The most common intraoperative complication is Schneiderian membrane perforation, with a reported incidence of up to 41% [7]. Among postoperative complications, wound infection, abscess formation, or dehiscence with drainage and maxillary sinusitis may occur [3].

Another possible complication may involve pulp necrosis and the further development of periapical pathosis in adjacent vital teeth [8]. However, the possible effect of the LSFE procedure on the endodontic and periapical status of adjacent vital teeth has not been fully elucidated. A recent retrospective study concluded that pulp necrosis is an extremely rare complication after sinus augmentation and the probability of tooth devitalization is ≤0.7% [9]. However, tooth vitality was evaluated according to panoramic and periapical X-ray without clinical evaluation and vitality tests.

Hence, the aim of the present study was to check the effect of the LSFE procedure on the pulpal and periapical status of adjacent vital teeth based on CBCT and tooth vitality test records.

2. Methods

Human ethics approval for this retrospective study was obtained from Tel-Aviv University ethics committee (institutional ethics committee of Tel-Aviv University proposal no 32.17).

The files of patients treated by LSFE between 2009 and 2015 and with follow up of one year after sinus augmentation were retrospectively evaluated, and the cases were selected according to the following inclusion and exclusion criteria.

Inclusion criteria:

- Partial edentulism in the posterior maxilla;
- Prosthetic treatment plan that included the insertion of 1–3 implants in the posterior region of the maxilla, requiring lateral sinus floor elevation;
- Sinus augmentation performed by the lateral window approach;
- One sinus elevation procedure per patient;
- At least one vital tooth showing a normal response to thermal pulp testing and normal periapical tissues adjacent to the edentulous area;
- CBCT performed before and 6 months following LSFE and panoramic X-ray examination performed 6 months after implant placement.

Exclusion criteria:

- Active periodontal disease;
- Previous history of sinus pathology;
- Negative response to thermal pulp testing or the presence of periapical pathology in adjacent teeth before LSFE;
- Complete loss of the posterior premolars and molars;
- Root canal-treated teeth adjacent to the edentulous area;

All the procedures were performed by the same operator (IB).

3. Description of the Surgical Procedure

Surgery was performed under local anesthesia according to the technique described by Boyne and James [10]. Mid-crestal and vertical releasing incisions were made, and a full-thickness flap was elevated. The lateral window was created using a low-speed headpiece and a rounded, 5 mm-diameter diamond bur (FRIOS drill set, Dentsply Friadent, Mannheim, Germany) under cooling with sterile physiological saline. The window was extended laterally and apically approximately 3 mm from the apex of the adjacent teeth [11]. The sinus membrane was raised, and the area was filled with a particulate bone graft material using the bi-layering technique. A combination of approximately 0.5 g
deproteinized bovine bone mineral (DBBM Bio-Oss, Geistlich Pharma AG Wohlhusen Switzerland) was placed close to the Schneiderian membrane while particulate mineralized corticocancelous allogenic particles (MinerOss, BioHorizons Birmingham, USA/Maxgraft, Botiss biomaterials Berlin, Germany) filled the remaining cavity [11–14].

Following the bone grafting, the access window was covered with a resorbable collagen membrane. Soft tissues were approximated using horizontal mattress and single interrupted sutures (4-0 polyglactin 910, Vicryl Rapide™ Ethicon, Inc., Somerville, NJ, USA). Suture remnants were removed 2 weeks following the procedure.

The postoperative instructions included rinsing with 0.2% chlorhexidine solution twice a day for 2 weeks, and antibiotics were prescribed for 10 days (Augmentin, 875 mg, GlaxoSmithKline, Brentford, Middlesex, UK). No anti-inflammatory medication was prescribed and the patients were instructed to take over the counter analgesics of their preference when needed.

3.1. CBCT Scan Evaluation

For the same patient, the same CBCT device was used for both evaluations, without changing the set-up. However, different instruments were used for different patients. Thus, there was standardization within but not between the patients.

Measurements were digitally performed.

Preoperative measurements:

- Minimal distance between the root apex and the sinus floor;
- Minimal distance between the edentulous bone crest and the sinus floor;
- Spatial relationship to the maxillary sinus, classified as described by Shahbazian and colleagues [15,16]:
  - Type 1: Distinct distance between the root tip and the sinus floor (i.e., >0.5 mm distance);
  - Type 2: Roots are in close contact with the inferior border of the maxillary sinus (i.e., <0.5 mm distance);
  - Type 3: Roots are projecting laterally over the sinus but appear outside the sinus;
  - Type 4: Roots have an intimate relationship with the sinus floor.

3.2. Postoperative Measurements

- Largest distance between the root apex and the newly formed sinus floor;
- Distance between the edentulous bone crest and the sinus floor (Figure 1).

![Figure 1](a) (b)

**Figure 1.** Representative panoramic view of the treated area: (a), baseline; and (b), after augmentation.

Measurements were digitally performed on CT scans pre- and 6 months postoperatively with dental imaging software (AB Denpax Viewer, A.B. Dental, Ashdod, Israel) (Figures 2 and 3). All measurements were separately performed by two independent examiners (T.B. and G.S.) on equivalent cross-sectional images.
was repeated after 2 min. Only conclusive cases were included; teeth with no response on either
application were rated negative for pulp vitality. A thermal tooth vitality test was evaluated clinically
according to the periapical index criteria described by Estrela et al. in 2008 [17], as follows:

The pulpal status of the teeth adjacent to the sinus floor elevation area was clinically evaluated
using thermal pulp vitality testing.

A cold test was performed by spraying a cotton pellet with tetrafluoroethane (−26.2 °C, Endo-Ice
refrigerant spray; Coltene/Whaledent, Inc., Mahwah, New Jersey, USA), which was placed on the
middle third of the facial surface of the tooth for 5 s or until the patient reported feeling pain. The test
was repeated after 2 min. Only conclusive cases were included; teeth with no response on either
application were rated negative for pulp vitality. A thermal tooth vitality test was evaluated clinically
at least 6 months post-surgery by the operator (I.B.). The periapical status of the teeth adjacent to the
sinus floor elevation area was evaluated preoperatively and 6 months following the surgery, according
to the periapical index criteria described by Estrela et al. in 2008 [17], as follows:

**Figure 1.** Representative panoramic view of the treated area: (a), baseline (slice 38); and (b),
after augmentation (slice 8).

**Figure 2.** Representative CT images shown by the AB Denpax Viewer, presenting the vertical ridge
height measured at the middle of the crest and the planned implant axis: (a), baseline (slice 38); and (b),
after augmentation (slice 8).

**Figure 3.** Representative CT images shown by the AB Denpax Viewer, presenting the bone height
measured apically from the tooth apex: (a), baseline (slice 30); and (b), after augmentation (slice 12).
Intact periapical bone structures

Diameter of periapical radiolucency > 0.5–1 mm

Diameter of periapical radiolucency > 1–2 mm

Diameter of periapical radiolucency > 2–4 mm

Diameter of periapical radiolucency > 4–8 mm

Diameter of periapical radiolucency > 8 mm

Score (n) + E * Expansion of periapical cortical bone

Score (n) + D * Destruction of periapical cortical bone

* The variables E (expansion of cortical bone) and D (destruction of cortical bone) were added to each score whenever detected in the CBCT analysis.

Two observers (G.S. and T.B.) independently performed all measurements using the AB Denpax (A.B. Dental, Ashdod, Israel) software system; the evaluators were calibrated for similar interpretations of the results.

Data were statistically analyzed by the intraclass correlation coefficient (ICC = 0.999). The results are presented as the mean of the measurements; p-values were considered significant at p < 0.05.

4. Results

A total of 158 LSFE procedures were evaluated, among which only 18 met the inclusion criteria. Overall, 20 teeth (1 third molar, 10 s molars, 1 first molar, 7 s premolars, and 1 first premolar) in 18 patients (12 females and 8 males) were tested as vital. In 4 out of the 18 patients, a single tooth was missing. There were no intraoperative (excessive bleeding, Schneiderian membrane perforation) or postoperative (surgical site infection, abscess formation, or dehiscence with drainage and maxillary sinusitis) complications within the 18 evaluated cases.

Based on the preoperative CBCT scan, the spatial relationship to the maxillary sinus was classified according to the criteria described by Shahbazian and colleagues (Table 1) [15].

| Parameters | Type 1 | Type 2 | Type 3 | Type 4 | Total |
|------------|--------|--------|--------|--------|-------|
| PM1        | 1      |        |        |        | 1     |
| PM2        | 4      | 2      | 1      |        | 7     |
| M1         |        | 1      |        |        | 1     |
| M2         |        | 3      | 6      | 1      | 10    |
| M3         |        |        | 1      |        | 1     |
| Total      | 4      | 6      | 9      | 1      | 20    |

There were no statistically significant differences between the examiners. The reliability of the measurements was excellent (ICC = intraclass correlation coefficient = 0.999). All results are presented as the mean of the measurements obtained by the two examiners (Table 2).

| Parameters                  | Apex to Sinus Floor Distance | Ridge Height at the Edentulous Area |
|-----------------------------|------------------------------|------------------------------------|
|                            | Baseline 6 Months            | Baseline 6 Months                  |
| Mean ± SD                   | 1.05 ± 1.71                  | 8.25 ± 3.86 mm                     |
| Range                       | 0–5.63                       | 4.33 ± 2.27                        |
| Mean difference ± SD        | 7.17 ± 3.35 *                | 12.95 ± 3.38 *                     |
| N                           | 20                            | 20                                 |
| 6 Months                    | 17.29 ± 3.02                  | 7.82–22.18                         |

* p < 0.01.
There was a statistically significant difference in the ridge height between the baseline and 6 months postoperatively and in the distance from the apex to the sinus floor between pre- and 6 months postoperatively ($p < 0.01$). In addition, a positive statistically significant correlation was found between the preoperative distance from the apex to the sinus floor and the preoperative edentulous ridge height ($p = 0.03$).

5. Discussion

Since certain vessels responsible for the blood supply of the posterior upper teeth may be found within the lateral bony sinus wall and underneath the Schneiderian membrane, opening the bone window and raising the Schneiderian membrane during the LSFE procedure may pose a risk to the vitality of adjacent teeth [8,9,18]. However, no loss of vitality or periapical pathology was found in any case in the present study. A strict surgical protocol and rigorous surgical technique make it possible to open the lateral window and to raise the Schneiderian membrane without damaging the tooth vascular bundle, thus preserving the blood supply. In most cases, lamina dura can be expected around the apex of the teeth with normal periapical tissues.

In 4 out of the 18 patients, a single tooth was missing. In such cases, the surgical procedure is more difficult due to the restricted operating area and difficulty accessing the anterior sinus wall. Especially in these cases, caution should be practiced to prevent damaging the apex of adjacent vital teeth. In the current study, at least 3 mm of bone was preserved between the apex of the involved teeth and the lateral bone window margin, thus reducing the possibility of this complication. This is especially important in type 2–4 cases [11].

To the best of our knowledge, there have been no previous evaluations of tooth vitality following sinus floor augmentation involving thermal pulp vitality testing. The loss of tooth vitality has been reported following Le Fort I maxillary fracture without segmentalization. After Le Fort I osteotomy, electric and thermal pulp testing revealed that in 2/25 of the patients (8%), recovery took place after 10 days in the premolar and molar regions. Accordingly, following this procedure, the loss of tooth sensitivity can be expected in the short term; however, after 8 weeks, 24/26 of the patients showed full recovery, and at the end of the 24 weeks, all patients (100%) showed a full recovery of tooth sensitivity [18]. The results of the present study are in accordance with these results; however, it should be taken in consideration that LSFE is a more conservative and restricted procedure than Le Fort 1 maxillary fracture without segmentalization, especially taking into consideration that the caliber of the vessels supplying the lateral antral wall is rather large even in severe maxillary atrophy and after complete disappearance of the centro-medullary vessels [18].

Our report is in agreement with a previous publication by Beck and colleagues [9]. Beck reported a probability of $\leq 0.7\%$ for tooth devitalization after maxillary sinus augmentation, which is an extremely rare complication. They found only a single case of tooth vitality loss out of 357 adjacent teeth, which might be attributable to the surgical procedure. Their conclusion was based only on retrospective analyses of periapical and panoramic radiographs. In their study, the authors claimed that the “partial manipulation and/or disturbance of the blood supply most likely occurred during maxillary sinus augmentation, and this may explain the devitalization of tooth #26 and the need for endodontic therapy” [9]. However, it appears from the X-ray that a loss of vitality could be due to several other reasons and not necessarily to the maxillary sinus augmentation.

In the present study, all cases were evaluated clinically by vitality testing and radiographically by CBCT. The better diagnostic accuracy of CBCT for detecting periapical lesions has been well documented [15,16], especially in combination with thermal pulp vitality testing 6 months after surgery.

Our study involved only a limited number of cases; however, we used strict inclusion criteria and examined only LSFE cases with an extension of the surgical bone window laterally above the adjacent root apexes. The extension of the surgical window laterally allows the surgeon to gain better access for raising the Schneiderian membrane, thus limiting the incidence of membrane perforation as
a complication. This approach is highly recommended, especially if adjacent teeth are present. It is extremely important to maintain a safety zone of at least 3 mm of bone apically relative to the root apex during window preparation, especially in type 2–4 cases (16 out of 20 teeth in our study).

Our results contradicted those of a series of three cases reported by Romanos [8]. The teeth presented with “devitalization” 3 to 30 months following a sinus floor augmentation procedure. However, only a single patient with a 30 month follow up and previous implant failure that led to repeated surgical interventions exhibited a periapical lesion. In the other two cases, the teeth did not respond to pulp vitality testing and were reported to have “no signs of blood circulation” by the endodontist [6].

When a cold test is applied to healthy pulp, it usually results in a sharp localized sensation for the duration of the test and for a few seconds after the removal of the stimulus [15]. It has been demonstrated that cold pulp vitality tests are reliable and useful [16,17]. Although it is not possible to determine the histopathological status of the pulp on the basis of the pulp sensitivity tests alone, there is a significant relationship between the lack of response to these tests and pulp necrosis [15,19].

In posterior maxillary areas with a residual bone height of 5–8 mm and a relatively flat sinus floor, the transalveolar technique for sinus floor augmentation may be considered more conservative and less invasive than the conventional lateral approach [20]. The average bone height in the edentulous area in our study was 4.4 mm. The loss of proximal tooth vitality during lateral window sinus floor elevation should not be a concern or criteria to prefer a transalveolar procedure. However, one should take into account that this is a retrospective study based on a limited number of cases, therefore more comprehensive prospective comparative studies are needed to confirm these findings.

6. Conclusions

LSFE, following a strict surgical protocol and careful tissue management, is a predictable and safe procedure regarding the risk of vitality loss and periapical pathology in adjacent vital teeth.

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