A Study in Fresh Human Cadaver Heads Examining the Incidence of Maxillary Sinus Membrane Perforation During Crestal Sinus Elevation Comparing Osteotomes to Osseodensification Drills.

Thaer Alqadoumi

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A Study in Fresh Human Cadaver Heads Examining the Incidence of Maxillary Sinus Membrane Perforation During Crestal Sinus Elevation Comparing Osteotomes to Osseodensification Drills.

by

Thaer Alqadoumi

A thesis submitted in partial satisfaction of the requirements for the degree Master of science in periodontics.

April 2022
Each person whose signature appears below certifies that this dissertation in his/her opinion is adequate, in scope and quality, as a dissertation for Master’s in Science degree.

____________________________________
Chairperson
Yoon Kim, Professor of Periodontics

__________________________________________
Abdulkareem Alhumaidan, Assistant Professor of Periodontics

__________________________________________
Jaime Lozada, Professor of Restorative Dentistry
ACKNOWLEDGEMENTS

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# CONTENT

List of figures ................................................................. vi

List of Abbreviations ....................................................... vii

List of tables .................................................................... viii

Abstract ............................................................................ ix

Chapter

1. Introduction and Review of the Literature ..................... 1

2. Materials and methods ................................................ 4

   Pre-operative Examination ........................................... 5

   Control and Experimental groups ................................. 6, 7

   Membrane perforation assessment ............................... 8

   Statistical Analysis ..................................................... 8

3. Results ............................................................................... 9

4. Discussion .......................................................................... 12

5. Conclusion .......................................................................... 16

References ............................................................................. 17
### FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Axial cut of the maxillary sinus</td>
<td>5</td>
</tr>
<tr>
<td>2. Control group: BAOSFE</td>
<td>6</td>
</tr>
<tr>
<td>3. Experimental group: Osseodensification</td>
<td>7</td>
</tr>
</tbody>
</table>
### ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAOSFE</td>
<td>Bone added crestal sinus elevation using osteotomes</td>
</tr>
<tr>
<td>CBCT</td>
<td>Cone beam computed tomography</td>
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<td>mm</td>
<td>Millimeter</td>
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</tbody>
</table>
TABELS

Table:

1: Membrane perforations results on the osteotome side.

2: Membrane perforations results on the osseodensification side.
ABSTRACT
A Study in Fresh Human Cadaver Heads Examining the Incidence of Maxillary Sinus Membrane Perforation During Crestal Sinus Elevation Comparing Osteotomes to Osseodensification Drills.
by
Thaer Alqadoumi
Advanced Periodontics & implant surgery
Loma Linda University, April 2022
Dr. Yoon Kim, Chairperson

Introduction: Crestal sinus membrane elevation technique is a surgical procedure that helps gain vertical bone volume when there is a pneumatization of the maxillary sinus. Due to some visual limitations inherent to the procedure, the potential for maxillary sinus membrane perforations and subsequent complications exists. A crestal sinus lift using osseodensification drills has been used lately but there are not many studies to support the protocol. The primary aim of the study is to evaluate the incidence of sinus membrane perforation during Osseodensification compared to the incidence of bone added crestal sinus elevation using osteotomes (BAOSFE). The secondary aim is to observe when the perforation occurs, during instrumentation, bone placement or implant placement.

Methods: A total of 20 sinuses of 10 fresh human cadaver heads were used in a split mouth design. One side received BAOSFE (control group), and the other side received Osseodensification lift (test group). Presurgical cone beam computed tomography (CBCT) scans were taken to evaluate the available subantral bone height and to provide a reference point to standardize the amount of elevation. All sinuses were planned for 5 mm sinus lift with simultaneous implant placement. The perforation of the membrane was recorded using a direct camera video recording on skull-less human cadaver heads.
The integrity or the disruption of the maxillary sinus membrane assessed and recorded as the membrane perforation for statistical comparisons. McNemar’s test was used for statistical analysis.

**Results:** The rate of sinus membrane perforation in the BAOSFE was 40% and the rate for osseodensification group was 50%. There was no statistical difference between both groups (p=0.564). When evaluating the timing of the perforation, most of the perforations happened at the time of implant placement, 20% in the control group and 40% in the test groups (p=0.480). Meanwhile, 10% of the sinuses perforated at the time of drilling in the test site compared to 20% in the control group with no significant difference (p=0.317). No perforation was noted at the time of bone graft placement.

**Conclusion:** No significant difference was found between both groups in the incidence of membrane perforation.
CHAPTER ONE

INTRODUCTION AND REVIEW OF THE LITERATURE

Sinus Augmentation is a surgical procedure where bone is added below the sinus floor in the deficient posterior maxilla to gain more bone volume for implant placement, a direct and indirect approaches are proposed depending on the available subantral bone. The conventional technique for maxillary sinus elevation commonly known as a lateral approach of sinus elevation involves surgical access through the lateral wall of the maxilla, followed by elevation of the sinus membrane and insertion of a bone graft material. While this technique is considered invasive, it has comparatively low incidence of surgical and post-surgical complications due to the ability to directly visualize the sinus membrane.

The most common surgical complication is the perforation of the sinus membrane and it occurs in 10% to 35% of sinus floor elevation procedures. Membrane perforations are linked to post-operative complications like acute or chronic sinus infection, swelling, bleeding, and loss of the graft material. Khoury and Proussaefs et al reported that there is a correlation between implant failure and sinus membrane perforation.

In 1994 Summers introduced a less invasive procedure for sinus membrane elevation with simultaneous implant placement. This procedure is indicated when the residual amount of alveolar bone is 6 mm below the sinus floor. The sinus membrane is elevated with osteotomes from a crestal approach with the added bone (BAOSFE) High Success rate was reported when the technique was utilized in the presence of 6 mm or more alveolar bone for lifting up to 4mm in order to place a 10 mm long implant.
Various clinical studies using the osteotome technique have shown favorable results with regards to implant survival.\textsuperscript{16, 17} Although there is a systematic review with meta-analysis of eight reports presented implant survival rates of 95.7–96.0\%, only few reports however describe the incidence of membrane perforations during BAOSFE.\textsuperscript{17} Tan et al\textsuperscript{18} reported transcrestal membrane perforation varied widely between 0\% and 21.4\%. Due to the visual limitations and the lack of clear confirmation of possible sinus membrane perforations, the potential undetected membrane perforations may be greater than the lateral window technique.

Crestal sinus lifting based on the osseodensification concepts was introduced.\textsuperscript{19} The osseodensification technique, a biomechanical osteotomy preparation preserves bone through a non-excavating drilling process utilizing specially designed burs to progressively expand the osteotomy while compacting bone into its walls and apex. The literature is very scarce on incidence of sinus perforation during osseodensification crestal sinus lift technique.
AIM

The primary aim of this study was to evaluate the incidence of sinus membrane perforation during crestal sinus lift of 5 mm height comparing BAOSFE procedure to osseodensification technique and the secondary aim was to evaluate the timing of the perforation occurs, during elevation, bone graft placement or implant placement. The null hypothesis was that there was no difference in the perforation incidence between the two techniques. The alternate hypothesis was there was a significant difference in perforation incidence between the two techniques.
Ten human fresh frozen cadaver heads (frozen within 24 hours from death) were used for the evaluation of the maxillary sinus during crestal sinus floor elevation. The cadavers were thawed before the experiment.

Inclusion criteria: (1) partial or complete edentulism of the posterior maxilla limited to the premolar-molar areas; (2) crestal residual bone height to be between 5-8 mm beneath the maxillary sinus floor as measured on the pre-operative cone beam computed tomography (CBCT) scans.

Exclusion Criteria: (1) Dentate posterior maxilla. (2) crestal residual bone height is less than 5 mm beneath the maxillary sinus. (3) any sinus pathology noted in pre-operative CBCT scans.

Control and Experimental Groups

A total of 20 sinuses were operated in a split mouth design, therefore there were 10 sinuses in each group. While the right side received BAOSFE technique, the control group, the left side received osseodensification technique, the experimental group.

All surgical procedures were performed by one experienced surgeon. The surgeon was not informed about the incidence of the perforation during all the procedures.
Pre-Operative Examination

All the cadaver heads were scanned using a CBCT unit (Newtom Evo, kVP 110) prior to the surgical experimentation and evaluated for any pathology and the anatomical integrity of the sinus cavity. Also, it was be used to measure the dimensions and anatomy of the sinus floor prior to the experiment.

For a direct visual assessment of the incidence of membrane perforations, a metal automatic saw was used to remove skull of the cadaver heads and all the contents until exposing the maxillary sinuses. (Figure 1)

![Figure 1 Axial cut of the maxillary sinus](image-url)
Video Camera Recording:

A high-definition (4K quality) video camera was set with the direct view of the maxillary sinus to record the sinus membrane during procedures to detect any perforation.

CONTROL Group: BAOSFE:

Edentulous Areas: A prior analysis of the remaining bone below the sinus floor was made for access location to the maxillary sinus floor.

1. The osteotomy was made to 1 mm of bone below the sinus floor. That remaining bone was intruded below the maxillary sinus floor utilizing a series of osteotomes (Straumann osteotomes, Basel) for the elevation of the sinus floor.

2. Bone graft, calcium phosphosilicate putty (Nova bone, Osteogenics Biomedical, TX) was added to lift the sinus membrane for 5 mm and the height of the elevation achieved was verified with the depth markings on the series of osteotomes.

3. An implant (Neobiotech, Pasadena, CA) 4 mm in diameter and 10 mm in length was placed following the manufacturer’s instructions (Figure 2).

Figure 2 Control group: BAOSFE
EXPERIMENTAL group: Osseodensification

Edentulous Areas: A prior analysis of the remaining bone below the sinus floor was made for access location to the maxillary sinus floor.

1. The first drill, the 2.0 drill was used up to 1 mm below the sinus floor in a counterclockwise mode at 1100 RPM with copious irrigation.

2. Then the second drill, 3.0 drill was used to 5 mm deep to break the sinus floor and extend up to 3 mm beyond the sinus floor using a pumping motion at 1100 RPM with adequate irrigation.

3. The bone grafting step was done with the calcium phosphosilicate bone at the speed of 200 RPM in the counterclockwise mode. Once the graft was placed into the osteotomy site, the graft was pushed further into the sinus with the pumping motion using the 3.0 drill up to 3 mm beyond the sinus floor.

4. The implant placement was the same as the control group (figures 3).

Figure 3 Experimental group: Osseodensification
Membrane perforation assessment

One examiner recorded all surgical procedures with the video camera and another examiner reviewed the recordings to assess the presence of the perforation and the timing of the perforation blindly to the group allocation.

Statistical Analysis

The statistical analysis was done using the McNemar’s test to compare the incidence of the sinus perforation at the alpha level of 0.05.
CHAPTER THREE

RESULTS

A total of 10 cadaver heads with 20 sinuses, 10 sinuses for the BAOSFE and 10 for the osseodensification technique were used for the study. It was found that the rate of sinus membrane perforation in the BAOSFE group (control group) was 40% and the rate for osseodensification group (test group) was 50%. There was no statistical difference between both groups (p=0.564). When evaluating the timing of the perforation, most of the perforations happened at the time of implant placement, 20% in the control group and 40% in the test groups (p=0.480). Meanwhile, 10% of the sinuses perforated at the time of drilling in the test site compared to 20% in the control group with no significant difference (p= 0.317). No perforation was noted at the time of bone graft placement.
Table 1

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CHAPTER FOUR
DISCUSSION

This study evaluated the incidence of maxillary sinus membrane perforation when lifted to 5mm with BAOSFE and osseodensification techniques on fresh human cadaver heads. Summers in 1994\textsuperscript{10} suggested 4 mm elevation to be the safety margin using a series of osteotomes. In a systematic review of various crestal approaches, it was reported that sinus membrane perforation rate ranged from 0 to 21\%.\textsuperscript{18} It was also reported that the implant survival decreased after the first year of implant loading with studies having less than 5 mm of initial alveolar bone height.

Regardless of surgical techniques, this study demonstrated the risk of sinus membrane perforation is high, over 40\%, if the sinus membrane is lifted 5 mm. We noticed a higher incidence of perforation at the time of implant placement, which may indicate lower predictability of the crestal sinus approach for 5 mm or more lift.

The result of this study is similar to literature when the sinus lift was more than 4mm. In a research project for mater of science in Dentistry at Lom Linda University School of Dentistry, Alhumaidan\textsuperscript{20} found that the incidence of maxillary sinus membrane perforation of BAOSFE and internal sinus manipulation assessed with an antroscopy when the sinuses were lifted to 6mm was 47.1 and 53.4\% respectively and recommended that clinicians should keep in mind that the sinus elevation with crestal approach beyond the 4 mm increases the risk of perforation substantially. Garbacea et al\textsuperscript{21} in a pilot study on fresh human cadavers, they compared three different crestal sinus floor elevation techniques and found that when the crestal elevation
exceeded the recommended safety margin of 4mm and lifted to 5 mm instead, the rate of perforation increased to 40%. They reported no difference in perforation rate between all three techniques.

Detecting the sinus membrane perforation during crestal sinus lift is challenging as the visualization is limited. Nkenke et al\textsuperscript{7} and Berengo et al\textsuperscript{22} reported the use of a maxillary sinus endoscope during BOSFE. When the procedure was carried out without visualization, there was little opportunity to detect perforations. Nkenke et al.\textsuperscript{7} concluded that the perforation confirmed with endoscopy was often negative in Valsalva maneuver, a clinical test to verify the sinus membrane perforation. It indicates the limited effectiveness of the Valsalva maneuver. Berengo et al.\textsuperscript{22} suggested that the perforation of the sinus membrane may be more likely to occur with membrane distension assumes a localized vertical augmentation pattern. When CBCT was compared to the antroscopy, the detection of the sinus perforation on post-op CBCT scans presented overall over 60% accuracy and 64.3% predictive value only.\textsuperscript{20} It was reported that periapical radiographs were less diagnostic of perforation of the sinus membrane compared to CBCT.\textsuperscript{21} In this study, a new method of detecting the sinus perforation was used, a direct visual assessment while the sinus lift with the implant placement surgery was performed. Having the direct visual access provides an opportunity for the examiner to note the sinus membrane perforation and the timing of the membrane perforation accurately.

Osseodensification may provide less discomfort to patients during the crestal sinus lift when compared to the osteotome technique. There is report on vertigo with the use of osteotomes\textsuperscript{23}. In a multicenter study, Huwais et al\textsuperscript{24} in three centers, reported the
outcome of vertical increase on 222 patients who had osseodensification and crestal sinus lift technique. While the residual bone height at baseline was 5.4 mm, following the crestal sinus elevation, a significant vertical increase of 7 mm was observed. No sinus membrane perforations and no late implant failures were observed during the 5 years follow up period, yielding a cumulative implant survival rate of 97%. It seems like the studies reported good clinical outcomes of crestal approaches with limited/lower perforation rate. However, the true membrane perforation may not have been detected clinically as indicated in the literature. It is reasonable to assume the size of the perforation of sinus membrane confirmed with endoscopy is small and or limited as it was not clinically detected with Valsalva maneuver.

The presence of the small sinus membrane perforation is of interest. Although literature indicated that the sinus perforation negatively affects the implant survival, the effect of the small perforation not detected clinically during the crestal approach on implant survival is unknown. In a systemic review\textsuperscript{18} of the crestal sinus approaches, it was reported that the implant survival decreased after the first year of implant loading with studies having less than 5 mm of initial alveolar bone height. The clinically undetected sinus perforation during the crestal approach might have been the factor for the decreased survival rate.

There are limitations in this study. First, in our study the cadaver heads were previously frozen and thawed immediately prior to the study. Chan and Titze\textsuperscript{25} showed that postmortem tissue changes observed on fresh and frozen specimens have little impact on the mechanical properties of tissue. In a similar study using 20 fresh cadavers, however, Pommer\textsuperscript{26} found that the changes after freezing may increase the tissue fragility
resulting in, perforation of the Schneiderian membrane when stretched. Therefore, it is assumed that the incidence of sinus perforation in previously frozen cadaver heads might be higher than in living humans.

Secondly, standardizing the height of sinus lift to 5 mm when adding the bone graft on the osseodensification was challenging while the height of the elevation achieved was verified with the depth markings on the series of osteotomes in BAOFE group. The osseodensification drill, 3mm in diameter was used in a pumping mode to push the bone into the sinus 3mm beyond the sinus floor. After a couple of attempts of placing the bone graft, it was estimated that the lifted height was 5mm. Further studies with a larger sample size are recommended to evaluate if there is a difference between pre-molar and molar sites in incidence of perforations, or if adding more bone graft may decrease the chance of perforation at the time of implant placement.

The results of this study confirmed that the lifting the sinus through the crest of 5 mm and more is not predictable and increases the chances of membrane perforations specially at the time of implant placement. It is recommended that crestal sinus lift is to be up to 4 mm.
CHAPTER FIVE

CONCLUSION

There was no statistically significant difference in the maxillary sinus membrane perforation rates between both techniques and most of the perforations happened at the time of implant placement.
REFERENCES


20. Alhumaidan A. Master of Science in Dentistry research paper, The Evaluation of Maxillary Sinus Membrane Perforation Utilizing Internal Sinus Manipulation Technique - A Fresh Human Cadaver Study- Loma Linda University. 2015


