THE ROLE OF TITANIUM MESH IN LIMITING DIMENSIONAL CHANGES OF MAXILLARY SINUS GRAFT: RANDOMIZED CLINICAL TRIAL

ABSTRACT

Objectives: The dimensional changes that occurs during the healing of the grafting material in external sinus lift procedure is always present and sometimes may lead to difficulties in placing the dental implants in the second stage. This study aims to evaluate the efficacy of adding a titanium mesh as a new fixed floor of the sinus to minimize these changes.

Materials and Methods: this randomized clinical trial included 8 patients who needed bilateral 2-stages sinus lift. On one side sinus lift was carried out using Deproteinized Bovine Bone Matrix (DBBM) mixed with A-PRF+ (Group A) while on the other side a titanium mesh was fixed as a new sinus floor above the same mixture (Group B). CBCT radiographs were taken preoperatively (T0), directly postoperatively (T1), and 9 months after surgery (T2). Linear measurements were recorded in the same points in all three radiographs, graft volume was measured and compared using 3D Slicer software.

Results: the mean bone height (BH) at T1 was 13.08 and 13.56 mm while at T2 was 11.56 and 13.56 mm in groups A and B respectively. The mean reduction in BH was 1.68 and 0.00 mm in groups A and B respectively. The graft volume (GV) at T1 was 1.49 and 1.63 cc and at T2 was 1.19 and 1.53 cc, the mean volume shrinkage was 0.29 and 0.1 cc in groups A and B respectively. The differences between the groups in both linear and volumetric changes were statistically significant.

Conclusions: within the limitation of this study it may be concluded that adding a titanium mesh as a new floor of the sinus helps limiting the shrinkage of both the linear dimensions and overall graft volume.

Key Words: Cone-beam computed tomography, deproteinized bovine bone matrix, lateral sinus lift, sinus augmentation, titanium mesh.
INTRODUCTION
Placing dental implants in posterior Maxilla might be inapplicable due to sinus pneumatization and thus require sinus lift procedure to augment the bone in this area prior to implant placement.

Sinus lift technique was introduced by Tatum et al. where he proposed creating a lateral window to gain access to the Schneiderian membrane and elevate it. Boyne and James introduced the use of autogenous bone to Tatum original procedure but later several biomaterials were introduced to the technique including Deproteinized Bovine Bone Matrix (DBBM), Alloplasts, Allografts and even Platelet rich fibrin (PRF). A healing time of 6-9 months is required depending on the biomaterial used.

During that time a dimensional change to the graft occur due to continuous pneumatization of the sinus and remodeling of the graft particles and the collapse of the gaps between these particles. The percentage of the shrinkage both linear and volumetric varies depending on the biomaterial used. Zhang et al. found a 16% linear and 22% volume shrinkage of DBBM. Another study reported 10% shrinkage of DBBM after 8-9 months, while this percentage rises to 17.65% when using calcium phosphate with DBBM mixture in 2:1 ratio, and 13% in hydroxyapatite and autogenous bone mixture. Allografts seems to undergo more resorption as only 82% of allografts remained after 6 months and 60% after one year. In a systematic review about dimensional changes after lateral sinus lift Shanbhag et al. reported that graft resorption is inevitable especially with autogenous bone which reach 45% while when other biomaterials or the mixture of autogenous bone with biomaterials are used this percentages varies between 18-22% although this reduction in graft volume didn’t seem to effect implant placement or survival.

Cone-Beam Computed Tomography (CBCT) is a reliable diagnostic tool and is widely used in the treatment planning of dental implants and in the diagnosis of several pathologies in the jaws. CBCT was successfully used to follow the changes in graft dimension in several studies by using many computer softwares.

Choukroun et al. first introduced the concept of Platelet Rich Fibrin (PRF) and was under constant development so the same author introduced Advanced PRF Plus (A-PRF+) which is a more advanced form of PRF based on low centrifugation speed and less time thus trapping a higher number of leukocytes in the fibrin matrix and therefore increasing cytokines release from it.

PRF became widely used in regenerative dentistry because of its ability to promote angiogenesis and growth factors release, PRF was used in improving the healing of extraction sites, with immediate implant placement, in the treatment of Periimplantitis, in mucogingival surgeries, and in the treatment of periodontitis.

PRF was used in sinus lifting in several studies either alone or in a mixture with DBBM. The benefit of this mixture was advocated by the authors who reported better new bone formation and faster healing, however this subject is still controversial as a recent meta-analysis showed no evidence on the necessity of adding PRF to the grafting material.

In a case series, Atef et al. used a titanium mesh as space maintainer in a lateral graftless sinus lift and found promising results so Bahaa-eldin et al. performed a pilot study where they were able to place an implant in the newly formed bone under the titanium mesh but they reported that the density of this bone was far less than that of the bovine xenograft.

We proposed a modification to Atef et al. technique by placing a titanium mesh on top of the graft material as a new floor of the elevated sinus and fixing this mesh with titanium screws to the lateral wall of the sinus to minimize the dimensional change of the graft material.

The aim of this study was to evaluate the dimensional changes in a grafted sinus with xenograft mixed with A-PRF+ compared to adding a titanium mesh on top of the same mixture as a new floor of the elevated sinus.
MATERIAL AND METHODS

Study Design
This research was approved by Damascus University ethical committee for scientific research ID#1926 dated 14/5/2018 and the study protocol adhere to the international agreements (Helsinki Declaration revised 2008)

The study is a split mouth design clinical trial where a standard sinus lift is performed on one side using DBBM mixed with A-PRF+ (Control Group – Group A) and on the other side the same mix was used in addition to a titanium mesh (Test Group – Group B).

Patient’s recruitment
8 patients who visited Damascus University– faculty of dentistry– Department of Periodontology – post-graduate clinic and needed bilateral sinus lift procedure were invited to participate in the study.

Inclusion criteria included 6 months since the last extraction, no smoking, residual bone height less than 5mm while exclusion criteria included pregnancy, diabetes, current treatment with corticosteroids and smoking.

After explaining the procedure, a written consent was signed by each participant. The sides were allocated randomly using a coin toss.

Surgical Procedure
The sinus lift procedure was carried out following the protocol proposed by Tatum et al.\textsuperscript{1}, after flap elevation and the exposure of the lateral sinus wall a bony window was prepared using piezoelectric instrument, then the Schneiderian membrane was elevated by manual instruments. The bony window was left in place and elevated with the membrane.

After the completion of the elevation A-PRF+ was prepared following the original protocol by Choukroun\textsuperscript{17} and then mixed with the DBBM biomaterial (Bonefill® Mix, Bionnovation, Bauru, Sao Paolo, Brazil) and the mix is used to fill the sinus and finally the osteotomy was covered by a collagen membrane (Biocollagen®, Bioteck S.p.A., Arcugnano, Vicenza, Italy).

In the test group the depth of the sinus was measured using a periodontal probe, then a piece of titanium mesh (Titanium Wire Mesh, Orthomax, Vadodara, Gujarat, India) was cropped to the desired dimensions and fixed on the lateral wall of the sinus using 4mm titanium screw (Mini Screw Ø1.5mm, Orthomax, Vadodara, Gujarat, India) (Figure 1B).

Another modification was introduced to the original Atef et al.\textsuperscript{32} technique where they cropped the mesh in an (L) shape while we cropped and then bend the mesh in a (˅¯) shape (Figure 1A) which also provided additional 2-3 mm lift above the upper margin of the bony window.

We also used some A-PRF+ membranes as pads under the mesh to avoid any tear to the membrane while placing the mesh.

In case a membrane perforation occurred A-PRF+ membranes were used along with a piece of collagen membrane to cover the perforation.

Patients were informed that this mesh will not be removed in the future as it will be incorporated in the newly formed bone and in close contact with the Schneiderian membrane which will make its removal impossible without damaging the membrane.
**Radiographic assessment**

A cone beam CT radiograph was taken before (T0) and immediately after the operation (T2) and after 9 months (T3) (Figure 2).

![Image](Image)  
Figure 2: A) Panoramic reformatting of a patient directly after surgery, B) Panoramic reformatting of the same patient after 9 months, C) Oblique slice in the middle of the titanium mesh directly after surgery, D) Oblique slice in the same point after 9 months

Linear radiographic evaluation was carried out by taking measurements in the same points and directions in all three CBCT radiographs. These points were determined depending on fixed anatomical landmark to match all three radiographs like neighboring teeth and nasal septum based on the technique described by Anduze-Acher et al.\textsuperscript{34} The distance between the nasal septum and the slice of interest was measured and applied in all three radiographs while the direction of measurement was determined by repeating an angle between the direction of measurement and a horizontal line tangent to the lowest point of the alveolar crest.

3D volumetric measurements were recorded using 3D Slicer software were the segment editor tool was used to mark the graft boundaries in all slices then the software calculates the volume using the segment statistics tool.\textsuperscript{35}

**Statistical Analysis**

Data were analyzed using statistical software (IBM SPSS Statistics version 22). Unpaired Student t-Test was used to analyze the difference in bone dimensions during healing process between the two groups. Results were considered significant at P < .05 with 95% confidence intervals.

**RESULTS**

This study included 8 patients (5 women, 3 men) with mean age (52.13 years) who needed bilateral sinus lifting without implant placement.

The differences in mean bone height (BH) (Table 1) before the surgery and the graft height directly after surgery was not statistically significant between the two groups. While it was higher in the test group after 9 months with statistically significant results.

<table>
<thead>
<tr>
<th>Table 1: Mean Bone Height Value in the study groups compared before (T0), directly after surgery (T1) and after 9 months (T2)</th>
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<tr>
<td><strong>T0</strong></td>
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<td><strong>BH</strong></td>
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<td>Group A</td>
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BH: Bone Height (mm)  
*: P<0.05 is considered statistically significant

The mean graft height (GH) (Table 2) directly after surgery was not statistically significant between the groups but after 9 months the mean graft height was 8.99±1.93 in group A and 10.88±0.58 in Group B and this difference between the groups was statistically significant.

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<th>Table 2: Mean Graft Height and 2D Shrinkage compared between the study groups directly after surgery (T1) and after 9 months (T2).</th>
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<td><strong>T1</strong></td>
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<td><strong>GH</strong></td>
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<td>Group B</td>
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GH: Graft Height (mm)  
*: P<0.05 is considered statistically significant
The mean linear bone height reduction in the control group was 1.68 mm while in the test group when the measurements were made directly under the titanium mesh there was no reduction in bone height and these differences were statistically significant (Table 2).

The mean graft volume (GV) directly after surgery was not statically different between the two groups. At 9 months after surgery graft volume was significantly higher in the test group and the mean graft volume shrinkage was 0.29 and 0.10 cc in group A and group B respectively and there was a statistically significant difference between the groups. (Table 3)

In the study group the installment of the titanium mesh as a new floor of the elevated sinus provided protection for the graft material from the continuous pressure thus allowed the biomaterial to be remodeled and replaced by new host bone without loss of height. This space maintenance effect of the mesh is one of the fundamental principles of guided bone regeneration, as this protected space is essential for bone graft healing by hard tissue cells which will regenerate the bone during the healing and maturation time.

The comparison between the two groups showed statistically significant difference in term of linear measurement reduction over time.

Volumetric analysis of the graft showed some shrinkage in both groups and this shrinkage was statistically significant between the two groups. In the control group the mean volume shrinkage was 0.29 cc (20%) which correlate to the previously established graft shrinkage in the literature. In the test group the applied mesh covered most of the graft but on the sides the graft was still subject to some pressure thus explaining the minor reduction in volume with an average of 0.1cc (5.93%). As a study by Guo et al. showed an overall reduction of DBBM graft volume by 19.4% and more specifically 0.29% in the bucco-palatal, 5.87% in the mesio-distal, and 14.32% in the vertical direction thus explaining the finding of our study where the titanium mesh offered protection.
to the graft from the shrinkage in the vertical dimension while it was still under some pressure in the mesio-distal direction which resulted in the statically significant less mean graft volume reduction in the test group compared to the control group.

This study had some limitations, such as the width of the titanium mesh was limited to 10 mm or 15 mm due to its design so in all the cases the mesh’s width was 10 mm and sometimes even if we had a wider osteotomy/Sinus we were not able to place wider mesh and as mentioned before the effect of the mesh application was at its best directly under the mesh so for future study we recommend using a more flexible mesh design that allows to perfectly crop the mesh to the width of the osteotomy.

We also believe that the real benefit of the protection offered by the mesh application is when using other than the bovine biomaterial e.g.: Allograft/autogenous alone bone or mixed with DBBM which are more prone to resorb during the healing time thus we recommend to study the application of the titanium mesh above these biomaterials.

CONCLUSIONS
Within the limitation of this study it may be concluded that adding a titanium mesh as a new floor of the elevated sinus helped in protecting the underling graft from forces applied from continuous pneumatization thus eliminating linear shrinkage directly under the mesh and minimizing the overall shrinkage of the graft.

This technique may be applied to improve the final outcome of sinus lift procedure and make it more predictable and guarantee a sufficient graft volume after healing time thus facilitate implant placement.

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REFERENCES


