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Graft - Less Sinus Lifting Using Titanium Mesh As A Space Maintainer: A Histomorphometric and Radiographical Study

Research Article

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Abstract

Aim: This study aims to evaluate the effectiveness of graft-less sinus lift procedure by using a titanium mesh as a space maintainer after membrane elevation compared to the standard sinus lift using xenograft mixed with advanced platelet rich fibrin plus.

Material and Methods: This study included 16 patients who needed a two-stage external sinus lift. Patients were randomly allocated to two groups, the first received conventional sinus lift using xenograft mixed with advanced platelet rich fibrin plus (A-PRF+) as grafting material (control group), while the second group received graft-less sinus lift by using a fixed titanium mesh as a new sinus floor which serve as a space maintainer (Test group). Patients were evaluated radiographically using cone beam CT immediately after surgery and after 9 months. Core biopsies were collected at implant placement for histomorphometric evaluation.

Results: The mean bone gain was 8.99mm and 4.14mm in the control and test groups respectively while the new bone volume was 1.19cc and 0.49cc in the control and test groups respectively. The differences between groups were statistically significant. Histomorphometric data revealed statistically significant higher bone to soft tissue ratio (70.3/%) in the control group compared to the test group (46.7%).

Conclusion: With in the limitation of this study the use of Titanium mesh as a space maintainer in graft-less sinus lift resulted in sufficient bone to place implants after 9 months healing, however the bone height and volume were statically less than the control group.

Keywords: Lateral Sinus Lift; Titanium Mesh; Bovine Bone Graft; Advanced Platelet Rich Fibrin.

Introduction

Sinus lifting by lateral window approach was first introduced by Tatum [1], then Boyne and James [2] proposed the use of autogenous graft with the same procedure. Several biomaterials were later used in lateral window sinus lift including allografts, xenografts, alloplasts (HA, β-TCP), platelets rich fibrin, and several composite grafts [3-5].

The idea of graft-less sinus lift was proposed for the first time by Lundgrun et al. [6] who inserted dental implants at the same time of the lift without using any grafting material. This technique requires the presence of enough residual bone height to provide primary stability for the dental implants which will act as tenting screw holding the elevated Schneiderian membrane creating a space under it that will be filled with blood clot. The formation of a stable blood clot is foundation for an eventful healing, the environment created under the elevated membrane offers perfect conditions for healing as it is a closed space surrounded by residual bone and it is preserved by the protruding dental implants

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allowing the formation of a blood clot that will fill the space and the healing will proceed without disturbance [7].

This is a promising technique although there are few studies about it and most of them are short-termed [8].

Thor rt al. reported that bone will continue to develop around the implants as time passes which give this technique the benefit of avoiding a second surgical site to obtain autologous bone or the coasts of using biomaterials [9].

It is recommended to under prepare the implant bed to increase the primary stability and to use an implant cervical design which helps with its stability [7].

In a case series, Atef et al. used a titanium mesh for the first time as a space maintaining device in lateral window sinus lift and found promising results [10] then Bahaa-eldin et al. followed it by a pilot study comparing the results clinically and radiographically between graft-less sinus lifting and the use of bovine xenograft and they found that the osteogenesis in the graft-less group was enough to place dental implants, however the bone density was better in the graft group [11].

The use of bovine xenograft in the sinus has been widely studied in the literature [12]. It has the benefit of being osteoconductive as 25% of new bone is formed after 6-8 months, it has a slow resorption rate, and it does not interfere with osteointegration [13].

Platelet rich fibrin (PRF) concept was proposed by Choukrounet al. and it was under constant development to further increase its benefits. Low centrifugation speed and less time led to trapping a higher number of leukocytes in the fibrin matrix and and therefore increasing the amount of released cytokines. This new protocol was called advanced PRF plus (A-PRF+) [14]. PRF was used in sinus lifting in several studies either alone or in a mixture with xenograft. The benefit of this mixture included better new bone formation and faster healing, [15, 16] however this subject is still controversial as a recent meta-analysis showed no evidence on the necessity of adding PRF to the grafting material [17].

Cone beam computer tomography is a novel radiographic diagnostic tool that may be used for the treatment planning and following up patients undergoing dental implant therapy [18]. It was used to make linear and volumetric analysis in sinus lift surgery [19-31].

Histomorphometric analysis after sinus graft healing showed different percentage of newly formed bone, residual grafting material, and connective tissue/bone marrow with different grafting materials [32].

The most important criteria that affect bone to implant contact thus higher implant survival rate is the amount of new bone formation caused by the grafting material [33].

Histomorphometric analysis is considered the gold standard method to estimate the amount of new bone formation and residual graft material and connective tissue in the grafted sites [34].

The human histomorphometry studies of graft-less sinus augmentation are extremely rare. The aim of the present study is to evaluate the outcome of graft-less sinus augmentation using titanium mesh as a space maintainer both radiographically and histomorphologically after 9 months of healing.

Material and Methods

Study Design

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

This study is a randomized clinical trial with two parallel groups where a standard sinus lift is performed using xenograft mixed with A-PRF+ (Control Group) compared to graft-less sinus lift using a titanium mesh as a space maintainer (Test group).

Patients Recruitment

16 patients who visited Damascus University - faculty of Dentistry - Department of Periodontology - post-graduate clinic and needed sinus lift procedure were invited to participate in the study.

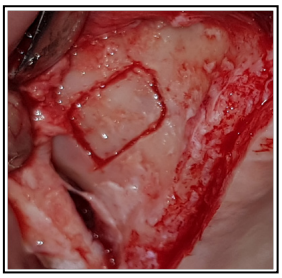
Inclusion criteria included 6 months since the last extraction, no smoking, residual bone height less than 5mm, while exclusion criteria included pregnancy, diabetes, current treatment with corticosteroids and smoking.

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

Surgical Procedure

The sinus lift procedure was carried out following the protocol proposed by Tatum, [1] after flap elevation and the exposure of the lateral sinus wall a bony window was prepared using piezo-

Figure 1. windows preparation with piezoelectric instruments.



electric instrument (Figure1), then the Schneiderian membrane was elevated by manual instruments. The bony window was left in place and elevated with the membrane.

A-PRF+ was prepared following Choukroun's [14] protocol, then cropped and mixed with the DBBM biomaterial (Bonefill® Mix - Bionnovation - Bauru - Sao Paolo - Brazil) and the mix was placed in the sinus cavity without over packing and finally the window was covered by a collagen membrane (Biocollagen® - Bioteck S.p.A.- Arcugnano - Vicenza – Italy).

In the test group sinus elevation was completed as in the control group, the depth of the sinus was measured using a periodontal probe, then a piece of titanium mesh (Titanium Wire Mesh - Or thomax - 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). A modification was made to the original Atef et al. [10] technique where they used the mesh in an (L) shape while we cropped and then bend the mesh in a ($\bar{V}$) shape (Figure 2) which increased the stability of the mesh as it engages the upper border of the window and also provided additional 2-3 mm lift above the upper margin of the bony window. We also used some A-PRF+ membranes to protect the Schneiderian membrane while fixing the mesh to avoid any possible tear to the membrane (Figure3).

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

Radiographic Assessment

A standardized cone beam CT radiograph was taken before (T0) and immediately after the operation (T2) and after 9 months (T3) (Figure 4).

Figure 2. The bending of the titanium mesh in the desired shape.

Figure 3. The fixation of the mesh on the top border of the bony window after protecting the Schneiderian membrane with A-PRF+ membranes.

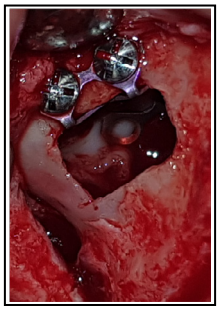
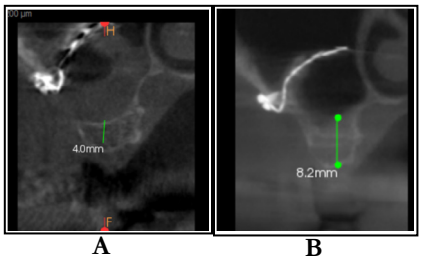
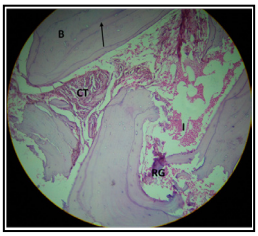


Figure 4. CBCT view in the same point (A) directly after surgery, (B) After nine months of healing.



A **B**

Figure 5. histological view X200 Group A: (B) bone lamellae with osteocytes lacunae, (Arrow) reverse line, (RG) residual graft, (CT) connective tissue, (I) inflammatory infiltrate.



Linear measurements were taken in the same points and directions in all three CBCT radiographs. Fixed anatomical landmark (i.e. neighboring teeth and nasal septum) were used to match all three radiographs based on the technique described by Anduze-Acher et al. [35], by measuring the distance between the nasal septum and the slice of interest and the same measurement was used in the follow up radiographs. The direction of measurement was standardized by repeating an angle anglebetween the direction of measurement and a horizontal line touching to the lowest border of the alveolar crest.

3D volumetric measurements were calculated using 3D Slicer software [36] were the segment editor tool was used to mark the healed bone boundaries in all slices then the software calculates the volume using the segment statistics tool.

Samples Collection

Biopsies were harvested after 9 months of healing at the time of implant placement using a trephine bur with an internal diameter of 3mm in the site of the implant.

The sample was immediately stored in 10% buffered formalin to preserve the bone structures after marking the most coronal part of the specimen by tolidine blue stain to distinguish the native bone from the newly formed bone while processing the sample, subsequently the specimens were decalcified in Nitric Acid 10% for 4 days approximately, then dehydrated in graded ethanol, cleared in xylene, and lastly embedded in paraffin wax. The paraffin wax containing the sample was cut into 4-5µm thick serial sections using a microtome and stained with hematoxylin and eosin (H & E) [37].

All samples were examined under a microscope connected to a digital camera. Pictures were taken for the most representative field of view at various magnifications and pictures were stored at the computer to be analyzed using a computer software program (NIH ImageJ, National Institutes of Health, Bethesda, MD) as used previously in similar studies [10, 38]. The threshold tool was utilized to distinguish connective tissue from hard tissue then the software calculated the surface area of each component.

In addition, the width of bone trabeculae was measured using the same program after inputting an objective micrometere to standardize the measurements.

Statistical Analysis

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

Results

This study included 16 patients (7 males, 9 females) with a mean age of 52 years. Patients were divided in to two parallel groups. Controlled group (Group A) who received a mixture of bovine xenograft and A-PRF+ while the test group (Group B) received a titanium mesh as a space maintainer with no graft at all.

The mean bone height before surgery was 2.41 mm and 2.08 mm, after 9 months of healing the bone height was 11.39mm and 6.25 mm in groups A and B respectively (table 1). The difference between the groups was not statistically significant before surgery but after 9 months it was higher in the control group by 5.14 mm and the difference was statistically significant ($p < 0.0005$).

The mean graft volume in the group A was 1.49 cc directly after surgery and 1.19 cc after 9 months while in group B the newly formed bone volume was 0.49 cc after 9 months (table 2).

Graft volume in group A was larger than new bone volume in group B by 0.71 cc. The difference between the groups was statistically significant ($p < 0.0005$).

Histologic examination of group A (Figure 5) showed trabecular bone with irregular lamellae, osteoblasts are observed on the surface of the lamellae, osteocyte lacunae were clearly identified, and reverse lines indicating previous remodeling process were evident, the marrow space was filled with fibrous tissue along with sparse inflammatory infiltrate consisted of B lymphocytes. Some bone graft remaining particles were seen in the samples.

Group B (Figure 6) showed similar findings as in group A but off course without the bone graft particles and marrow space showed abundant inflammatory infiltrate.

Histomorphometric data (table 3) showed a soft tissue mean area of 29.7% and 53.3% in groups A and B respectively, while hard tissue area was 70.3% and 46.7% in groups A and B respectively.

Mean bone trabecular width measured 299 and 174 µm in groups A and B respectively.

Discussion

In the present study lateral sinus lift was performed in two methods, the first a traditional technique with a mixture of A-PRF+ and bovine xenograft as grafting material. The bovine xenograft

Figure 6. Histological view X200 Group B: (B) bone lamellae with osteocyte lacunae, (CT) connective tissue, (F) fat tissue.

Table 1. Mean bone height before (T0) and after surgery (T1), and after 9 months of healing (T2).

	T0		T1		T2	
	BH	p value	BH	p value	BH	p value
Group A	2.41	0.512	13.08	0.741	11.39	0.000
Group B	2.08		12.75		6.25	
BH= bone height, P<0.05 is considered statistically significant						

Table 2. Mean new bone height and volume after 9 months of healing.

	T0		T2	
	NBH	p value	NBV	p value
Group A	8.99	0.000	1.19	0.000
Group B	4.18		0.49	
NBH= New bone height NBV= New bone volume P<0.05 is considered statistically significant				

Table 3. Histomorphometric Data.

	Soft Tissue	P Value	Hard Tissue	P Value	Trabecular width	P Value
Group A	29.7%	0.000	70.3%	0.000	299 µm	0.026
Group B	53.3%		46.7%		174 µm	
P<0.05 is considered statistically significant						

is one of the most studied biomaterial in the sinus, its excellent biocompatibility and its high resistance to resorption caused by continuous pneumatization when compared to autogenous graft or other biomaterials is well established in the literature [39-43]. On the other hand the second technique was a graft-less approach where a titanium mesh was fixed to the upper border of the window to act as a new stable floor of the sinus and a space maintaining device allowing the formation of a blood clot beneath it that will eventually turn into bone in a mechanism similar to the healing of an extraction socket where osteogenic cells migrate from the bony walls in to the clot and differentiate to produce new bone tissue [44, 45].

The titanium mesh used in this study is flexible and it can be adapted easily by cropping and bending to fit perfectly in its place while maintaining enough strength to withstand the pneumatization pressure allowing the stability of the blood clot and in the same time the holes in the mesh permit direct contact with the membrane which has osteogenic potential even though it's considered limited comparing to the bony walls [46].

The window was prepared with a piezoelectric device in a square shape to ease the adaptation of the mesh which is bended to engage the upper border of the window providing and extra mechanical stability before screw fixation and in the same time it raises the membrane for an extra 2 mm above the upper border of the osteotomy when compared to the original technique Bahaa et al. [11] used where they cropped the mesh in an (L) shape.

The results of the control group were as expected when using bovine xenograft where a sufficient bone height was gained to place dental implants although a minor reduction in graft height (1.68 mm) was observed during the healing time (table 1) which came in accordance with other studies in the literature which reported linear reduction by 16% and 22% volume reduction [23]. this reduction is due to the continuous pneumatization pressure on the graft material that may induce resorption of the biomaterial [47].

In the test group new bone formation (4.18 mm) was observed (table 2) after 9 months of healing which may be considered a relatively small amount but the presence of the titanium mesh allowed the insertion of longer implant as a graft-less study reported that bone continue to grow around the implant over time [9].

Overall new bone volume was statistically significant less in the test group as the bone formation in this group was limited to the space directly under the titanium mesh while no bone formation was observed on its sides. Thus, we recommend using this technique in narrow sinuses. The benefits provided by the present method arelower coast for the patients and it is easy to perform, however the limited overall bone quantity gained requires high clinical experience to be able to place the implants with enough primary stability in limited bone height.

Bone histomorphometry is the quantitative assessment of bone micro architecture, remodeling and metabolism [48]. Histomorphometric data analysis showed higher percentage of connective tissue in the test group. This may be explained by the role the graft

plays as a scaffold for bone formation which makes it easier for the cells to differentiate and depose new bone. While in graft-less sinus bone formation depends on the blood clot filling the space under the elevated sinus membrane then osteoprogenitor cells have to migrate from the bony walls and differentiate in to osteoblast and start deposing bone. Hence, the cells have to travel longer distance unassisted and require more time to generate enough bone tissue. Histomorphometric studies about graft-less sinus lift are extremely rare in one study by Moon et al. [49] samples were taken after graft-less sinus lift with simultaneous implant placement after 6 month of healing and they reported 38.7% vital bone formation around the implants.

Similar results were obtained in the healing of extraction socket where the group with no graft showed 52% connective tissue versus 44% in the xenograft group [50, 51].

The samples from both groups showed normal trabecular bone structures and the trabecular width measurements were with in range of trabecular standard width 150-400 µm, as mentioned in the literature, the structure varies depending on the bone function and location in the body [52-54].

Conclusion

With in the limits of this study, it may be concluded that the use of titanium mesh as a space maintaining device in graft-less sinus floor elevation is a considerable option. However, it is recommended to be used in narrow sinuses or where a limited augmentation is needed like the loss of one tooth.

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