Original Article

Comparison of Lateral Window and Osteotome Techniques in Sinus Augmentation: Histological and Histomorphometric Evaluation

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Abstract

Objective: The aim of this study was to compare the lateral window and osteotome techniques for sinus lifting using histological and histomorphometric methods.

Materials and Methods: In this clinical trial 10 patients (a total number of 14 sinus areas) who needed implant treatment in the atrophic posterior maxilla were enrolled. In all the cases the residual bone height between the sinus floor and the alveolar crest was less than 5 mm. Sinus augmentation was performed. The treatment modality for a given residual bone height was selected randomly and Bio-Oss was applied in all the cases as the graft material. After a healing period of about 10 months, in all the cases, the implants were placed and biopsies of alveolar crestal bone were obtained at the same time; biopsy specimens were evaluated using histological and histomorphometric methods. Fisher's exact and Mann-Whitney U tests were used to compare distribution of variables in the two groups. Statistical significance was defined at $P<0.05$.

Results: The new bone was located in direct contact with the biomaterial without any gaps. This viable bone consisted of lacunae containing osteocytes. Infiltration of inflammatory cells did not exhibit any significant differences between the two techniques. Foreign body reaction was not observed in any cases. Histomorphometric evaluations demonstrated that The mean values of the new bone in the lateral window and osteotome techniques were 30±6.0 and 25.2±5.2, respectively, with no significant differences between the two groups.. Moreover, the average quantity of residual biomaterial and connective tissue were similar for the two groups.

Conclusion: The nature and the volume of the new bone in lateral window and osteotome techniques were the same.

Key Words: Sinus Augmentation; Lateral Window Technique; Osteotome

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INTRODUCTION

In most cases, standard techniques of implant placement cannot be applied in the posterior maxilla due to poor bone quality and quantity. Insufficient bone volume as a result of maxillary sinus enlargement leads to a decrease in

bone height in the posterior area. Various vertical bone augmentation procedures have been introduced to date [1]. The most common technique for elevating the sinus floor is the lateral window technique first introduced by Tatum in 1977 and then published by Boyne and James in 1980 [2]. The long-term success of this technique has been reported even with the use of different types of graft materials and implants [3].

In 1994, Summers introduced a new technique for elevating the sinus floor with the use of special instruments called osteotomes. In this technique, the schneiderian membrane is lifted from the alveolar crest by applying an osteotome. Application of graft materials decreases the risk of membrane perforation [4].

Both the above-mentioned techniques can be applied in one- or two-stage protocols. However, the height of the residual bone is a factor which determines the protocol that should be applied. If the residual bone height is more than 5 mm and primary stability of the implant is achievable, one-stage protocol is adopted and sinus lifting is implemented at the same time as the implant placement; otherwise, it is essential to use the delayed approach and place the implants after the healing period [1,3]. Based on the results of studies on sinus augmentation techniques, the osteotome technique is a predictable and efficacious technique for simultaneous or delayed implant placement [1,5-7].

In this technique, the average amount of sinus lifting has been reported to be 4.4±0.2 mm without bone grafting [8] and 3-7 mm with bone graft materials [2].

Studies have shown that the crestal method using an osteotome in comparison to the conventional technique (lateral window) is less invasive and has some advantages including a shorter surgical duration and minimum post-surgical complications [5,9,10]. Furthermore, in the osteotome technique it is possible to condense the weak maxillary bone (bone types 3 and 4) and increase the implant-to-bone contact area, which leads to more primary stability [5,9].

Moreover, it has been noted that accessing the sinus from the crestal zone requires a smaller socket, which has a much shorter healing period [9]. Numerous clinical investigations have been carried out to compare osteotome with lateral window techniques with immediate and delayed implant placements for sinus lifting [1,4,11-17].

However, in the author's review of literature, no histological study comparing these two techniques can be found.

The effect of the osteotome technique on the healing process has been poorly understood. Here the question is whether or not the force and the temperature produced by tapping of the osteotome with the surgical mallet have any effects on factors such as the healing process, quantity of the new bone and severity of inflammation in the surgical zone. The osteotome technique is more convenient compared to the conventional technique due to the simplicity of application, less post-surgical complications and the shorter healing period. However, it is obvious that in order to confirm and validate the benefits of applying the osteotome technique as an alternative to the conventional technique (lateral window), it is essential for the comparative histological evaluations of the two methods to demonstrate similar results. Such a comparative study has not yet been conducted [9,12,15].

The aim of this study was to evaluate and compare the osteotome and lateral window techniques using histological and histomorphometric methods in patients with less than 5 mm of posterior maxillary alveolar residual bone, who were referred to the Dental Implant Research Center of Tehran University of Medical Sciences.

MATERIALS AND METHODS

In this research, which was a second-phase clinical trial (pilot) without blinding, 10 patients (six females and four males) were se-

lected from patients needing implant treatment in the maxillary posterior region who were referred to the Implant Department of Tehran University of Medical Sciences, School of Dentistry. The selected patients suffered from severe atrophy in the posterior area; consequently, the application of conventional methods for implant placement was impossible. In all the cases, the maximum bone height between the sinus floor and the crestal bone was less than 5 mm. Uncontrollable systemic diseases such as diabetes, acute sinus infections, chemotherapy within 12 months before surgery, radiotherapy of more than 5000 rads in the head and neck region and psychological problems were listed as the excluding criteria.

To evaluate the residual bone height, radiographs such as CT or CBCT were applied. All the patients were informed about the surgical procedure and its complications. It was essential for the patients to complete the consent form for participating in this study. The study protocol was approved by the Ethics Committee of Tehran University of Medical Sciences.

Surgical Procedure

Prophylactic antibiotics, 2 gr of amoxicillin or 600 mgr of clindamycin were prescribed one or two hours before the surgery. Chlorhexidine mouthwash (0.2% for 2 minutes) was applied just before the surgery. Natural randomization was performed to divide the patients into two groups so that in cases with 1-2 mm of residual bone height, the lateral technique was adopted and in patients with 3-4 mm of bone height the osteotome technique was applied. In both methods, Bio-Oss (Geistlish Pharma AG/Wolhousen, Switzerland) was used as the graft material.

In the lateral technique, the lateral wall of the sinus was exposed by performing a crestal incision and a mucoperiosteal flap. A bony window was created by applying a round bur. When the bony window became removable, the surgeon started to separate the sinus membrane from the inferior edge of the osteotomy region and pushed the membrane upward. The sinus membrane was carefully separated from the inner and inferior walls. At the same time, the external wall was pushed inward and upward to form a new horizontal ceiling for the space created. Care was exercised not to perforate the membrane; however, in the cases of perforation a resorbable collagen membrane (Biogide Geistlish Pharma AG/Wolhousen, Switzerland) was applied to cover the hole. The graft material (Bio-Oss) was mixed with normal saline solution and packed gently into the sinus in order to completely fill the cavity with bone substitute material and achieve the desired bone height. Next, a resorbable membrane (Biogide) was placed on the outer surface of the window and the flap was sutured as a primary closure.

In the second group, the sinus floor elevation procedure was performed by applying the osteotome technique. In this technique, the buccal and palatal mucoperiosteal flaps were prepared by means of a crestal incision and the alveolar ridge was exposed after reflecting the flap. Site positioning was marked using a small bur on the alveolar ridge and the osteotomy sites were prepared independently and separately relevant to the ultimate number of implants. The approximate location of the sinus membrane was determined based on initial radiographs. By applying a two-millimeter twist drill, the osteotomy was prepared so that the distance between the bottom of the osteotomy and the sinus floor was approximately 0.5-1.5 mm. The diameters of the osteotomy were gradually increased, using a combination of different drills and scaled osteotomes (ITI-Straumann) and osteotomy sites were prepared at a distance of 0.5-1.5 mm away from the sinus floor. The sinus floor was fractured with the final osteotome with the same diameter as the final drill. The odds of sinus perforations were assessed using Valsalva maneuver immediately after fracturing the sinus floor. In

case of sinus membrane perforation, the surgical method was converted to the lateral window technique and the site was covered with a resorbable collagen membrane (Biogide). In the absence of perforation, graft material (Bio-Oss) was placed in a multiple-step procedure in the osteotomy site and packed with an osteotome. Graft material elevated the intact sinus membrane after displacing the sinus floor, which was lifted with the final osteotome to the desirable height. After filling the cavity completely with bone graft material, the flap was sutured as a primary closure.

In both techniques, the sinus membrane was elevated to an appropriate level in order to provide sufficient space for placement of implants with a minimum length of 9 mm. All the patients were given 500 mg of amoxicillin, 4 times per day for 1 week. Furthermore, an anti-inflammatory and a nasal decongestant drug were prescribed when required. All the patients were instructed in how to take care after the sinus graft surgery. Any accidental sinus membrane perforation during the surgery and the possible occurrence of any post-surgical complications, such as acute infection and bleeding during the healing period were registered.

Histological Analysis and Histomorphometry

After a 10-month healing period, biopsy specimens were obtained from the alveolar crest with a 3-mm trephine bur in all the cases, simultaneous with implant placement procedures. It should be noted that histological evaluations were performed by one pathologist (PM) who was blind to the surgical techniques using only coded samples.

Each biopsy was fixed in 10% formalin in separate containers. After 48 hours, when complete fixation was achieved, the fixation solution was replaced with 10% formic acid for decalcification. The decalcification process lasted for 5 days, during which the acid was renewed daily. The specimens were assessed every day to evaluate the extent of decalcification. After completion of the decalcification process, the cylindrical specimens were cut longitudinally along their axial direction and divided into two equal parts.

The specimens were prepared for staining and microscopic sections using the conventional method. In this method, the specimens are placed in various solutions containing different concentrations of alcohol and xylene (xilol) in the preparation equipment to be cut and stained. After initial paraffinization, half-cylindrical specimens were embedded in paraffin blocks from their newly cut surfaces. Subsequently, paraffin-embedded blocks were serially sectioned using a microtome device (Laica, Germany) to produce slices with 5-µm thickness. At least five sections of each sample were placed on glass slides and stained by the conventional protocol for hematoxylin and eosin staining (H&E). The slides were studied under a light microscope (BX51, Olympus, Japan) at ×100 magnification (lens number 10).

The histological parameters evaluated in this study included the status of the residual biomaterial, the amount of the newly formed bone, the amount of connective tissue between the new bone and the residual biomaterial, the location of biomaterial in relation to the new bone, the lamellar-woven bone ratio, which is determined using polarized microscopy, the extent of inflammation in the connective tissue and the occurrence of a foreign body reaction. Photographs were taken using a digital camera (DP72, Olympus, Japan) from the central region of each slide and assessed by a histological evaluation software (Professional Analysis, Germany) to determine and register the area of the newly formed bone, the area of the residual biomaterial and the area of connective tissue. The mean value of these measured areas was calculated for 5 slides, which were cut out of each specimen and ascribed to the relevant specimen. In addition to bone structure, residual biomaterial and connective tissue, other factors such as inflammatory infiltrates and

foreign body reactions can be identified easily in these slides.

The inflammatory infiltration was reported as minor, moderate and severe. Moreover, the foreign body reaction was recorded in each case if observed. The extent of inflammation was determined based on the number of lymphocytes existing in the tissue and based on the type of inflammation (focal or diffuse inflammation). These parameters were assessed in all samples.

Statistical Analysis

Data were analyzed based on "per-protocol" analysis. The quantitative parameters were reported as mean values and standard deviations (Mean ± SD) and qualitative parameters were presented as crude and relative frequencies. Comparison of variable distribution between the two groups was carried out by Mann-Whitney U test and Fisher's exact test. Statistical significance was defined at $P<0.05$.

RESULT

In this study, a total of 14 sinuses in ten patients (bilateral in four cases) were augmented with Bio-Oss.

Lateral window and osteotome techniques were applied for augmentation in 8 and 6 sinuses, respectively.

In one case, the osteotome technique was converted to the lateral window technique due to membrane perforation during the sinus augmentation procedure.

Therefore, finally, 5 sinuses were considered in the osteotome group and 9 sinuses in the lateral window group. During the ten-month healing period, no post-surgical complications such as sinus infection or bleeding was reported. Patients' demographic data are presented in Table 1.

Histological Findings

Newly formed bone around the residual biomaterial mass was observed in all the specimens in both groups.

The new bone was in direct contact with the biomaterial without any gaps. This viable bone consisted of lacunae containing osteocytes in all cases. In the osteotome group, 45% and 55% of the new bone consisted of lamellar bone and woven bone, respectively.

In the lateral window group, the new bone consisted of 35% and 65% of lamellar bone and woven bone, respectively.

The lateral window technique exhibited more osteoid matrix compared to the osteotome technique. However, the osteoid matrix ratios were not significantly different between the two groups.

Table1. Patient Characteristics in Study Group

	Open (n=9)	**Closed (n=5)**
AGE	52.9 ± 6.1	53.2 ± 13.4
Gender		
Female	5(55.6%)	2(40.0%)
Male	4(44.4%)	3(60.0%)

The osteoid matrix/total bone ratios were estimated approximately 15% and 10% in the lateral window and osteotome techniques, respectively.

The values of inflammation parameters as the number of inflammatory cells and distribution patterns are presented in Table 2. The inflammation severity was considered as mild. In all the cases, chronic inflammatory cells, including lymphocytes, plasma cells and low quantities of macrophages were observed. No statistically significant differences were observed in the number of inflammatory cells between the two groups and no foreign body reactions were reported.

Histomorphometric evaluation results are presented in Table 3. The mean values of the new bone in the lateral window and osteotome techniques were 30±6.0 and 25.2±5.2, respectively, with no significant differences between the two groups. Moreover, the average amounts of residual biomaterial and connective tissue were similar in both groups.

DISCUSSION

Dental implant placement is often restricted by sinus enlargement in the posterior maxilla. Various sinus augmentation techniques have been introduced so far to tackle the problem. The conventional method for sinus augmentation is the lateral window technique. However, the osteotome technique can be regarded as an alternative less invasive technique to augment the sinus floor [13] and to improve bone density and quality [19].

In the current study, histological and histomorphometric differences of osteotome and lateral window techniques were evaluated. To the best of our knowledge, such a comparative study does not exist in the literature. The rationale of the present research was the fact that it is essential for a secondary technique to demonstrate similar clinical and histological results similar to the conventional method to be regarded as an alternative technique. The results of this study did not reveal statistically significant differences in the amount of new viable bone between the osteotome (25.2±5.2) and lateral window (30±6.0) techniques. Furthermore, the inflammation severity was almost similar in both groups without any significant differences. Therefore, the controlled force and the temperature produced by tapping of the osteotome with the surgical mallet did not affect the healing process and the formation of the new bone. In this study, a modified version of Summers' osteotome technique was applied, in which the osteotome was directly tapped to the sinus floor without using any intermediate graft material. The reason for application of the modified Summers' technique was to reduce the forces produced by the surgical mallet. Although the risk of membrane perforation is low in Summers' technique, due to utilization of graft material as an intermediate layer, severe tapping can be irritating for patients. On the other hand, tactile and auditory changes associated with sinus floor encroachment are considered warnings for the clinicians to change the mallet pressure.

Table 2. Inflammation Results Between Two Technique Groups

	Open (n=9)	**Closed (n=5)**	**P-value**
Inflammation	3 (33.3%)	4 (80.0%)	0.24
Focal	2 (22.3%)	1 (20.0%)	
Non-focal	1 (11.1%)	3 (60.0%)	

The clinician's experience and skills are essential for achieving a controlled fracture without perforation [18].

Various graft materials have been used for sinus augmentation. In this study, a deproteinized bovine bone mineral, known as Bio-Oss, was applied. Since it is necessary to maintain the space produced by elevating the schneiderian membrane for the staged implant placement, the low resorption rate of Bio-Oss makes it advantageous as a graft material. In this study, the implants were placed 10 months after sinus augmentation. Bone materials which are not resorbable, such as HA, also function as space maintainers and preserve the space created by elevating the schneiderian membrane for sinus augmentation [19] and also prevent the collapse of the schneiderian membrane.

There are several studies comparing the effect of the techniques adopted for sinus augmentation on the clinical outcome of the implants. In all the cases, similar success rates have been reported for both lateral window and osteotome techniques [12,16]. Crepsi et al. (2010), through a three-year study, reported a 100% survival rate for implants placed after the sinus floor was elevated using the osteotome technique [11].

Santagata (2010) suggested that if a series of incrementally larger osteotomes were used to achieve improvement of bone density, sinus floor elevation and simultaneous implant placement and even immediate loading will be possible [13]. In the literature review, sinus augmentation using osteotome technique and implant placement have been performed simultaneously, except for one case report, in which only clinical (not histological) evaluation of the osteotome technique was carried out. In this case report, implants were placed 6 months after sinus lifting (staged implant placement) due to the insufficient bone height of less than 5 mm from the sinus floor. It is suggested that in cases with more than 5 mm of residual bone height, implants can be placed simultaneously with the sinus augmentation procedure. However, if the residual bone height is less than 5 mm, staged approach should be undertaken; otherwise, primary stability of the implant might be undermined [15,18].

In the present study, a residual bone height of less than 5 mm was one of the including criteria; therefore, the staged approach was necessary. Moreover, a trephine bur was used to collect biopsy specimens from the alveolar crest at the same time as implant placement for histological evaluations.

Histomorphometric analysis on rabbits, performed by Nkenke et al. (2002), revealed that applying the osteotome technique increases new bone formation and enhances osseointegration of the dental implants.

Table 3. Output result between two technique groups

	Open	**Closed**	**P- Value**
Bone Formation	30 ± 0.6	25.2 ± 5.2	0.30
Residual Material	16.1 ± 12.9	8.6 ± 8.8	0.30
Lymphocyte	0.1 ± 0.2	0.2 ± 0.4	0.34
Connective Tissue	83.8 ± 12.9	91.3 ± 8.6	0.30

They also suggested carrying out the same study on humans [20].

According to the literature review conducted in this study, the only histological study evaluating the application of osteotome technique on humans is a case report by Khatibloo (2011), in which the sinus floor was elevated using the osteotome technique and after 45 months, biopsy specimens were obtained at the same time as the implant placement. Based on histometric analysis the new bone formation was estimated to be 24.8%, while the connective tissue and the bone marrow was 79.2%. The results of the current study were slightly higher than those reported by Khatibloo. However, the percentages of residual biomaterial in Khatibloo's study and the current study are significantly different. As reported by Khatibloo (2011), there was no residual biomaterial after 45 months, while the mean value of residual biomaterial in the present study was 8.6±8.8. This discrepancy might be attributed to the different biomaterials used in the two studies. The material used in Khatibloo's study was BCB, while in the present study Bio-Oss was used [14]. Different resorption times have been reported in various studies. The presence of Bio-Oss particles in the graft area in humans was reported by Avera (1997) after 44 months and even after 4 years by Piattelli 1999). Dies (1996) observed that only a limited amount of particles was resorbed after 9 months [17]. Based on histomorphometric findings, new bone formation in the lateral window technique in the present study (30±6) was similar to that of a study by Hans-Dieter 2004, in which Bio-Oss was the only material used for sinus augmentation (29.5±7). The mean value of the residual biomaterial was reported to be 14.9±6 in a study by Dieter 2004, which is slightly higher in comparison to that (16.1±12) in the current research. In Dieter's study, similar to the present study, the new bone was in direct contact with the biomaterial, without any gaps or connective tissue in between [21]. In 2001, Yildirim observed Bio-Oss in biopsy specimens 9.5 months after sinus augmentation and histological analysis in his study revealed that Bio-Oss was in direct contact with the new bone which consisted of lamellar and woven bone.

His findings were consistent with the observations in the current study [22]. In 2008, Iezzi observed 12±2.9% of Bio-Oss and 40±2.4% of bone which consisted of 50% lamellar and 50% woven bone after five years. No foreign body reaction was observed in Iezzi's study similar to the present study [23]. However, in our study a limited number of osteoclasts were present.

In cases of severe atrophic ridge (2 mm or less bone height) in the posterior maxilla, the osteotome technique is not an appropriate treatment modality since it is time-consuming with relatively less predictable results [13,18]. Therefore, in the present study, natural randomization was used to divide patients into two study groups, i.e. the patient's conditions determined the type of the treatment technique adopted. Lateral window technique was chosen for patients who had 1-2 mm of residual bone height and the osteotome technique was applied for patients whose residual bone height was 3-4 mm.

As the residual bone height does not affect the histological outcomes, dividing the patients into two study groups based on the natural randomization method does not lead to any biases in the study results.

Only one specimen of each augmented sinus was randomly chosen and histologically evaluated. Although this protocol decreases the sample size, it can lead to obtaining valuable statistical results and can be considered a positive aspect of this research.

In this study, the osteotome technique was successfully applied for patients with less than 5 mm of residual bone height, which was a significant achievement of the current study.

The volume of graft material used for one sinus augmentation procedure was 2-3 cc in the lateral window technique and less than 0.5 cc

in the osteotome technique, enabling both the patient and the physician to economize.

The small sample size, as a limitation of this study, can reduce the statistical power of the study. Due to the small access region and the close proximity of the bony walls in the osteotome technique, the healing period is expected to be shorter. Thus, it is recommended to perform histological evaluations 4-6 months after sinus augmentation in future studies.

CONCLUSION

1. The nature and the amount of the newly formed bone did not exhibit any statistically significant differences between the lateral window and osteotome techniques.
2. No statistically significant differences were observed between the two groups in terms of inflammation and edema.
3. In the osteotome technique, hammering forces did not affect the healing process in the sinus.
4. The osteotome technique can be applied in cases with less than 5 mm of residual bone height. However, the clinician should definitely be an experienced expert.
5. It is suggested that the osteotome technique should be considered as an alternative for the lateral window technique, especially in cases in which a septum exists in the sinus or there is a single tooth in the posterior maxilla, where there is a high risk of membrane perforation due to limited access for window preparation.

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