

PREVALENCE OF SCHNEIDERIAN MEMBRANE PERFORATION DURING MAXILLARY SINUS AUGMENTATION PROCEDURES USING ULTRASOUND VERSUS ROTARY TECHNIQUES

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ABSTRACT

Schneiderian membrane perforation is one of the main complications during sinus augmentation. The aim of the study was to investigate sinus membrane rupture in maxillary sinus lifting surgery with the ultrasound and with conventional rotary technique, analyzing the bone gain obtained after the operation using cone beam computed tomography (CBCT), and examining the post-augmentation survival of implants. Twenty-two patients requiring dental implant therapy in the posterior maxillary region with insufficient bone volume were included in the study. Patients were randomly and equally allocated to Piezosurgery group and the conventional rotary group. A total of 22 sinus lifting surgeries were carried out; 11 with ultrasound in piezosurgery group and 11 with DASK drills in conventional rotary group. A total of 47 dental implants were placed three months after sinus augmentation. Patients were randomly and equally allocated to Piezosurgery group and the conventional rotary group. In either Piezosurgery group or conventional group a total of 11 sinus lifting surgeries in 11 patients were performed. The bone gain obtained as a result of sinus lift was calculated using CBCT scanning. Perforations of Schneider's membrane with the ultrasound and rotary technique occurred in 9% and 18 % of the cases, respectively, with membrane integrity being preserved in 86.3% of operated patients. All 47 implants placed showed the implant success criteria throughout postoperative follow-up in the both study groups. No statically significant difference in bone gain was recorded between study groups. In conclusions, perforations of the membrane in sinus lift were more frequent with the rotary technique (18%) than with ultrasound (9%). Implant survival and bone gain were statistically no significant difference between the two study groups throughout follow-up period.

INTRODUCTION

After loss of teeth in the posterior maxilla, the alveolar ridge decreases by bone atrophy and osseointegration of implants in patients

with pneumatized maxillary sinuses are difficult to achieve¹⁻⁷. Sinus elevation allows maxillary bone augmentation and thus facilitates implant rehabilitation in patients with severe posterior maxillary atrophy. In direct maxillary sinus lift

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a vestibular osteotomy is performed, a bone window is prepared, and access is gained to the maxillary sinus for elevation of the membrane. The bone perforation can be carried out using an osteotomy drill in the context of the conventional rotary technique, or using ultrasound tips ⁶.

While the sinus elevation procedure is considered by some to be a relatively invasive procedure, a comparatively low incidence of surgical and postsurgical complications of the procedure has been reported ^{8,9}. The most common surgical complication is the perforation of the Schneiderian membrane ^{2,3,6,8,10-12}. It occurs in 7–10% to 35% of sinus floor elevation procedures ^{1,5,7,9,10}. Membrane perforations, according to the literature, are strongly associated with the appearance of postoperative complications and consist mostly of acute or chronic sinus infection, bacterial invasion, swelling, bleeding, wound dehiscence, loss of the graft material and a disruption of normal sinus physiologic function ^{2,3,5,8-13}.

Small perforations usually do not need treatment because the membrane folds on itself during the elevation ^{2-4,10}. However, large perforations are usually managed using a bio-absorbable membrane ^{2-4,7-10,12}, by placing a large lamellar bone sheet⁴, using a block graft inserted of a cancellous graft¹⁰ or by abandonment of the procedure ^{1-3,9,10,14}.

In elevation with the rotary technique, the main intraoperative complication is perforation of Schneider's membrane, which is observed in between 10-35% of all such operations ¹⁰, and which usually occurs in the osteotomy drilling phase while preparing the window for access to the sinus ⁹. With the purpose of reducing the risk of perforating Schneider's membrane, vestibular osteotomy using ultrasound has been proposed, as this reduces the risk of soft tissue damage ¹⁵ and percentage membrane perforation to seven percent ¹⁶.

Piezosurgery is based on ultrasonic principle with modulated frequency and controlled tip vibration range ¹⁷⁻²⁰. Selective cutting is possible

with different frequencies acting only on hard tissues. It is particularly important when working in close proximity to vital anatomical structures such as nerve, vessel, or Schneiderian membrane ^{15, 17}. Piezosurgery has a wide field of application in dental implantology including sinus lifting, autogenous bone harvesting, and bone crest splitting, and removing of failed implants ^{18, 19}. It provides precise bone cut without much pressure, which helps to prevent excessive heat that would result in bone damage ^{15, 18, 19}.

CYPRESS, California--Dentium USA, a manufacturer of dental products, has introduced a sinus elevation kit called DASK (Dentium Advanced Sinus Kit). DASK Drill #4 or #5 as conventional rotary technique is used to prepare a lateral sinus window for sinus lifting through the antrostomy (thin-out) approach using light pressure and rotating stokes. The DASK's diamond-coated drills were designed to help prevent sinus perforation and provide an optimal irrigation function. The internal irrigation not only has a cooling effect, it also adds hydraulic pressure. This slightly lifts the sinus during the procedure. Drill speeds for DASK drills #4 or #5 ranges from 800 to 1,200 rpm and 30 to 45N.cm with the irrigation process (<http://www.dentiumusa.com>).

Autogenous bone as grafting material for sinus augmentation is considered up till now as "the golden standard". However, there is a continuous search for alternative materials such as xenografts; an organic de-proteinized bovine-derived product Bio-Oss, allografts; demineralized freeze-dried bone (DFDBA) and a combination of these to form composite grafts for sinus lifting procedure ^{21, 22}. The present study was designed to compare the intraoperative and postoperative performance of the ultrasound piezosurgery technique versus conventional DASK diamond-coated rotary technique in application to sinus lift, analyzing sinus membrane perforation in direct maxillary sinus lift with both techniques, and analyzing the bone gain obtained after the sinus augmentation based upon

cone beam computed tomography (CBCT) scans and examining the post-augmentation survival of implants.

MATERIALS AND METHODS

Patients' selection

Twenty-two patients (16 males, 6 females) requiring dental implant therapy in the posterior maxillary region with insufficient bone volume were included in the study. Mean age was 46.10 ± 7.20 years. Inclusion criteria were the need for unilateral or bilateral sinus lifting with residual alveolar bone height less than 5 mm. patients who showed any uncontrolled systemic diseases, ongoing chemotherapy or radiotherapy or a history of maxillary sinus diseases were excluded. All patients were informed of the requirements for participation in the study and signed an appropriate consent form. Only one side was included in this study, even if the patient needed bilateral sinus lifting.

The osteotomy site included one premolar and one molar tooth width in 19 patients to standardize the size of bony window opened for each study group. In three patients only the osteotomy site included one premolar and two molar teeth. A total of 22 sinus lifting surgeries were carried out and a total of 47 dental implants were placed three months after sinus augmentation to restore missing maxillary posterior tooth or teeth. Before treatment, all patients were clinically and radiographically examined by panoramic radiography and cone beam computed tomography (CBCT) scanning in selected cases for available bone volume, bone quality, anatomy and any existing sinus pathology (figure 1)

Patients' grouping

Patients were randomly allocated to Piezosurgery group (PSG) and the conventional rotative DASK group (CSG) according to the device used for preparation of the lateral sinus window. In either Piezosurgery group or conventional rotative DASK

group a total of 11 sinus lifting surgeries in 11 patients were performed.

Surgical technique

All sinus lifting surgeries were performed under local anesthesia using articaine HCL 4% with epinephrine 1: 100,000 (Septocaine, distributed by Septodont, Inc, USA). A prophylactic oral antibiotic of one gm of augmentin (875 mg amoxicillin and 125 mg clavulanic acid, manufactured by Glaxo SmithKline, Egypt) was used, beginning 2 hours before the procedure and continued for 7 days. The sinus augmentation procedure followed the technique described by Tatum and coworkers¹⁴. A horizontal antero-posterior incision was made slightly palatal to the alveolar crest and supplemented by buccal releasing incisions at the anterior and posterior ends of the horizontal incision.

A full-thickness mucoperiosteal flap was raised and the lateral wall of the sinus was exposed. Osteotomy was performed with either Piezosurgery device (Piezosurgery, Mectron, Genova, Italy) in Piezosurgery group or rotative DASK (Dentium Advanced Sinus Kit; California-Dentium USA) drill #4 or #5 with drill speed 800 to 1200 rpm with internal irrigation in the conventional rotative DASK group with copious sterile saline. Drill #4 and #5 with a diameter of 6.0 mm and 8.0mm respectively and length of 2.5 mm has diamond coating cutting surface (figures 2, 3, and 4). Sinus membrane dissection and elevation were also performed with piezosurgery tips (figure 5) or direct sinus lift elevators. Care was taken not to perforate the sinus membrane.

After obtaining sufficient space by elevating the sinus membrane, inorganic bovine bone granules (Geistlich Bio-Oss) were used for grafting. The amount of grafting material used at each site varied according to the extent of maxillary bone resorption and the sinus anatomy. Geistlich Bio-Oss is a porous bone mineral matrix. It is produced by removal of all organic components from bovine bone. It is available in spongiosa (cancellous) granules.

The anorganic bone matrix of Geistlich Bio-Oss has macro- and microscopic structures similar to human bone. The formation and ingrowth of new bone at the implantation site of Geistlich Bio-Oss is favored, due to its trabecular architecture, interconnecting macro and micro pores and its natural consistency (<https://www.geistlich-na.com>).

Bony sinus windows were covered with a resorbable collagen membrane (Collagene AT, Sistema At; Italy). Mucoperiosteal flaps were primarily closed with 3/0 silk suture. Patients were advised not to blow their noses and to sneeze opening the mouth for one week after surgery. All patients were prescribed oral antibiotic of one gram augmentin twice daily for 7 days and 500 mg paracetamol twice daily, chlorhexidine mouth rinse starting from the next day of surgery twice daily for 15 days. Sutures were removed on the seventh postoperative day.

Time from the beginning of osteotomy to the completion of sinus membrane elevation and the incidence of membrane perforation during the sinus lifting surgery were assessed to compare the effect of the two techniques. Moreover, postoperative pain and swelling were self-assessed by the patient on a 4-point scale ranging from 0 to 3 where, 0, little/none; 1, some; 2, quite a bit; and 3 very much. Patients were asked to fill out the form on 8th, 24th,

48th, and 72nd postoperative hours and on the 7th postoperative day. CBCT scans of the surgical site immediately after sinus floor augmentation were carried out (figure 6).

Delayed implant insertion

Three months after sinus augmentation, a total of 47 Osstem TS implant system (Dental Direct UK Ltd; Osstem GmbH Hiossen Inc) of 11.5 and 13 mm length and Ø 4.0, and Ø 5.0 mm diameter were inserted in target sites of maxillary premolar-molar tooth in either Piezosurgery group or rotative conventional DASK group. Then 3 months after implant insertion, implants were loaded with the final prosthesis (figures 7, 8, and 9).

Postoperative radiographic evaluation

The preoperative residual bone height and the elevated bone height or bone gain after sinus floor augmentation was assessed and measured in the CBCT along the center of the proposed implant site immediately after sinus grafting as well as 3 months and 6 months after sinus floor augmentation and implant insertion. The residual bone height was measured from the top of the alveolar crest to the sinus floor. The elevated bone height was counted by subtracting between the post-surgical and initial ridge height.

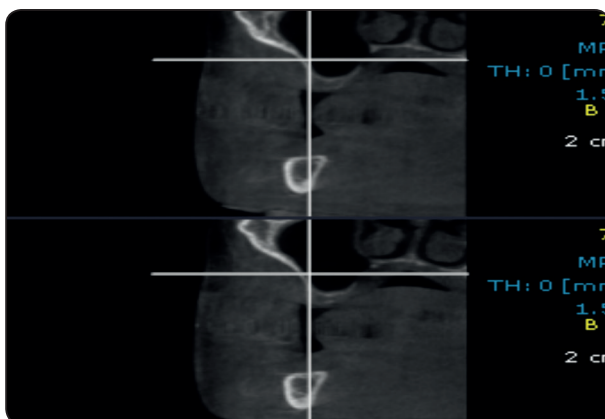


Fig. (1) Preoperative CBCT scans showing posterior maxillary resorbed alveolar ridges

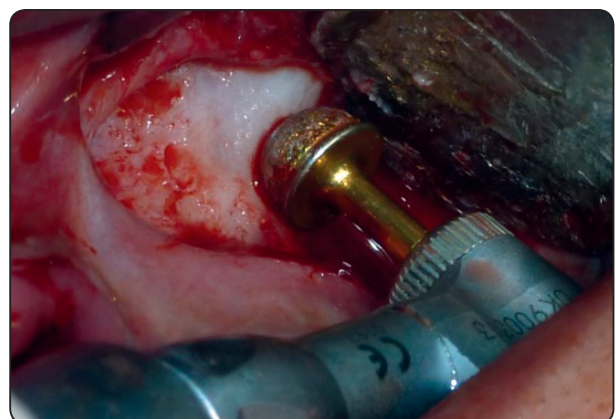


Fig. (2) DASK drill in use for creating the bony window for sinus lift

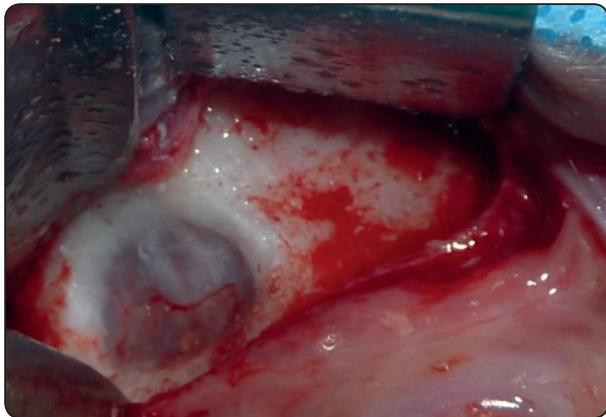


Fig. (3) Window opening using DASK drills with intact sinus membrane

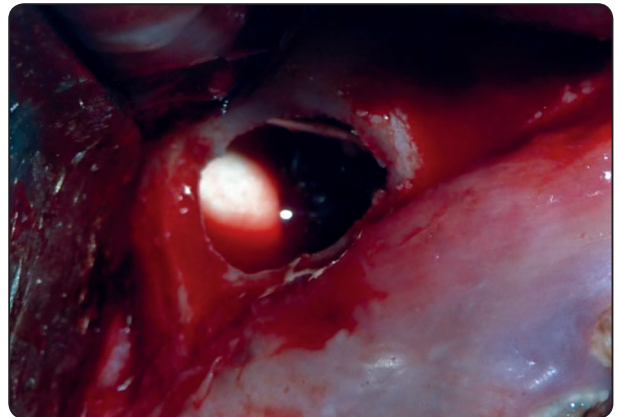


Fig. (4) Lifting sinus membrane for sinus grafting

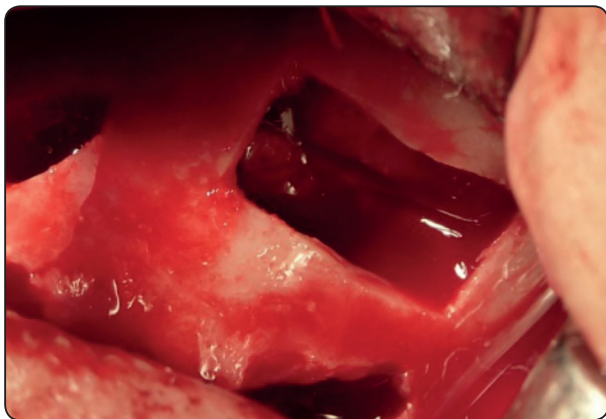


Fig. (5) Window opening using piezosurgery and lifting sinus membrane

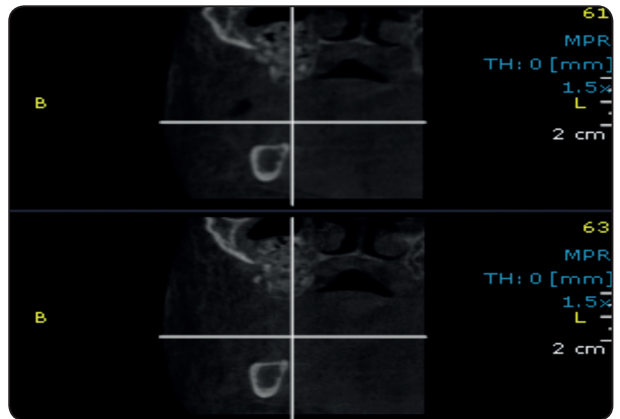


Fig. (6) CBCT scans of the surgical site immediately after sinus floor augmentation

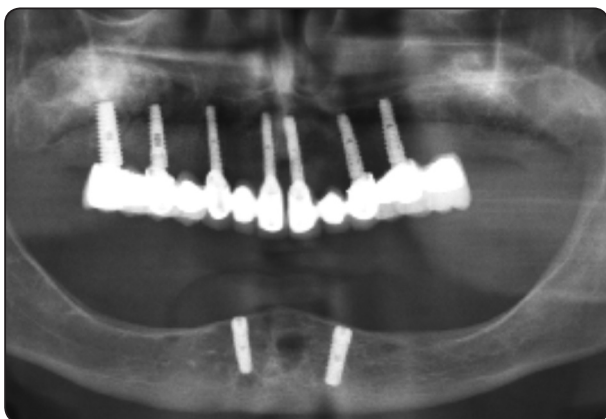


Fig. (7) Panoramic radiograph showed implants after loading

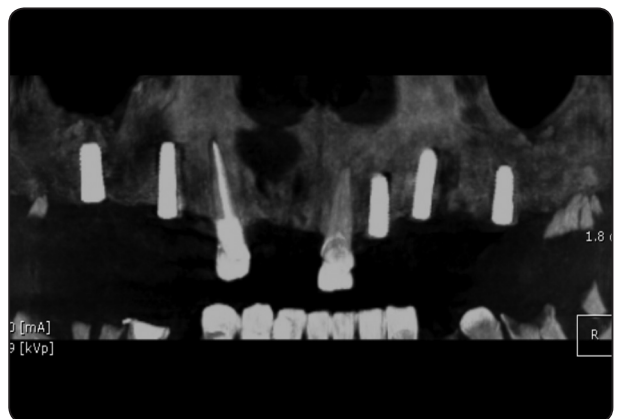


Fig. (8) CBCT scans showed implants in the bilaterally augmented maxillary sinus



Fig. (9) CBCT scan showed constructed prosthesis on implants

Statistical analysis

Data were presented as mean and standard deviation values. Paired t-test was used to study the effect of time on each group, to compare between the two groups and to compare between the percentages changes in bone height or gain of the two study groups. Mann-Whitney test was used to compare the other parameters between the groups and Fisher exact test was used to compare incidence of membrane perforation. $P \leq 0.05$ was considered significant.

RESULTS

The results of 22 patients were evaluated. The piezosurgery group consisted of 7 men and 4 women with age range of 37 to 52 years and a mean of 45.1 years. The conventional group consisted of 8 men and 3 women with age range of 36 to 53 years and a mean of 46.2 years. Only one membrane perforation occurred piezosurgery group (9%) and two perforations occurred in conventional surgery group (18%) during sinus lifting surgery (9% in each group). The perforation was closed with resorbable collagen membrane and the grafting procedure was completed. There was no statistical significant difference regarding time elapsed between the beginning of osteotomy to the completion of sinus membrane elevation between piezosurgery and conventional groups ($P = 0.523$).

Pain experiences were significantly higher in the conventional group than piezosurgery group on 8th postoperative hours ($P = 0.003$), 24th postoperative hours ($P = 0.018$) and 48th postoperative hours ($P = 0.017$). However, there were no statistical significant differences between the conventional group and piezosurgery group on 72nd postoperative hours ($P = 0.129$) and 7th postoperative day ($P = 0.412$). There was statistical significant more postoperative swelling in the conventional group compared to piezosurgery group on the on 8th postoperative hours ($P = 0.06$), 24th postoperative hours ($P = 0.02$) and 48th postoperative hours ($P = 0.07$). However, there were no statistical significant differences in postoperative swelling between the conventional group and piezosurgery group on 72nd postoperative hours ($P = 0.312$) and 7th postoperative day ($P = 1.10$). No post-operative wound dehiscence, oroantral fistula, barrier membrane exposure, and wound infection were recorded in either study groups in the current study.

Immediate CBCT scanning after sinus lifting surgeries in all patients showed proper sinus grafting. CBCT after implant insertion and 3 months after sinus grafting showed implants that inserted in the sinus cavity with dense grafted bone around them. Three months after implant insertion, CBCT showed that the sinus cavity around the implants was filled with a dense bone-like tissue. No implant was failed in both piezosurgery and conventional groups with 100% success rate.

The mean and standard deviation (SD) of the postoperative elevated bone height or bone gain in mm after sinus floor augmentation at different intervals in piezosurgery group and conventional group were represented in (table 1 and figure 10). There were no statistically significant differences in postoperative elevated bone height or bone gain between piezosurgery group and conventional group through all postoperative intervals. At the 6th postoperative month after sinus grafting (3 months after implant insertion) conventional group showed a statistically significant increase in the mean bone height than piezosurgery group. The effect of time

on the mean elevated bone height or bone gain after sinus lifting surgeries to the 6th postoperative month in piezosurgery group and conventional group were represented in (table 2). There was significantly increase in the mean postoperative elevated bone

height through all postoperative intervals in both study groups. The percentage changes in bone height were presented in (table 3 and figure 11). There was no statistically significant difference between the study groups through most postoperative intervals.

TABLE (1) The means and standard deviation (SD) values and the results of paired t-test for bone height at different periods in piezosurgery group and conventional group

Periods	Mean ± SD Bone height in mm in CBCT Scan Piezosurgery group	Mean ± SD Bone height in mm in CBCT Scan Conventional group	t-value	P-value
Preoperative	5.3 ± 0.8	5.1 ± 0.7	0.050	0.952
Immediately after sinus lift	19.4 ± 0.7	19.0 ± 1.0	-0.728	0.484
3 months after sinus lift	18.9 ± 1.1	18.6 ± 0.8	-0.922	0.399
6 months after sinus lift	17.9 ± 0.9	17.1 ± 0.7	-2.601	0.029*

*: Significant at $P \leq 0.05$

TABLE (2): The means bone height in mm differences and results of paired t-test for CBCT in piezosurgery group and conventional group

Group	Period	Mean difference	t-value	P-value
Piezosurgery group	Preoperative – Immediate after sinus lift	-14.1	-27.326	<0.001*
	Preoperative – 3 months after sinus lift	-13.6	-25.415	<0.001*
	Preoperative – 6 months after sinus lift	-12.6	-24.344	<0.001*
	Immediate after sinus lift– 3 months after sinus lift	0.5	4.503	0.001*
	Immediate after sinus lift– 6 months after sinus lift	1.5	25.019	<0.001*
	3 months after sinus lift -6 months after sinus lift	1.0	15.323	<0.001*
Conventional group	Preoperative – Immediate after sinus lift	-13.9	-32.617	<0.001*
	Preoperative – 3 months after sinus lift	-13.5	-36.299	<0.001*
	Preoperative – 6 months after sinus lift	-12.0	-32.823	<0.001*
	Immediate after sinus lift– 3 months after sinus lift	0.4	3.967	0.003*
	Immediate after sinus lift– 6 months after sinus lift	1.9	14.000	<0.001*
	3 months after sinus lift -6 months after sinus lift	1.5	8.7523	<0.001*

*: Significant at $P \leq 0.05$

TABLE (3) The means percentage change in bone heights in CBCT in the two groups

	Mean % changes in piezosurgery group	Mean% changes in conventional group	t-value	P-value
Preoperative - Immediate after sinus lift	-266.03	-272.5	0.132	0.881
Preoperative – 3months after sinus lift	-256.6	-264.7	0.281	0.773
Preoperative – 6 months after sinus lift	-237.7	-235.2	0.974	0.362
Immediate after sinus lift – 3 months after sinus lift	2.5	2.1	0.913	0.371
Immediate after sinus lift – 6 months after sinus lift	7.7	10	5.377	<0.001*
3 months after sinus lift – 6 months after sinus lift	5.29	8.06	3.521	0.007*

*: Significant at $P \leq 0.05$

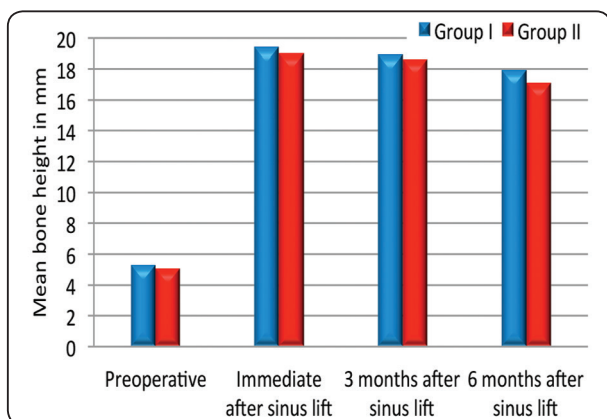


Fig. (10) Bar chart represents means bone height values in CBCT for piezosurgery group (group I) and conventional rotary group (group II)

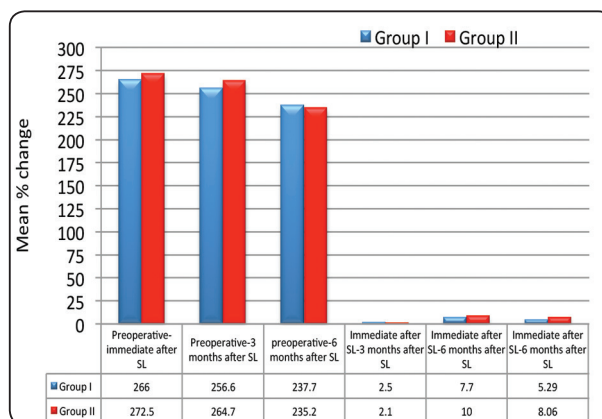


Fig. (11) Bar chart represents means percentage change in bone height values in CBCT scanning for piezosurgery group (group I) and conventional rotary group (group II)

DISCUSSION

Grafting of the maxillary sinus is a method for reaching sufficient bone height for posterior maxillary implant placement and has proven to be a highly successful method and to give predictable results ^{2, 3, 5, 10, 13, 14}. There are different techniques and armamentaria presented to perform this surgery ²³⁻³⁰. Oscillation frequency used in Piezosurgery is designed for acting only on mineralized tissue; therefore, the cutting tip becomes inactive when it contacts to soft tissue ^{17-19, 31}. Piezosurgery is safely used in dentistry where there is high risk of damaging vital soft tissue such as nerves, vessels, and so on ^{17, 19, 20}.

The most commonly reported intra operative complications of sinus augmentation are membrane perforations ^{4, 6,8,11}. It has been reported to occur in 7-35% of sinus floor elevation procedure ^{1, 5, 7,9,10}. The intact sinus membrane is essential for graft stability and prevention of sinus infection. It is reported that sinus membrane perforation risk is reduced by using Piezosurgery ^{17, 32}. Wallace et al ³³ reported 7 membrane perforations in a total of 100 sinus lifting. All the perforations occurred while using hand instruments for membrane elevation but not during the use of Piezosurgery itself. Ultrasound is associated with fewer perforations of the membrane. In this context, Vercellotti et al ¹⁵

performed 21 direct maxillary sinus lift procedures in 15 patients, with a perforation rate of only 5%. Barone et al¹⁸ conducted a study that compared conventional drills and piezoelectric device in maxillary sinus floor elevation. They concluded that the time required for window osteotomy was higher with Piezosurgery, but membrane perforation rate was smaller compared with the conventional method (23% vs. 30%).

In the present study, sinus lift with the ultrasound technique afforded a higher success rate than the rotary technique. Membrane perforations were likewise less common with piezosurgery (9% versus 18% with the conventional rotary DASK technique). In contrast, Barone et al³⁴ treated 26 patients, 13 with the conventional rotary technique and 13 with ultrasound, and observed no statistically significant differences between the two techniques in terms of membrane perforation. Of 22 direct maxillary sinus lifts performed in the present study, a smaller number of perforations of Schneider's membrane were documented (13.6%). In contrast, Thor et al³⁵ in 20 patients performed 27 direct maxillary sinus lift procedures with the rotary technique. There were 11 membrane perforations (41% of the overall operations). Using the same technique, Swartz-Arad et al⁹ obtained a similar result; with 36 perforations in 81 maxillary sinuses lift procedures (44% of the operations). Ultrasound is associated with fewer perforations of the membrane.

Repairing of the perforations can be challenging due to size of the perforation, and there is a risk of surgical failure^{12, 36, 37}. In all cases of perforation of the sinus membrane we placed a reabsorbable collagen membrane, as indicated by Hernandez-Alfaro et al³⁸ for perforations measuring less than 5 mm in size. Some authors considered that tearing the Schneiderian membrane was a factor that diminished the implant survival rate: Proussaefs et al¹² obtained a lower implant survival rate when they were placed in the sinus lifts with perforated membrane (69.5%), than when they were placed in sinus lifts with intact membrane (100%). Khoury¹

also found a lower survival rate for implants in the interventions in which perforation of the sinus membrane took place. Some authors^{39, 40} did not consider the tearing of the membrane a negative factor in the survival rate of the implant. Schwartz-Arad et al⁹ considered that the tearing of the membrane influenced the occurrence of post-surgical complications, but did not influence the survival rate of the implants. Interestingly, in this study, all the 47 implants had been integrated properly with no complications.

There is a general agreement in the literature regarding the longer time period required for operations with the Piezosurgery device^{17,19,32}. However, in our study, although the time for osteotomy and membrane elevation was longer in the Piezosurgery group than the conventional group, the difference was not statistically significant. Piezosurgery produces less vibration and noise as it uses micro vibrations, in contrast to macro vibrations and the noise produced by conventional rotary technique^{15,17}. This makes the Piezo-system more manageable and allows greater intraoperative control. Heinemann et al¹⁷ and Torrella et al²⁴ stated that Piezosurgery provides more comfort to the patient and to the practitioner during the operation and causes less morbidity and complications compared with conventional rotary methods. It is claimed that clear operation site can be provided by using the Piezosurgery device^{18,20}. It maintains a blood-free surgical field during bone cutting due to air-water cavitation effect of the ultrasonic device^{15,26}.

In this study, postoperative pain and swelling were significantly less in Piezosurgery group than the conventional group. Pain and swelling are the most encountered complications due to the nature of bone surgery, and intraoperative trauma to bone tissue is the most prominent causative factor. In the current study, the ultrasonic nature as well as more precise cut and less pressure during bone manipulation with the Piezosurgery hand piece provided less pain and swelling postoperatively.

Regarding bone gain, Vercellotti et al¹⁵ compared the bone regeneration achieved with the ultrasound technique versus the rotary technique. To this effect the authors performed a series of ostectomies with the two techniques, in one same dog. After 56 days of follow-up, greater bone regeneration was noted in the operations performed with ultrasound. In our study, the bone gain achieved after the operation and 3 months after the operation at the time of implant insertion as well as 6 months after the operation at the time of implant loading showed statistically no significant difference when comparing piezosurgery group with conventional group.

CONCLUSION

Perforations of the sinus membrane are more frequent in direct sinus lift when using the conventional rotary technique (18%) than with ultrasound (9%), with no significant difference in both survival of the implants and the bone gain in both study groups. Sinus lifting procedure performed with Piezosurgery causes less pain and swelling postoperatively compared with the conventional rotary technique. Ultrasound technique allows for precise removal of bone with minimal risk of injury or perforation of the Schneider membrane. The DASK diamond-coated rotary technique reduces the incidence of sinus membrane perforation and provides an optimal irrigation function. CBCT assesses accurately the bone gain following sinus floor augmentation procedure.

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