A Comparative Study of the Incidence of Schneiderian Membrane Perforations during Maxillary Sinus Augmentation with a Sonic Oscillating Handpiece versus a Conventional Turbine Handpiece

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ABSTRACT

Background: Sonic instruments may reduce perforation rates of the schneiderian membrane during lateral window sinus augmentation procedures. This study compares the incidence of membrane perforations using a sonic handpiece with an oscillating diamond insert versus a turbine handpiece with a conventional rotary diamond stone during lateral window sinus augmentation procedures.

Materials and Methods: A retrospective chart analysis identified all lateral window sinus augmentation procedures done during a defined period. Among these procedures, those performed with a sonic handpiece and an oscillating diamond insert (experimental) and those performed with a conventional turbine and rotary diamond stone (conventional) were selected for this study. Reported occurrences of sinus membrane perforations during preparation of the osteotomy and elevation of the sinus membrane, as well as postoperative complications, were recorded and compared between treatment groups.

Results: Ninety-three consecutive patients were identified for a total of 130 sinus augmentation procedures (51 conventional, 79 experimental). Schneiderian membrane perforations were noted during preparation of the lateral window osteotomy in 27.5% of the sinuses in the conventional group and 12.7% of sinuses in the experimental group. During membrane elevation, perforations were noted in 43.1% of the sinuses in the conventional group and 25.3% of sinuses in the experimental group. Both differences in perforation rates were statistically significant ($p < .05$). There was no statistically significant difference in postoperative complications.

Conclusions: In this study, the use of a sonic instrument to prepare the lateral window osteotomy during sinus elevation procedures resulted in a reduced perforation rate of the Schneiderian membrane compared with the conventional turbine instrument.

KEY WORDS: dental implant, piezoelectric surgery, Schneiderian membrane, sinus augmentation, sonic surgery

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INTRODUCTION

Several applications for the use of sonic and ultrasonic instruments in clinical dentistry have been demonstrated, particularly in the fields of periodontics and endodontics.[1–7] These instruments have been used for numerous applications in implant dentistry including sinus augmentation procedures, atraumatic tooth extractions, ridge split procedures, and harvesting of block bone grafts.[4–7]

Following tooth loss in the posterior maxilla, remodeling of the alveolar ridge, and pneumatization of the maxillary sinus decrease the height of bone in this region. Maxillary sinus augmentation procedures are, therefore, frequently required to compensate for this loss of bone in order to allow the placement of dental implants of adequate length. Different surgical approaches are available that include the internal sinus elevation[8,9] and the lateral window technique.[10,11]

The most common complication during the lateral window technique is perforation of the schneiderian membrane, and the reported frequency ranges between 11% to 56%.[12–15] Although there are several ways to manage and repair schneiderian membrane perforations, these events require a high level of clinical experience and knowledge and add to the cost and time required for the sinus augmentation procedure.[13,14,16] Furthermore, large membrane perforations may result in abortion of the sinus elevation procedure, and some authors have reported decreased success rates for implants placed in augmented sinuses that had a perforation.[17,18] Therefore, methods and materials that can avoid or limit the incidence of membrane perforations should be preferred and adopted in clinical implant dentistry.

One of the first reports on the application of ultrasonic generators for preparation of the lateral window osteotomy claimed several advantages, such as reduced risk of sinus membrane perforation, improved vision of the operative area during osteotomy preparation and a more conservative osseous incision.[19] Later, Vercellotti presented a technique that used a piezoelectric device using specifically designed inserts and reported only one perforation out of 21 lateral window osteotomies.[4] More recently, Wallace and coworkers reported on 100 consecutive cases using the piezoelectric instrument to prepare the lateral window osteotomy, and they demonstrated a sinus membrane perforation rate of 7%.[20] Of note, none of the perforations occurred when using the piezoelectric device but instead occurred during manual elevation of the membrane with hand instruments after the initial window preparation. Today, several kind of piezoelectric surgical units are available on the market; however, their mechanism of action is very similar. The vibration, obtained by mechanical compression of a ceramic crystal, ranges from 20 to 45 KHz. The energy is then transmitted to the surgical tip that oscillates along one of the cartesian axis (either x, y, or z), depending on the angulation of the tip shaft. The amplitude of vibration of the surgical insert ranges from 13 to 72 μm. The aforementioned properties allow the surgeon to perform a slow but precise osteotomy. Moreover, the contact of a surgical insert vibrating at a frequency inferior to 50 KHz does not tear nor lacerate soft tissues (i.e., nerves and blood vessels). On the other hand, sonic instruments operate at a frequency of 6,000 to 9,000 cycles per second (6–9 kHz) using compressed air from the dental unit. In 2011, Geminiani and coworkers[6] published the first case report where a sonic instrument with a diamond-coated insert (SF979.000.016; Komet, Rock Hill, SC, USA) was used to successfully prepare the lateral window osteotomy during a sinus augmentation procedure. This device had a vibration frequency of 6 kHz and a 240 μm wavelength. The same group later conducted a retrospective case series study where the presence of sinus membrane perforations was investigated using this technique.[21] Their findings revealed that among 40 lateral window elevation procedures, three perforations occurred during the preparation of the osteotomy window (7.5%), whereas a total of seven (17.5%) schneiderian membrane perforations were noted after elevation.

Although the feasibility and safety of the use of sonic instruments has been demonstrated, no comparative study has been published between the sonic handpiece and a conventional turbine using rotary diamond stones when the outcome of interest was the incidence of intraoperative membrane perforation. The aim of this study was to compare the incidence of schneiderian membrane perforations during lateral window maxillary sinus augmentation procedures between the sonic handpiece with an oscillating diamond insert and a conventional turbine with rotary diamond stones.

MATERIALS AND METHODS

The ethical committee (RSRB) of the University of Rochester (protocol #35862) approved this retrospective study. Between November 2008 and May 2012, 95 consecutive patients (age 29–87 years, mean 59 years) requiring a lateral window maxillary sinus augmentation in preparation for dental implant placement were identified from the pool of individuals treated at Eastman Institute for Oral Health, University of Rochester, Rochester, NY. Eight different residents in the Division of Periodontics performed the surgical procedures. All operators were required to undergo a training course in lateral window sinus augmentation. The course involved training in the anatomy and physiology of the maxillary sinus, the surgical protocol for lateral window osteotomy preparation, identification and treatment of sinus membrane perforations, as well as management of intraoperative and postoperative complications.

Two different surgical techniques were utilized for the lateral window maxillary sinus augmentation: conventional or experimental. The conventional technique followed the description of Tatum,[11] whereas the experimental consisted of a modification of the latter as recently described by the authors.[6] Briefly, the surgical protocols consisted of the following procedure: local anesthesia of the patient's surgical site with either lidocaine HCl 2% with epinephrine 1:100,000 or articaine HCl 4% with epinephrine 1:100,000 followed by reflection of a mucoperiosteal flap with a mesial vertical releasing incision. In the conventional technique, the osteotomy of the lateral window was prepared with a surgical turbine handpiece (Impact Air45, Palisades Dental LLC, Englewood, NJ, USA) until complete identification of the maxillary sinus membrane was achieved. In the experimental technique, the osteotomy was started using the same surgical turbine handpiece and completed utilizing the sonic handpiece (Sonic handpiece SF1LM, Komet, Rock Hill, SC, USA) coupled with a dedicated diamond-coated insert (SF979.000.016, Komet) as described below. As the sonic instrument removes bone at a slower rate than the surgical turbine, the thickness of the bone was reduced prior to using the sonic instrument was made in order to expedite the surgical procedure. The amount of osteotomy to be performed using the turbine handpiece was determined based on the thickness of the lateral wall as assessed on the preoperative imaging (cone beam computed tomography). When the lateral wall was thick (>2 mm), the osteotomy was started with the surgical turbine handpiece fitted with a round diamond stone, leaving approximately 1 mm of residual bone. The last 1 mm of bone was removed using the sonic handpiece. When the lateral wall of the sinus was thin (≤2 mm), only the sonic handpiece and insert were used to perform the entire osteotomy.

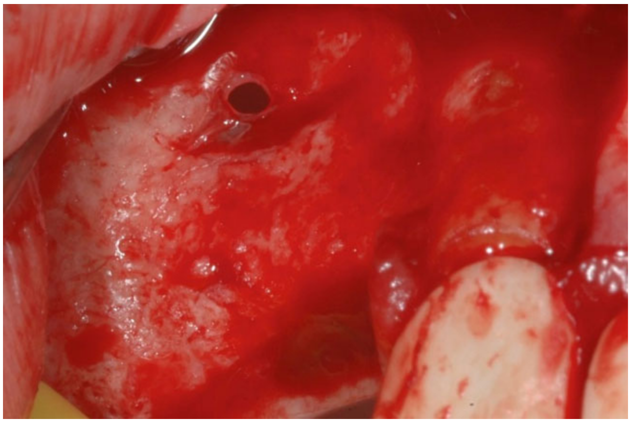

Figure 1 Perforation of sinus membrane noted during preparation of the lateral window osteotomy.

Immediately following the preparation of the lateral window osteotomy, the membrane was evaluated for perforations using 2.5 to 3.5× magnification loupes (Figures 1 and 2). The elevation of the membrane up to the medial wall was then accomplished using dedicated sinus elevation hand instruments (Sinus lift surgical kit, SLKNKIT, Hu-Friedy, Chicago, IL, USA). The presence of perforations of the schneiderian membrane was again evaluated by direct inspection (using 2.5–3.5× magnification loupes) and by assessing the mobility of the membrane when the patient took deep breathes. When a perforation was detected, a repair was attempted by extending the lateral window osteotomy in an anterior, posterior, superior, or inferior direction as needed, thus

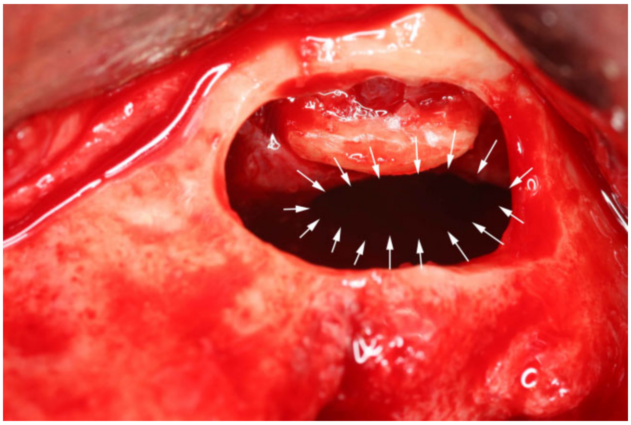

Figure 2 Perforation of sinus membrane during membrane elevation.

having the membrane fold on itself upon further reflection. When this was not possible or sufficient, perforations were repaired using other techniques such as suturing or placement of a collagen barrier.

The prepared subantral cavity was then grafted with freeze-dried bone allograft (Puros, Zimmer Dental, Carlsbad, CA, USA), xenograft (Bio-Oss, Geistlich Pharma AG, Wolhusen, Switzerland) or a combination of the two. In some cases, autogenous bone was also harvested from adjacent sites and added to the graft mixture. The lateral window osteotomy was then covered with an absorbable collagen barrier (Bio-Gide, Geistlich Pharma AG), as the use of such membranes is associated with higher implant survival rates.[22] Subsequently, a periosteal-releasing incision was performed, and flap replacement was achieved with tension-free primary closure using a combination of horizontal mattress and simple interrupted sutures. Postoperative instructions were given to patients in addition to an antibiotic regimen consisting of amoxicillin/clavulanic acid (500/125 mg every 12 hours for 1 week) or clindamycin (300 mg every 6 hours for 1 week). An inflammatory regimen consisting of iburofen (600 mg every 6 hours) was also prescribed.

In cases where concomitant implant placement was possible, the implant osteotomies and implant placement were performed following membrane elevation. Feasibility of concomitant implant placement was determined based on the amount of residual bone height available (greater than 4 mm) as well as the ability to achieve primary stability of the implant. In order to avoid perforation of the membrane during implant osteotomy preparation and placement, the membrane was kept elevated during these procedures with the use of a membrane elevation instrument. In cases where simultaneous implant placement was not possible, implants were placed with a delayed approach.

Two independent investigators (AG and DSW) performed data collection. When conflicting results arose between investigators, an agreement was reached by discussion. The data collection consisted of a chart review and the recording of all variables in a customized Excel spreadsheet (Excel 2003; Microsoft, Redmond, WA, USA). These treatment variables included the following: technique used for the preparation of the lateral window osteotomy; incidence of perforation of the sinus membrane; time of occurrence of the perforation (during preparation of the osteotomy or during elevation of the sinus membrane); and postoperative complications (flap dehiscence, sinus infection, pain not controlled by analgesic medications). The information was recorded as it was reported in the dental record of each patient. If the investigators encountered conflicting or unreadable information, the treating surgeon was contacted for clarification, and the data were updated accordingly.

Fisher's exact test was used to assess the influence of the conventional and experimental technique on the occurrence of perforations at different time points (during osteotomy preparation and during elevation of the membrane). All analyses were implemented with SAS 9.2 (SAS Institute Inc., Cary, NC, USA).

RESULTS

The total number of patients treated with a lateral window maxillary sinus augmentation was 95. Two patients were excluded from the study, because the patient record was not available for review. This resulted in a total of 93 consecutive patients (130 maxillary sinus augmentation procedures) included in the study (Table 1). Perforations of the schneiderian membrane during preparation of the lateral window osteotomy were detected in 14 out of 51 sinuses (27.5% of the sinuses) in the conventional group and 10 out of 79 sinuses (12.7% of sinuses) in the experimental group.

TABLE 1 Patient Information and Results of Study

	Group	
	Conventional	Experimental
Number of patients	42	51
Number of maxillary sinuses treated	51	79
Incidence of membrane perforations		
During window osteotomy (%)	14 (27.5)	10 (12.7)
During membrane elevation (%)	22 (43.1)	20 (25.3)
Incidence of postoperative complications per procedure		
Flap dehiscence	5	10
Sinus infection	2	2
Uncontrolled pain	2	3

Conventional: High-speed surgical handpiece with rotary burs. Experimental: Sonic.

Perforations of the schneiderian membrane during manual elevation were present in 22 out of 51 sinuses (43.1% of the sinuses) in the conventional group and 20 out of 79 sinuses (25.3% of sinuses) in the experimental group. According to Fisher's exact test, both these differences in perforation rates were statistically significant ($p < .05$). Postoperative complications (Table 1) affected five out of 42 patients in the conventional group (9.8%) and 15 out of 51 patients in the experimental group (19%). This difference was not statistically significant ($p > .05$).

TABLE 2 Comparison of Sonic and Ultrasonic Instruments for Bone Surgery

Characteristic	Sonic	Ultrasonic
Frequency	6–9 kHz	20–45 kHz
Amplitude	60–1000 μm	13–72 μm
Direction of action	Three axes (x, y, and z)	One axis
Source of vibration	Compressed air	Piezoelectric
Source of irrigation	Dental unit water reservoir	External reservoir

DISCUSSION

The null hypothesis investigated in this study was that there is no difference in the incidence of perforations of the schneiderian membrane during lateral window sinus augmentation procedures performed with a conventional turbine handpiece with rotary diamond stones versus a sonic handpiece with a diamond-coated insert. The sonic handpiece had a statistically significant lower perforation rate (12.7%) during preparation of the osteotomy window and elevation of the membrane (25.3%) versus the conventional turbine handpiece and rotary diamonds (27.5% and 43.1% of perforations, respectively); therefore, we rejected the null hypothesis.

High survival rates have been reported for implants placed in grafted sinuses.[22–24] Unfortunately, perforation of the schneiderian membrane is the most frequent complication encountered during lateral window sinus augmentation. The use of ultrasonic instruments during the preparation of the lateral window osteotomy seems to reduce the occurrence of this type of complication.[20] Although the exact mechanisms behind the selective cutting action of bone as opposed to soft tissue of sonic devises are still not fully understood, the reduced perforation rate may be attributed to the handpiece's high frequency that produces vibrations ideal for ostectomy and osteoplasty while allowing for preservation of soft tissue.[25,26]

When comparing the results of the present study with those of another study utilizing an ultrasonic piezoelectric instrument, the rate of perforation of the schneiderian membrane during preparation of the osteotomy with the sonic handpiece (12.7%) was found to be higher than that observed with an ultrasonic piezoelectric instrument.[20] Although this difference could be anecdotally attributed to the different amplitudes and frequencies of the two oscillating instruments (Table 2), a more plausible and likely explanation could be differences in operator experience between the studies. In the present study, periodontal residents performed all the sinus augmentation procedures, whereas experienced clinicians executed all procedures in the ultrasonic piezoelectric study.[20]

Although the aforementioned retrospective studies seem to find significant clinical benefits in the use of sonic or ultrasonic instruments for the preparation of the lateral window osteotomy, a recent randomized controlled clinical trial failed to demonstrate a significant difference in the incidence of schneiderian membrane perforations when sinus augmentation was performed with a conventional turbine handpiece/rotary burs or an ultrasonic piezoelectric instrument.[27] In this study, the occurrence of membrane perforations was 30% for the piezoelectric device and 23% for conventional rotary instruments.[27] The outcome of this clinical trial should be interpreted carefully, because differences in the surgical technique and patient selection may account for the discrepancy in these results. Indeed, they utilized the piezoelectric device for preparation of the lateral window osteotomy and for sinus membrane elevation.[27] In contrast, Wallace and coworkers[20] switched to the use of manual sinus membrane elevators following preparation of the lateral window osteotomy with the piezoelectric instrument. Additionally, as acknowledged by the authors of the study, the sample size ($n = 13$) may not have been large enough to allow enough power to detect significant differences between the experimental and control groups. Therefore, it is possible that a type II statistical error could have occurred.[27]

In the present study, a significant difference in the rate of recorded membrane perforations between conventional and experimental groups was seen, not only

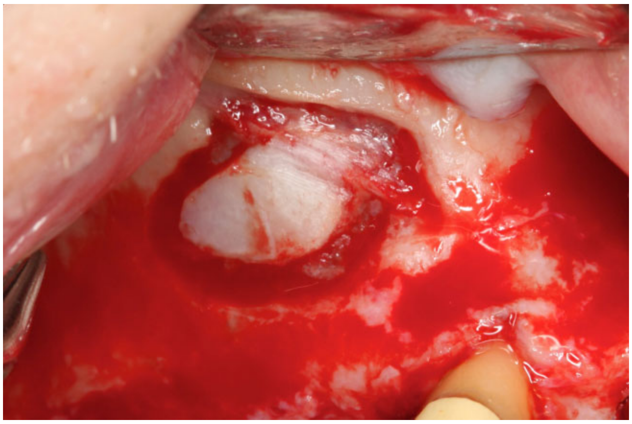

Figure 3 Intraosseous artery identified and isolated during lateral window osteotomy using the sonic instrument.

during the preparation of the lateral window osteotomy, but also during the elevation of the membrane. Because the membrane elevation was carried out with the same technique (manual elevation with dedicated sinus elevators) in both groups, this result is puzzling to the authors. It could be speculated that the preparation of the lateral window osteotomy with rotary instruments, while not causing a clearly visible perforation, might somehow weaken or compromise the integrity of the membrane, thereby causing a greater likelihood of membrane tear during manual elevation. Although this speculation may be plausible in light of the fact that rotary instruments were used in very close proximity to the membrane during the latter part of the osteotomy, this study did not investigate this variable, and this remains purely a speculation.

Subjectively, clinicians involved in the present study noted that the low vibration frequency of the sonic instrument increased operator visibility and tactile control when compared with the turbine handpiece and rotary diamonds. Additionally, when an intraosseous branch of the posterior superior alveolar artery involving the area of the osteotomy was present, the sonic instrument was capable of separating the artery from the bony wall facilitating its elevation (Figures 3 and 4). Furthermore, a recent in vitro study showed that surgeons with minimal experience had a reduced perforation rate when utilizing a piezoelectric device for osteotomy preparation as compared with a conventional rotary device, although the difference was not statistically significant.[28]

There are a limited number of studies directly comparing the sonic and ultrasonic devices. Heinemann and coworkers[29] histologically compared the effects of ultrasonic, sonic, and conventional turbine rotary devices on fresh porcine mandibular jaws. They found that the average heat generated by the sonic instrument was similar to that generated by the conventional rotary cutting instrument (1.54–2.29°C), whereas the piezoelectric device produced a greater rise in temperature (18.17°C). At the histological level, the bone matrix adjacent to the defects created by all three instruments displayed intact osteocytes and a similar damage zone diameter in the apical region; however, the sonic instrument produced narrower defects with smooth cutting surfaces and minimal damage in the coronal defect zone when compared with the other two instruments. The significance of these results is not clear.

The number of postoperative complications between the two groups was not statistically significant ($p > .05$); however, the patients in the sonic group experienced more flap dehiscence. Although the reason of this difference was not investigated in this study, we could speculate that the increased surgical time required to prepare the lateral window osteotomy with the sonic handpiece might have played a role in the increased incidence of this type of complication. While up to the end of this study, all of the patients presenting with flap dehiscence healed completely, the long-term sequelae of this postoperative complication remains unknown.

Limitations of the present study should be noted. As this is a retrospective analysis, there is no possibility for randomization, and although consecutive cases were used, there is still the possibility of selection bias. Furthermore, the accuracy of data collection is limited to

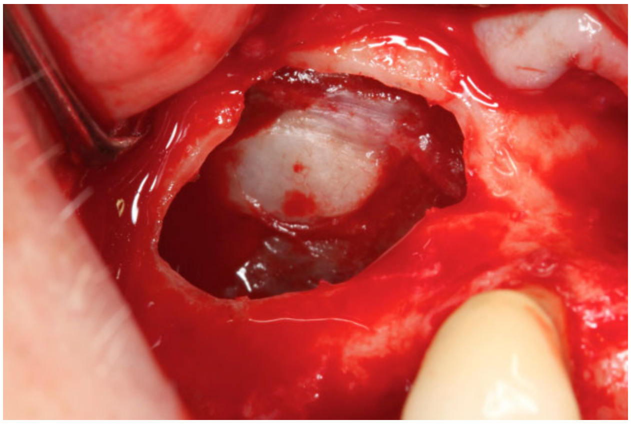

Figure 4 Lateral window prepared and elevated with intraosseous artery intact.

what was reported within the chart. Although clinicians in a residency program performed all the procedures, differences could still exist in terms of clinicians' surgical experience. Moreover, there is a difference in the number of patients and treated sinuses between the two groups. Finally, this study did not investigate the occurrence of membrane perforations when a surgical electric handpiece was used for the osteotomy of the lateral window. The reduced vibration and increased tactile feedback of the surgical electric handpiece may play a major role in the reduction of this intraoperative complication. This question should be investigated in further studies.

To the best of the authors' knowledge, this is the first study comparing the use of a sonic oscillating handpiece and a conventional turbine handpiece during sinus augmentations; however, further prospective studies are needed to compare the efficacy and time needed to perform the lateral window osteotomy between sonic, piezoelectric, and rotary instruments.

CONCLUSION

Within the limits of this study, the use of sonic instruments during lateral window sinus elevation procedures results in a lower schneiderian membrane perforation rate than conventional turbine handpieces with rotary diamond stones.

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