AN *IN VITRO* COMPARISON OF PIEZOELECTRIC AND ROTARY OSTEOTOMIES DURING LATERAL SINUS WALL SURGERY

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ABSTRACT

Piezoelectric and high speed rotary instrumentation have proven to be viable methods of preparing osteotomies during lateral sinus wall surgery. Piezoelectric units have been suggested to have superior access and control as well as the ability to discern between soft and hard tissue. The major disadvantage of the piezoelectric technology is the reduced speed at which osteotomies are prepared. The purpose of this study was to evaluate the difference in operator perception, speed and membrane damage between the two modalities.

Seven different operators prepared 4 osteotomies in 2 mm thick polyurethane sheets backed by 0.2 mm thick plastic wrap. The preparation speed and incidence of membrane damage were recorded after each osteotomy. The operator perception of each modality was recorded at the end of the preparations. Several questions were asked to evaluate the accuracy, visibility, vibration, comfort and ease of use of both modalities.

Results showed that rotary instrumentation was 160% faster than piezo ($p<0.001$), but resulted in 370% more damage and 130% more perforations ($p<0.01$). Surveys of operator preference showed piezo units with higher scores for accuracy and visibility ($p<0.05$).

This study showed that *in vitro* a piezo unit compared to a rotary unit results in less membrane perforation and damage, higher perception of accuracy and visibility, but longer osteotomy preparation time.

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CHAPTER 1

INTRODUCTION

Piezoelectric technology had its first use in dentistry described by Catuna in 1953; relating to cavity preparation. In 1955, Zinner[1] used this technology to scale teeth. Piezoelectric units became more efficient and smaller but their use for bone cutting was still in its infancy.[2,3,4,5] The first published use of a piezoelectric unit specifically for surgical bone cutting was the Mectron, the article was published in 2000 by Vercellotti.[6] That led the way for other manufacturers to produce piezoelectric units and the general acceptance of piezoelectric technology as a viable alternative to rotary instrumentation for ostectomy, osteotomy, and osteoplasty in dentistry and in other fields.

The lateral window approach to maxillary sinus augmentation is a common procedure in implant therapy. It was invented by Tatum,[7] but first published by Boyne and James in 1980.[8] The procedure augments an often deficient height of bone in the posterior maxillae due to sinus pneumatization. After or during augmentation implants may be inserted in the posterior maxillae to restore posterior maxillary occlusion. The lateral window approach requires a 'window' to access the underlying Schneiderian membrane. During preparation of the window inadvertent contact with the membrane may cause damage or a perforation.[9] The rate of perforation has been reported to be anywhere from 10-50%.[10] Classically the window osteotomy has been created using rotary instruments. Due to the ability of piezoelectric technology to differentiate between mineralized and non-mineralized tissue when cutting, these units have been reported to minimize the incidence of membrane tearing to 3.6-7%.[10,11] This is one possible advantage of piezoelectric units over rotary instruments. However, the studies showing reduced perforation rates with piezoelectric units are more recent and have the aim of specifically evaluating sinus perforation rates.

Another significant advantage is the clearance of fluid from the surgical site creating more visibility for the surgeon. During lateral sinus wall surgeries this is extremely important as a perforation in the membrane can come from as much as 0.1 mm of overextension. Also aiding in the surgical visibility is the narrow diameter of some of the tips of piezoelectric units. Surgical ease may be increased when using piezoelectric technology due to the ability to use various tips of different shapes. This contrasts sharply with rotary instruments which consist of circular instruments. The inferior cut at the harvest site during ramus block grafts surgeries is significantly easier to access safely with the reach of a 90 degree bend in the tip of the piezoelectric unit. Additionally, patient sensation of vibration is decreased when using piezoelectric units. When compared to rotary instrumentation, piezoelectric prepared ostectomies have been shown to result in increased viable osteocytes and less necrotic tissue.[12] Moreover, some authors[13] have reported increased osteogenic and improved cytokine activity. The last point is equivocal though, as the integrity of such studies have been challenged[14] and are of notably of low evidence level.

There are disadvantages to piezoelectric technology as well. The most published disadvantage is that of time. In lateral sinus wall surgery, piezoelectric units were reported to make the entire procedure take 15% longer.[15] Wisdom tooth extraction was reported to require 35% more time when using piezoelectric units.[16] However, others who studied the time issue found no difference in increased time when utilizing piezoelectric units for orthognathic surgeries.[17] Another disadvantage is the acquisition of a piezoelectric unit itself with some units costing near 8,000 USD. Tips for the piezoelectric units last much longer than burs but are far more expensive.

One must be very judicious when considering the advantages and disadvantages of using piezoelectric technology for lateral sinus wall surgeries as the weighting for clinical practice can be quite equivocal. Probably the two most influential issues with using piezoelectric technology for lateral wall osteotomies are that of surgical time and membrane perforation. The effect of increased surgical time may be an increased infection rate and increased post-operative discomfort. The effects of membrane perforation may be decreased implant survival and increased graft infection; more so when the perforations are larger.[18,19] Proussaefs et al. looked at 12 subjects requiring bilateral sinus augmentation and reported 33.58% bone formation for non-perforated sinus grafts and only 14.17% bone formation for perforated sinus grafts after healing.[20] They also looked at implant survival and found at second-stage implant surgery the non-perforated membrane implant survival rate was 100% whereas it was only 69.6% ($p=0.0028$) in the perforated group. While perforation of the Schneiderian membrane may be detrimental to implant therapy, consideration should be given to the major cause of perforation. Studies[10,11] have shown that perforations are most often associated with elevation of the membrane using hand instruments after initial osteotomy where the difference between using a piezo tip or bur may have no effect. It is still plausible to achieve a decrease in membrane perforation due the use of a piezoelectric unit though, as damage to the membrane during osteotomy preparation may not reveal itself until elevation.

The purpose of this study is to evaluate the differences between piezoelectric units and a high-speed bur *in vitro* with respect to operator perception, speed and membrane damage during lateral wall osteotomies.

CHAPTER 2

METHODS AND MATERIALS

Polyurethane sheets (2x130x180 mm -- Sawbones Worldwide Inc.) were used to simulate the lateral sinus wall *in vitro* as shown in Figure 1. The density of polyurethane used was consistent with cortical bone lateral to the maxillary sinus (40 pcf). The sheets were then marked with 16 20x20 mm circles as shown in Figure 2. Each sheet was sided with a plastic wrap (0.02 mm thick – Saran plastic wrap, a low-density polyethylene) simulating a thin Schneiderian membrane and held down via adhesive tape (3M, Scotch) as shown in Figure 3.

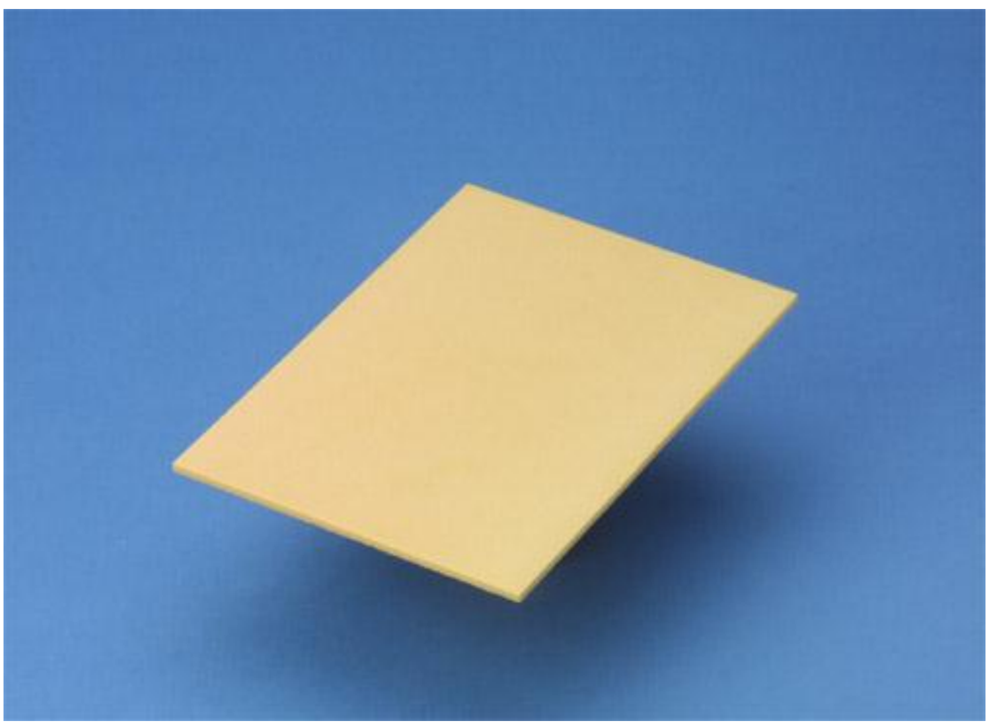

Figure 1. A polyurethane sheet.

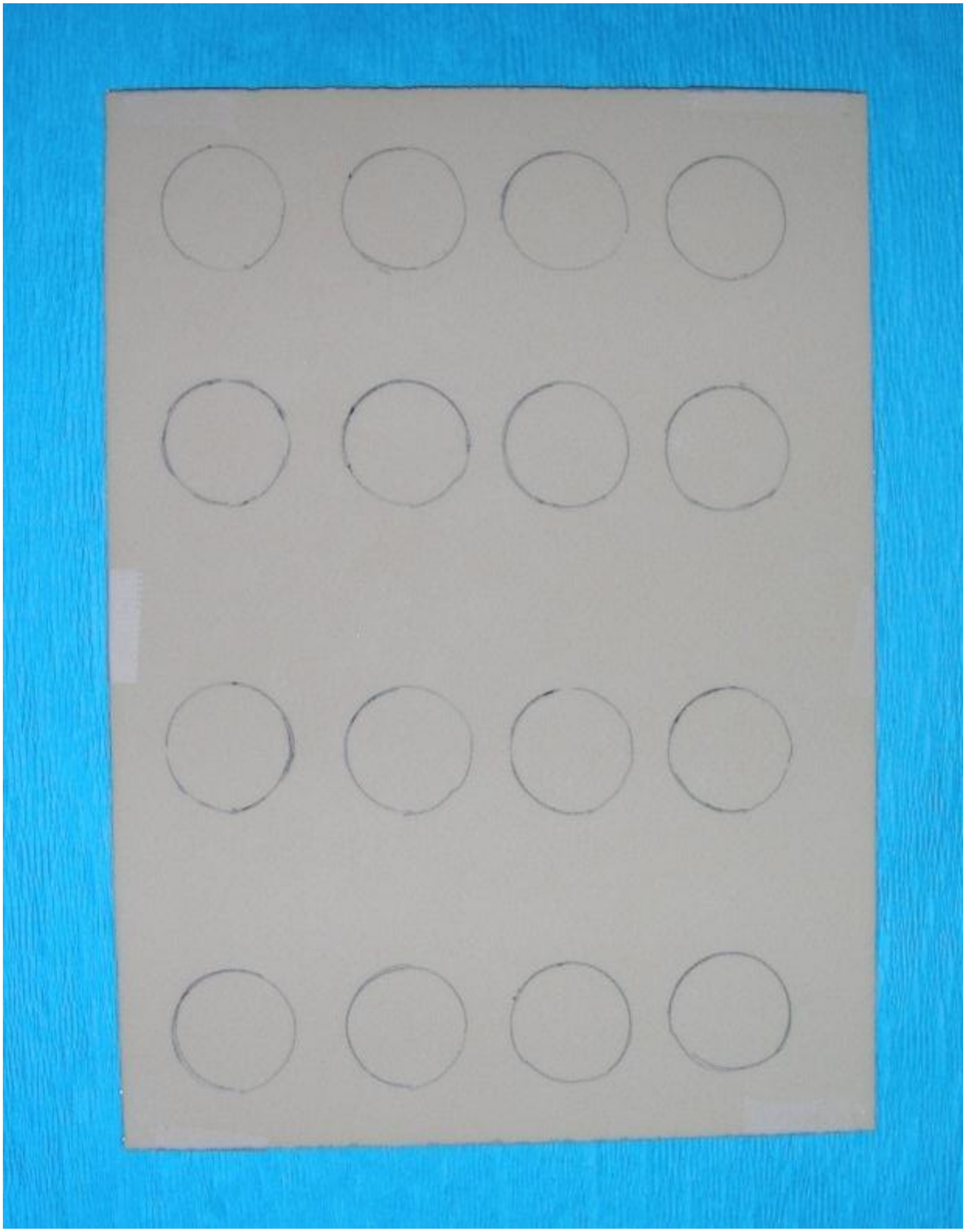

Figure 2. Front of marked and wrapped polyurethane sheet.

Figure 3. Back of marked and wrapped polyurethane sheet.

Figure 4. Armamentarium.

The rotary instrument used was a W&H Synea HS handpiece with a new coarse round diamond bur for each operator (Brasseler USA, 6801.31.014). The piezoelectric instrument used was the VarioSurg Ultrasonic Bone Surgery System with a new VarioSurg SG7D round diamond tip as shown in Figure 4. The power setting of the VarioSurg Ultrasonic bone Surgery System was placed at 100% and the water setting at 2 as shown in Figure 5.

Figure 5. VarioSurg Ultrasonic Bone Surgery System.

The sheets were positioned on two tables so that the osteotomy currently being prepared had no table underneath (in order to properly simulate perforations). The operators were instructed to pay attention to accuracy, vibration, comfort, visibility, and ease of use during their osteotomies. The operators were also instructed that they would see a blue hue simulating thin bone before osteotomy perforation and that membrane damage and perforations were being recorded and should attempt to be avoided. Seven operators (6 graduate periodontal residents, 1 graduate periodontal instructor) then made 4 circular osteotomies each simulating a lateral window approach, following the traced outlines as shown in Figure 6. Osteotomies were timed by an independent observer with a stopwatch and considered complete when the polyurethane window was able to be completely removed with minimal force. Two of each of the operator's osteotomies were made with a bur and the other 2 with a piezo tip for a total of 4 osteotomies per operator.

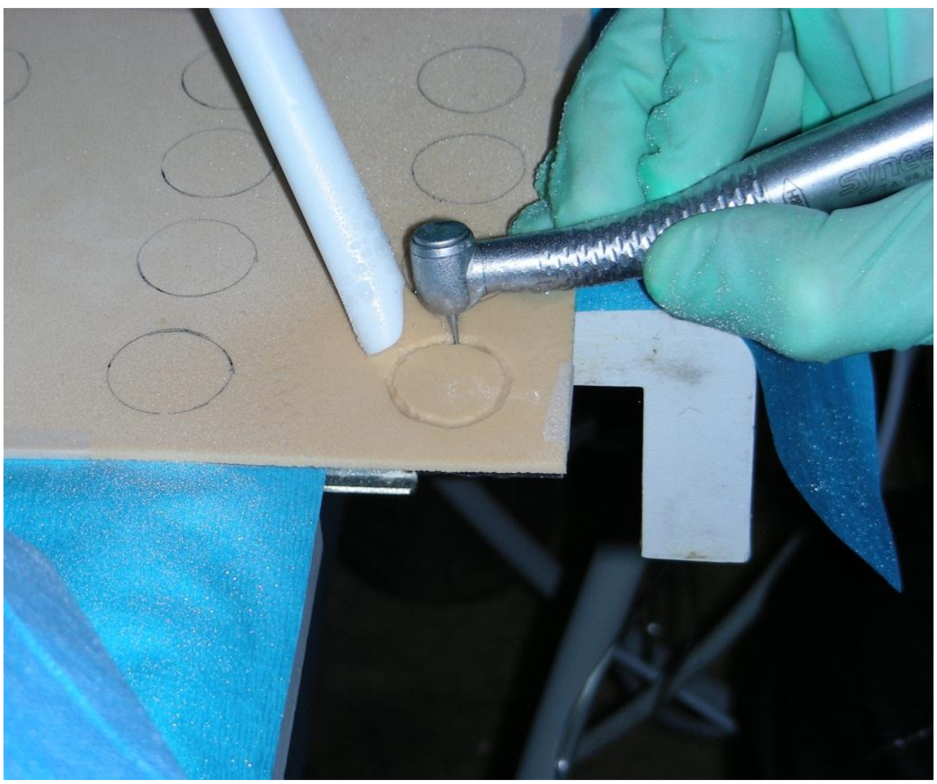

Figure 6. Osteotomy preparation.

After each operator completed their set of 4 osteotomies they were surveyed on operator perceptions using a VAS. This included perception of accuracy, vibration, comfort, visibility, and ease of use. The plastic wrap was then cleaned and studied under magnification to visualize and record damage and perforations as shown in Figure 7. A 'site' was defined as the width of a bur (2 mm) around the periphery of the osteotomies. A perforation was recorded at a site if it showed any communication of air from one side to the other. Damage was recorded at a site if the plastic wrap was altered enough to cause visible distortion of light when taut. Reproducibility measurements were conducted by repeating damage and measurement scores 5 times for the first 4 osteotomies.

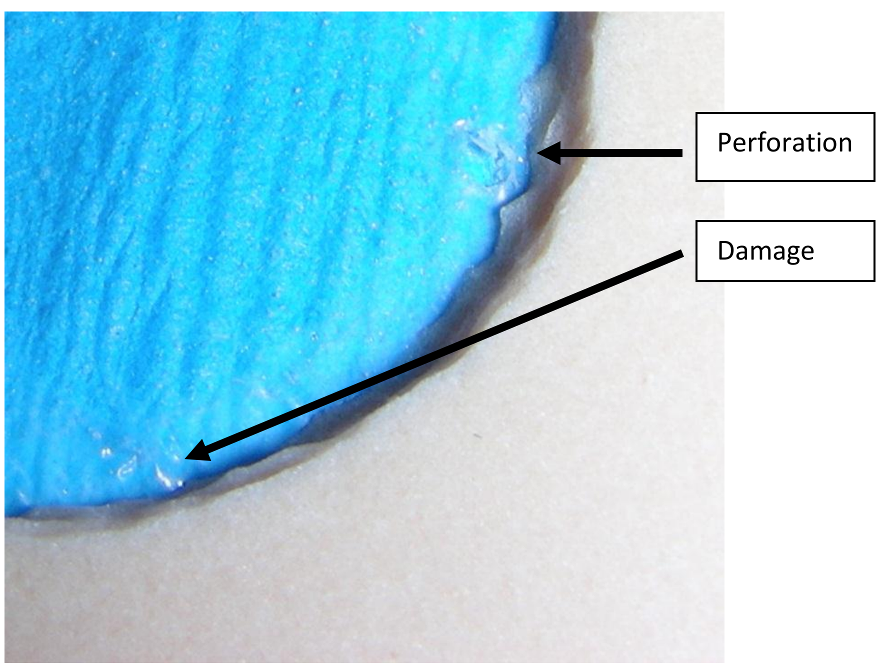

Figure 7. Magnified view of membrane damage and perforation.

Statistical analysis to detect statistically significant differences between the two modalities (piezoelectric and rotary) was performed using repeated measures ANOVA for all operators for speed, perforations and damage. A paired t-test was used to detect statistically significant differences between the modalities on the basis of VAS of accuracy, vibration, comfort, visibility, and ease of use from the survey. A p-value of <0.05 was considered statistically significant.

CHAPTER 3

RESULTS

The average times for each operator to complete an osteotomy with each instrument is shown in Figure 8. The rotary instrumentation was significantly faster than piezoelectric technology. Average intra-operator osteotomy times for the piezo varied from 2.2-4.5 times higher than the bur. Average osteotomy times between all operators were 2.6 times faster when using a bur ($p<0.001$).

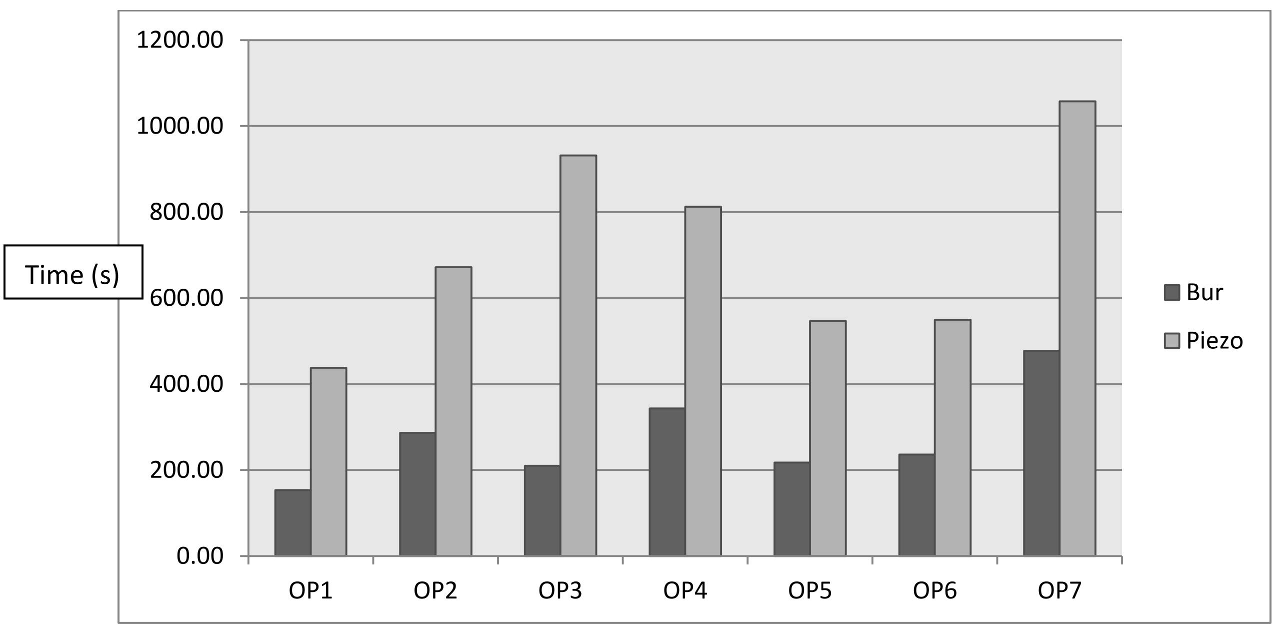

Figure 8. Cutting speed of piezoelectric versus high-speed bur.

The average number of sites of perforation and membrane damage for each operator with each instrument is shown in Figure 9 and Figure 10. On average, rotary instrumentation yielded 4.7x more damage than piezoelectric instrumentation and 2.3x more perforations ($p<0.01$) as shown in figure 11. The damage and perforations were 100% reproducible upon 5 different re-examinations of the first 4 osteotomies.

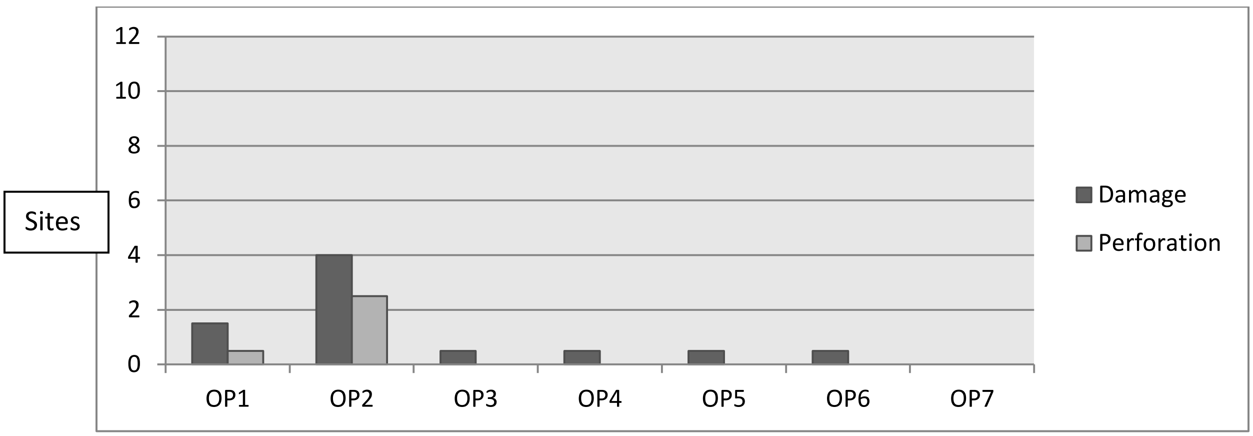

Figure 9. Average number of sites of damage and perforation using piezoelectric instrumentation.

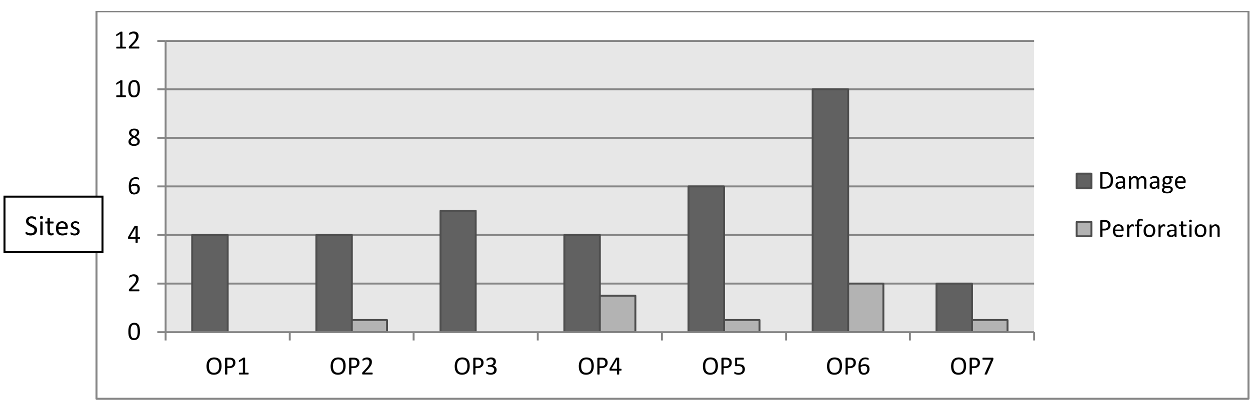

Figure 10. Average number of sites of damage and perforation using rotary instrumentation.

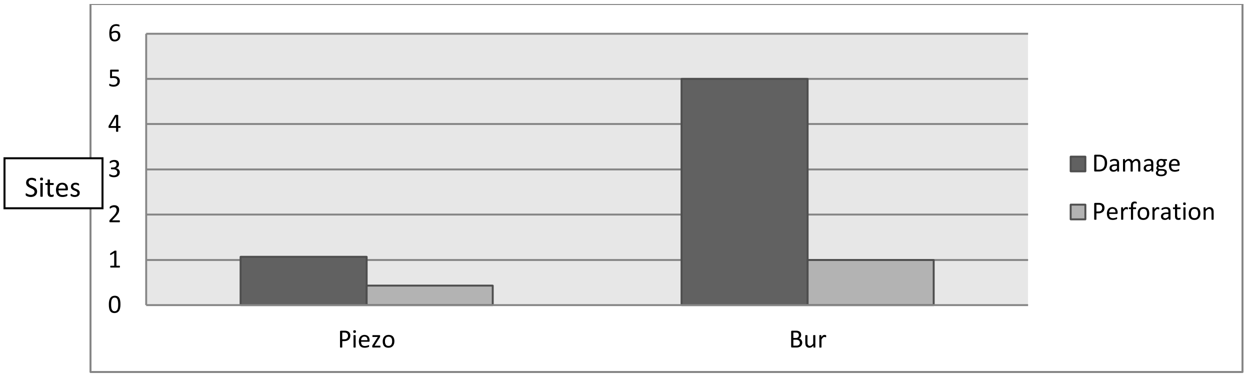

Figure 11. Average number of sites of damage and perforation.

VASs of perceptions during osteotomy preparation are shown in Figure 12. Piezoelectric instrumentation scored statistically significantly higher than rotary instrumentation for accuracy and visibility ($p<0.05$). No statistically significant differences were found between the two modalities on the basis of vibration, comfort or ease of use ($p>0.05$) based on the paired t-tests.

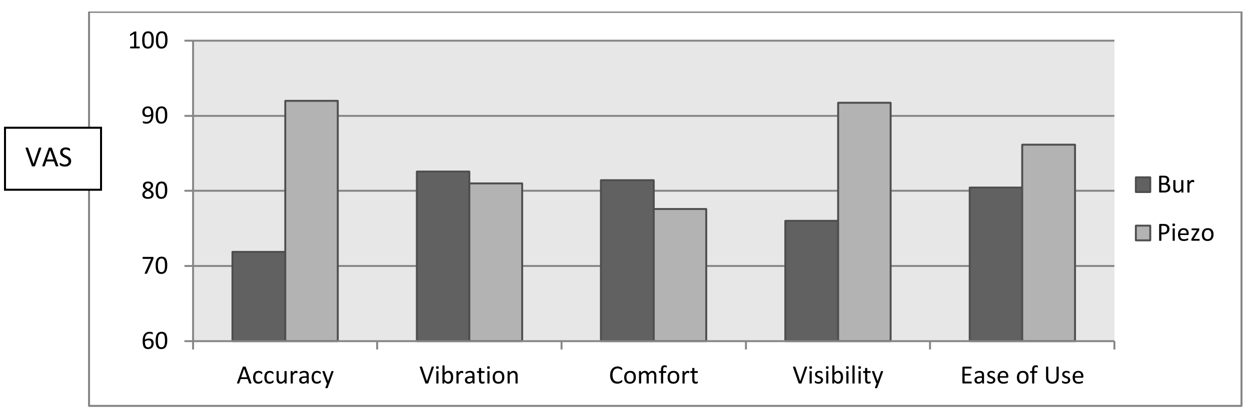

Figure 12. Average VAS scores of operator perception on rotary and piezo instrumentation.

The bur also yielded consistently more jagged osteotomies than the piezo tips as illustrated in Figure 13.

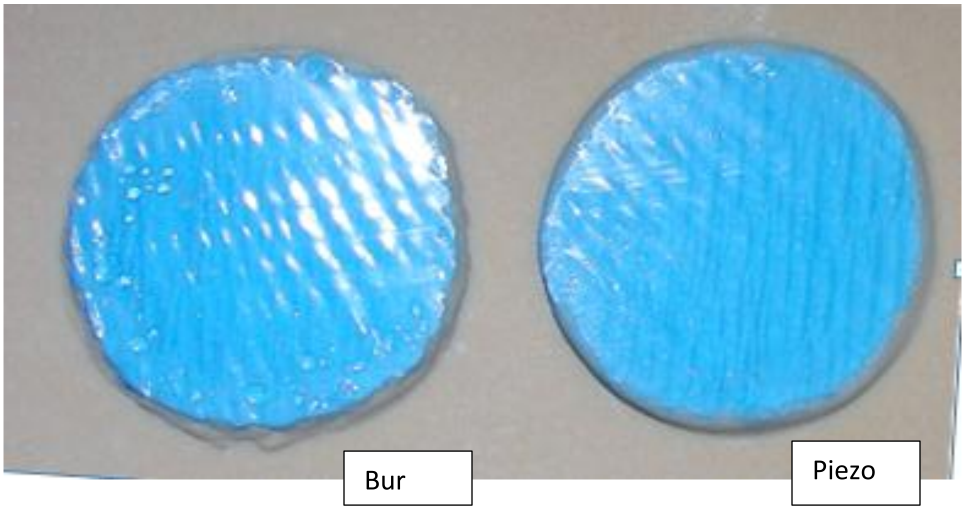

Figure 13. Bur and piezo osteotomies in a polyurethane sheet.

CHAPTER 4

DISCUSSION

With the significant increases in implants being placed, sinus augmentation procedures for deficient posterior maxillae are becoming more and more popular. There is a current paucity of data comparing the various instrumentation available for use during sinus augmentation procedures.

This study found high speed rotary instrumentation to be 160% faster than piezo instrumentation for the preparation of a window osteotomy in a lateral window approach to maxillary sinus augmentation in an *in vitro* model. This difference is consistent with other studies[15, 16] which found 15-35% longer *in vivo* operations considering that the osteotomy may only comprise less than a quarter of the total time required for the sinus augmentation. This suggests the use of a piezoelectric unit for preparing maxillary sinus osteotomies will cause significantly longer surgical times than using a high speed rotary unit.

Osteotomies created via piezoelectric units had less than half the number of sites showing damage and/or perforation. This is also consistent with other studies[11] that showed reduced perforation rates when using the piezoelectric unit to prepare the window osteotomies. This study further supports the notion that piezoelectric units reduce the likelihood of membrane damage and/or perforation compared to high speed rotary instrumentation. The reduction in damage and perforations may be due to the piezoelectric technology itself or simply due to the less aggressive nature of the technology.

Accuracy and visibility as judged by operator perception was statistically significantly higher when using a piezoelectric unit. This is expected as the high speed bur head was close to the cutting tip often blocking view. Additionally, due to the increased cutting speed of the bur, accuracy is expected to decrease.

Polyurethane blocks were selected as the bone analog due to similar properties to natural bone. The American Society for Testing Materials considers polyurethane a standard test for *in vitro* assessment of orthopedic devices.[21,22] The density of polyurethane used was consistent with cortical bone lateral to the maxillary sinus (40 pcf). The plastic-wrap (Saran – low-density polyethylene) attached to the back of the polyurethane blocks was chosen based on its similar properties to the Schneiderian membrane. The average Schneiderian membrane can withstand tensile forces of 7.3MPa.[23] Low-density polyethylene used in a plastic sheet can withstand a tensile force of 9.9MPa.[24] While this is similar, the low-density polyethylene can undergo 390% elongation compared to 132% with the average Schneiderian membrane. Still, the low-density polyethylene was able to easily record markings from the burs and piezo tips when held taut under light. For these reasons the plastic wrap was chosen as the Schneiderian membrane analog.

This study chose to use a round diamond piezoelectric tip instead of a saw piezoelectric tip. Both have been used for sinus augmentation procedures. In 2010, Sohn et al.[25] showed statistically insignificant differences in perforation rates between using a saw versus round diamond piezo tip during lateral sinus wall augmentation and concluded that the saw was a more effective tip. However, their conclusion was erroneous as they reported over 3-fold the number of perforations when using a saw tip compared to the round diamond tip despite statistical insignificance ($p=0.26$). This suggested that the saw tip was associated with more perforations, not a similar amount as stated in the study. Thus, in this study we decided to use the round diamond tip.

A question unanswered is whether or not the difference in the damage, perforation, and accuracy is due to the difference in technology or simply due to the aggressiveness of the technology. Perhaps a less aggressive bur or slower headpiece would yield similar results to the piezoelectric unit.

There are limitations to this data. The polyurethane blocks are not identical to bone and presented more rigid fixation of the window during osteotomy than is present *in vivo*. Thus, more aggressive osteotomies were required to complete the osteotomy and remove or elevate the window. This helps explain why this study had a much higher rate of membrane perforation than other studies.[26,27] Additionally, the plastic wrap had different properties than the Schneiderian membrane. The wrap had a slightly higher tensile strength and was able to undergo significantly more elongation. Another limitation is that the access to the osteotomy site was extremely ideal. This study failed to take into consideration the significant access difficulties associated with this procedure *in vivo*. Also, despite attempts to avoid this, most operators admitted that if it were a live patient they would have likely taken more time to prepare their osteotomies due to the associated consequences. A final limitation is that this study only examined perforations and damage created during osteotomies. Studies[10,11] have shown minimal perforation rates during the osteotomy stage of the lateral sinus lift procedure. Most perforations occurred on during lifting with hand instruments and were associated with either a very thin membrane or a septum. However, it is possible that method in which the osteotomies were prepared may affect the tear rate during lifting due to membrane damage.

Future research should be directed at completing *in vivo* studies to see how applicable this data is in clinical practice and how osteotomies affect overall sinus perforation rates. Additionally, future research should compare the difference between rotary and piezoelectric technology with equal aggressiveness to discern if the difference in results found here is due to aggressiveness or technology. A final area for future research is to detail when damage and perforations occur and to isolate the temporal causes associated.

CHAPTER 5

CONCLUSION

In an *in vitro* model of lateral sinus wall osteotomies, a rotary unit with a round diamond bur will prepare the osteotomy 140% faster ($p<0.001$) when compared to a piezoelectric unit with a round diamond tip. However, the rotary unit will result in the perception of less accuracy, and visibility, ($p<0.05$) as well as more 370% more membrane damage and 130% more membrane perforations ($p< 0.01$).

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