Piezoelectric device use in sinus osteotomy for equines is feasible but may extend time to accomplish frontonasal bone flap

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OBJECTIVE
Sinus osteotomy is currently performed in equine surgery with conventional surgical methods, such as trephines and oscillating bone saw, leading to subsequent trauma to the bone during cutting. Piezoelectric devices are now used in maxillofacial surgery in humans as a standard tool as it is less traumatic than the oscillating bone saw and shortens the healing period. The aim of this study was to show that the piezoelectric device can be used for equine sinus surgery, compare its use with the oscillating bone saw, and describe the outcome of cases involving osteotomy performed with a piezoelectric surgical device.

ANIMALS
10 horse specimens for cadaveric study and 11 client-owned equines for clinical evaluation.

METHODS
Each cadaveric head underwent a frontonasal bone flap on a randomly assigned side with the piezotome and the oscillating bone saw on the opposite side. Surgical time was recorded for every procedure, and gross examination was performed. A Welch t test was used to compare the surgical time between piezoelectric and oscillating saw use. For the clinical study, animals presented for sinonasal surgery at the hospital from March through October 2023 were included.

RESULTS
Osteotomy was possible with the piezotome in all animals. Surgical time was significantly increased when using the piezotome in comparison with the oscillating saw (P < .05). All clinical patients were treated adequately for the sinonasal disorder they were presented for using the piezotome instead of the oscillating saw. No adverse effects nor long-term complications related to its use have been noted, and preservation of the surrounding soft tissues was evident.

CLINICAL RELEVANCE
The use of a piezoelectric device in equine surgery is feasible. However, the cadaveric study showed an increased surgical time to perform a frontonasal bone flap.

Keywords: piezotome, horse, sinus, sinusitis, piezoelectric surgery

Sinonasal disorders are common in horses of all ages. To adequately diagnose and treat sinus disease, open access to the paranasal sinuses is often needed. Currently, minimally invasive access to sinuses is preferred, but larger osteoplastic flaps are sometimes needed for removal of large masses.

Those procedures can be invasive regarding the extensive access needed to treat conditions such as sinus cysts or progressive ethmoidal hematomas.1,2 In addition to incisional complications to the bone and periosteum, other problems, such as inflammation, hematoma formation, significant blood loss, and postoperative pain, are described both in humans3 and equine species, and suture exostosis has been reported in horses.4–7

Manual instruments, such as osteotomes paired with a mallet or trephines, are chosen to prevent...
heat generation during bone cutting. However, they necessitate significant force, operate at a slower pace, and consequently pose a risk of mechanical damage to surrounding tissues.\textsuperscript{11,12} Powered instruments (such as an oscillating bone saw) can cause thermal injury when used without cooling. This can induce osteonecrosis at the incision site and impair postoperative healing.\textsuperscript{10} In the human literature, piezoelectric surgery has been described as an efficient tool to achieve bone cutting while preserving the surrounding soft tissues.\textsuperscript{11,12} The main advantages described in piezoelectric surgery include selective cutting for mineralized tissue, resulting in less damage to surrounding neurovascular structures, reduced bleeding, improved healing, precise cutting, and excellent visibility.\textsuperscript{13} Piezoelectric devices are often presented with a built-in light-emitting diode light on the instrument, improving the visibility of the surgical site combined with less blood contamination and excellent flushing. Unfortunately, piezoelectric surgery is also said to prolong surgical time compared to powered bone-cutting devices.\textsuperscript{14}

The piezoelectric surgical tools use 6 piezoelectric ceramic rings activated by an electrical current to selectively disrupt the mineralized tissue (eg, bone). This is triggered in the handpiece, and an ultrasonic harmonic oscillation is created and transmitted to the surgical insert tip. Harmonic acoustic shockwaves and the pressure-induced cavitation effect allow the cutting instrument to disrupt the bone precisely and selectively. Thermal bone injury is prevented by the continuous water-cooling system incorporated into the instrument.\textsuperscript{11}

The aim of the study is to show that the piezotome can be used as a bone-cutting instrument for equine sinus surgery both in cadaveric heads and live horses and that surgical time would be different compared to the use of an oscillating bone saw.

**Methods**

**Ethical statement**

The study was divided in 2 sections: a cadaveric model and a retrospective study with client-owned animals. All horses used for the cadaveric study were humanely euthanized for reasons unrelated to sinonasal disorders. All animals in the second phase of the study were treated for their condition; owner consent was obtained to use the piezotome, and hospital records have been reviewed.

**Section 1: cadaveric study**

Cadavers were either used immediately or the heads were removed from the body within 30 minunites of euthanasia, frozen at \(-18^\circ\text{C}\), and subsequently thawed at room temperature for 72 hours before use. The heads were placed on a table during the procedure, or the horse cadaver was placed in lateral recumbency, on the left and right side, successively.

For each cadaveric head, the surgical site was clipped before incision, and frontonasal flaps were created with the piezotome on 1 side randomly determined by flipping a coin and with the air-powered oscillating saw on the opposite side.

An incision was made through the skin, subcutaneous tissue, and periosteum with a No. 24 scalpel blade using standard landmarks to make a sinonasal flap of 10-cm length and 5-cm width. The caudal margin of the flap was made halfway between the medial canthus and the supraorbital foramen from the dorsal midline and 5 cm laterally. The lateral margin of the flap was a 10-cm line vertically oriented. The rostral margin of the flap was a horizontal perpendicular line 5 cm from the lateral line to the dorsal midline.\textsuperscript{6} Prior to bone incision, the periosteum was manually elevated with a Smith Peterson osteotome 2 mm on either side of the bone incision site. For both methods, all of the frontonasal bone flaps were made by the same surgeon (LAD).

**Oscillating bone saw**

An air-powered oscillating bone saw (pneumatic multidrive MPX-610; De Soutter Medical) was used with a blade of 1-cm width on the randomly assigned side of the head. An assistant surgeon was continuously flushing the surgical site with saline (0.9% sodium chloride) during the procedure to avoid overheating of the bone and respiratory contamination for the surgeon with bone microparticles. Both the surgeon and assistant were wearing surgical face-masks during the procedure.

**Piezotome**

A piezotome (OP1 Piezo, bone-cutting tip; iM3) with a scalpel insert was used as the alternative surgical technique on the opposite side of the head. The device provided light and constant flushing with saline (0.9% sodium chloride) while cutting the bone by using ultrasonic vibrations (Figure 1).

For both techniques, bone incision time was recorded manually by the surgeon with a stopwatch before starting bone incision and at the end of the procedure when the bone incision was completed. Careful hand elevation with both hands on the flap enabled the surgeon to lift and create a fracture at the base of the flap.\textsuperscript{2} Both flaps were then inspected macroscopically for gross appearance. Discoloration, precision of the cutting line, and any other events on the surgical site were recorded.

**Section 2: clinical cases**

Retrospective data of client-owned animals presented to the hospital for sinonasal disorders necessitating sinuscopy, sinonasal bone flap, or nasal bone osteotomy from March through October 2023 were included in the study. Oral examination, radiographic examination, and/or head computed tomography were performed prior to surgery. Animals received nonsteroidal anti-inflammatories (phenylbutazone, 1.1 mg/kg, IV, q 24 h) and antibiotics (potassium penicillin 22,000 UI/kg, IV, q 8 h; gentamycin, 6.6 mg/kg, IV, q 24 h) peri- and postoperatively for 5 days. The surgery was performed either under standing sedation and analgesia (morphine, 0.1 mg/kg, IV; detomidine constant rate infusion to effect)
with a maxillary nerve block (mepivacaine, 10 mL; additional subcutaneous infusion as needed) or under general anesthesia (ketamine, 2.4 mg/kg and midazolam, 0.1 mg/kg; IV induction, inhaled isoflurane maintenance) in lateral recumbency with the affected side up.

The surgical site was clipped and aseptically prepared with a combination of 2 successive scrubs of chlorhexidine digluconate 0.5% soap and 80% alcohol scrubs in an eccentric manner from the middle of the surgical field to the outside. The clinical landmarks used for surgery were the same as would be used for conventional sinus surgery. Sinonasal bone flaps were made as previously described. Sinoscopy portals landmarks used to access the conchofrontal sinus were centered on a point situated 60% of the distance between medial canthus of the eye and dorsal sagittal midline of the head and 0.5 cm caudal to the medial canthus. To access the caudal maxillary sinus, the portal was centered 2 cm rostral and 2 cm ventral to the medial canthus of the eye. All surgeries were performed either by a resident surgeon (LAD) and/or a dental surgery specialist (EP).

Follow-up of the clinical cases was either through referring veterinarians in communication with the surgeon involved, through control examination at the clinic, or telephonic interview, and possible complications were noted. Any abnormalities visible to the veterinarian or the owner at less than 2 weeks postoperatively were considered short-term complications.

**Statistical analysis**

Analysis was performed with standard computer open-source software R, version 4.2.3. For the cadaveric portion of the study, the surgical times reported have been compared between the treatment groups. As the data were normally distributed (Shapiro-Wilk test) but the standard deviations (or equivalently the variances) were unequal in the 2 samples, a Welch t test was used to compare the mean surgical time between the piezotome and the oscillating saw. The results showed a significant difference in the mean surgical times of the 2 groups (P = .001), rejecting the hypothesis that there is no surgical time difference with a 95% confidence interval (84.20 to 271.59). The significance level of this study was set at 0.05 (5%).

**Results**

**Section 1: cadaveric study**

Ten adult horses euthanized for reasons unrelated to sinonasal disorders were used in the study. The breeds included 6 Warmblood horses, 2 Anglo-Arabians, 1 Quarter Horse, and 1 Standardbred. There were 3 geldings, 1 stallion, and 6 mares. The
Figure 2—Double cutting line (A, black arrow) visible after using the oscillating bone saw to create a frontonasal bone flap in the cadaveric study. Rostral is to the left, caudal to the right; the flap is elevated in a standard manner using an osteotome (white arrow). Single cutting line realized with the piezotome with a curved edge of the flap (B, white dotted arrow).

Figure 3—Sinusotomy of the right conchofrontal sinus performed with the piezotome on a standing sedated Warmblood horse (A) showing excellent visibility of the surgical site, the cutting line is continuous and precisely performed (B), macroscopic aspect of the bone flap after piezotome use (C); scale bar = 2.5 cm.
ages ranged from 1 to 18 years old, with a median age at presentation of 9 (5.8) years old.

Frontonasal sinus flaps and sinus access were performed successfully in all cases for both techniques. All approaches required 1 attempt, except for case 6, where an improper placement of the tip of the piezotome led to unscrewing of the cutting insert during the procedure. The mean time to achieve the sinusotomy procedure with the piezotome was significantly longer (Welch t test, \( P < .05 \); mean time of 6 minutes and 38 seconds [standard deviation 1 minute and 5 seconds]) in comparison with the oscillating bone saw (mean time of 3 minutes and 40 seconds [standard deviation 1 minute and 18 seconds]) (Supplementary Table S1).

Macroscopic inspection of the bone incision revealed in 3 cases that the conventional technique with the oscillating saw led to 2 separate incision paths next to each other, which was not observed with the piezotome. Also, using the piezotome allowed rounding of the corners of the bone flap (Figure 2), which was much more difficult to achieve with the oscillating saw. Overall, the surgeon had greater control and precision using the piezotome even though a learning curve was necessary for proper use and to avoid discoloration of the bone flap due to thermal damage. This was observed in 5 cases when the surgeon increased manual pressure on the piezotome.

**Section 2: clinical study**

Ten client-owned horses and 1 donkey presented for sinonasal disorders were included in this study. The mean age at presentation was 12 years old (6.5). Breeds included 10 Warmblood horses and 1 donkey, 7 geldings, 1 stallion, and 3 mares. One horse underwent a maxillary bone flap, 5 horses underwent a frontonasal bone flap, and 4 horses underwent a sinuscopy (3 frontal and maxillary approach and 1 conchofrontal approach). The donkey underwent a complete excision of an osteosarcoma involving the caudal part of the left nasal bone and rostral part of the left maxillary bone (Supplementary Table S2). During the procedures, visibility was excellent, and no technical issues were encountered (Figure 3). In 1 case, slight discoloration of the incised bone was visible, likely due to thermal damage. During the surgery, no horse reacted at the time of incision with the piezotome.

Eight horses had good cosmetic healing of the surgical site, with a follow-up of at least 90 days and a mean structured telephonic interview or consultation follow-up of 153 days (88 days). Euthanasia was necessitated postoperatively in 2 cases: 1 due to an uncontrollable hemoabdomen caused by a disseminated hemagiosarcoma 5 days postoperatively and another due to a meningitis likely related to a tooth extraction following the surgery at day 51. The second horse demonstrated adequate healing of the incision at the time of euthanasia. All other clinical cases had an early postoperative period without major complications at the incision site. Two horses had mild swelling that resolved within 2 weeks. One horse was lost to follow-up after 14 days. No long-term complications were recorded for the horses included in the study.

**Discussion**

To the authors’ knowledge, this is the first time the use of a piezotome is described and safely used in equine patients undergoing sinonasal surgical procedures. As mentioned previously, there are several potential advantages to piezoelectric surgery. With the handpiece of the piezotome being equipped with a flushing line activated continuously with the blade, there is no need for a surgical assistant to continuously flush to avoid overheating and thermal damage as observed with the oscillating saw. Additionally, visibility of the cutting line is improved with the piezotome because the handpiece is equipped with light-emitting diode lighting, which reduces the complaint of the surgeon to constantly adjust the surgical light or wear a head light. Another advantage of the piezotome is the ease of use as a “cutting pen.” The oscillating saw is heavier, more difficult to manipulate, and requires both hands at any time, making the procedure laborious and tiring. Conversely, the cutting rate of the oscillating saw is higher than the piezotome, which leads to shorter surgery time. However, when using the oscillating bone saw, there is less control along the cutting site, which can result in 2 distinct incision paths next to each other (n = 3) and more iatrogenic damage to the surrounding soft tissues. This observation could be attributed to a lack of surgeon experience or skills; therefore, the piezotome might be easier to use than the oscillating saw for an inexperienced surgeon.

The results of this study showed that the piezotome can be used as a bone-cutting instrument for equine sinus surgery both in cadaveric heads and live horses. Even if the surgical time was increased, the piezotome appeared to be advantageous in other aspects compared to the oscillating bone saw. Round bone flaps can be easily created with the piezotome, leading to round ostectomies for sinuscopy or round corners for bone flaps. There is no scientific support that rounding the corners of an ostectomy flap will increase bone healing, but it is definitely considered more practical for sinuscopy procedures and to replace manual trephines. However, there is a learning curve for the surgeon before being able to use the piezotome without causing thermal damage. The literature specifies that although piezoelectric surgery facilitates precise ostectomy, increased pressure on the handle can lead to complications. Increased manual pressure disrupts device vibration, causing energy conversion into heat and subsequent thermal damage. In this study, some discoloration of the bone at the level of the cutting line has been observed intraoperatively in 5 cadavers. This complication has occurred less frequently among clinical patients (n = 1). Training the surgeons dexterity during the cadaveric part of the study likely allowed a reduction of the thermal damage caused to clinical cases. An adaptation time before using the piezotome needs to be taken into consideration for the
surgeon to learn how to apply minimal pressure on the handle to enable the tip to vibrate effectively.

Further, in-depth histological analysis should be conducted to establish a link between macroscopic discoloration of the bone flap and bone healing.

It has been described that power-cutting instruments produce aerosols while cutting bone; thus, there is a need for constant flushing while using them to prevent inhaling aerosols and to avoid thermal damage to the bone. During this study, it was subjectively noted by the authors that little to no aerosols were created while using the piezotome.

This study demonstrated that the piezotome can be used in equine sinus surgery without major technical issues, adverse clinical effect, or complication on live patients. Besides the advantage of better visualization of the bone cut, it was also noticed that there is less noise disturbance. This is another advantage since sinus surgery is often performed on standing sedated horses.

As described in human literature, the ultrasonic power of the piezotome shows great advantages compared to conventional techniques for maxillofacial surgery. As the ultrasonic vibrations are selectively disrupting the mineralized tissue only, the sinusal mucosa is kept intact, which limits the bleeding and the trauma caused to the soft tissue. As a result, the visualization of the surgical site is improved and better healing is expected. However, large case cohort studies with radiological/histological comparisons between different osteotomy techniques are necessary to support this hypothesis.

No current literature has been published recording complications after sinus surgery related to the surgical method used (eg, trephine vs oscillating bone saw) to compare our results to conventional techniques, but in previous studies, 50% to 58% of the horses operated on presented a good cosmetic outcome without a specific surgical method reported. In this study, only 2 horses developed mild nonpermanent complications.

Piezoelectric surgery in horses is clinically relevant due to its possible use described in this study for sinonasal surgery. The costs implicated in the use of piezoelectric devices are likely to be comparable to other techniques, and disposables are resterilized for sinonasal surgery. The costs implicated in the use of piezoelectric surgery in equine patients should be conducted with greater numbers to be able to make conclusions on this topic.

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References


Supplementary Materials
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