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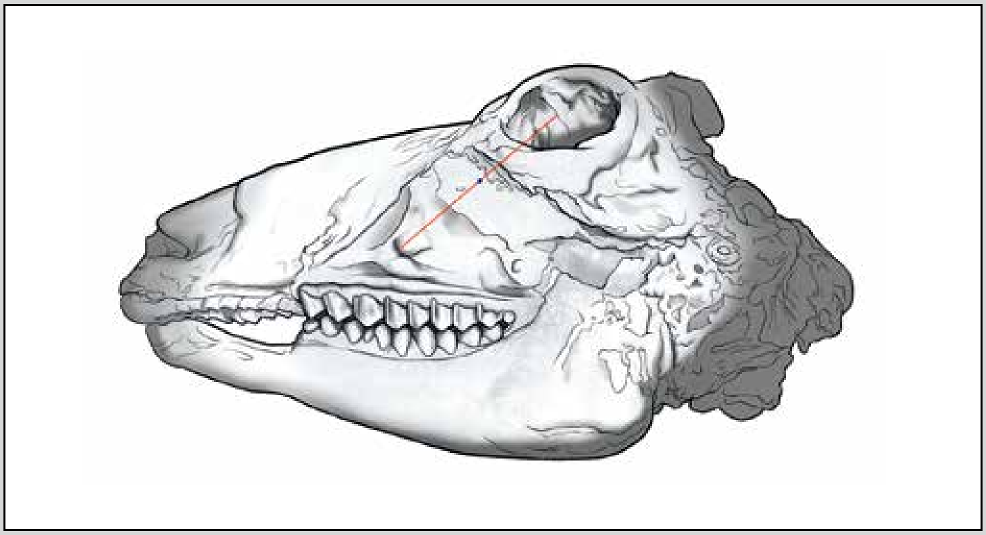
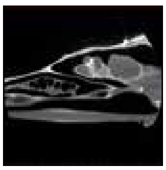


Incidence of Sinus Membrane Perforation Using Two Types of Implant Drills: An Ex Vivo Animal Study



Jerry Ching-Yi Lin, DDS, DMSc[1]
Wei Jen Chang, DDS, MS, PhD[2]
Myron Nevins, DDS[3]
David M. Kim, DDS, DMSc[3]

This ex vivo study evaluates the incidence of sinus membrane perforation during implant site osteotomy with two different types of drills and drilling techniques. Fifty goat heads with 50 sinus pairs (100 sinus sides) were assigned to two groups (osseodensification bur [OB] group and inverse conical shape bur [ICSB] group) to simulate transcrestal sinus elevation (50 sinus sides per group). An osteotomy was performed to pass through the lateral sinus wall no more than 3 mm. The integrity of the sinus membranes was examined and confirmed under a microscope. Of the 50 sinuses per group, the OB group presented with 14 (28%) perforated sinuses, while the ICSB group presented with 2 (4%) perforated sinuses. Of the 14 perforations from the OB group, 6 (42.9%) showed a pinpoint perforation pattern, 4 (28.5%) of which were not visible until direct air pressure was applied. Overall, the ICSB drill group demonstrated a lower sinus perforation rate than the OB group.
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[1]School of Dentistry, College of Oral Medicine, Taipei Medical University, Taipei, Taiwan ROC; Division of Periodontology, Harvard School of Dental Medicine, Boston, Massachusetts, USA.
[2]School of Dentistry, College of Oral Medicine, Taipei Medical University, Taipei, Taiwan ROC; Dental Department, Taipei Medical University Shuang-HO Hospital, New Taipei City, Taiwan ROC.
[3]Division of Periodontology, Harvard School of Dental Medicine, Boston, Massachusetts, USA.

Correspondence to: Dr David M. Kim, Harvard School of Dental Medicine, Division of Periodontology, 188 Longwood Ave, Boston, MA 02115, USA. Fax: 617-432-1897. Email: dkim@hsdm.harvard.edu

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Sinus elevation is an important procedure to increase the bone height of the posterior maxilla for implant therapy. Two approaches (lateral and crestal) can be applied to obtain access to the sinus membrane. First reported by Boyne and James[1] in 1980, the sinus membrane was elevated through the osteotomy on the lateral sinus wall. However, there were some limitations and drawbacks, such as anatomical issues, hemorrhage, prolonged healing time, and others.[2–5] In addition, surgical and postoperative complications (like membrane perforation, swelling, nose bleeding, sinusitis, infection, and hematoma) are not uncommon.[6–8]

Alternatively, the crestal approach (such as osteotome technique) reached the sinus membrane from the crestal direction with the aid of osteotomes.[9–11] The crestal approach has become popular due to its better accessibility and less technique-sensitivity. Since its introduction, numerous surgical modifications, devices, tools, kits, and burs have been invented to improve the crestal approach.[12–21] Unlike the original osteotome technique that fractures the sinus floor upward to lift the sinus membrane, modified surgical techniques focus on gaining access to the sinus membrane by removing the underlining bone

Fig 1 *Example of a half goat head model used by each group in the present ex vivo study.*

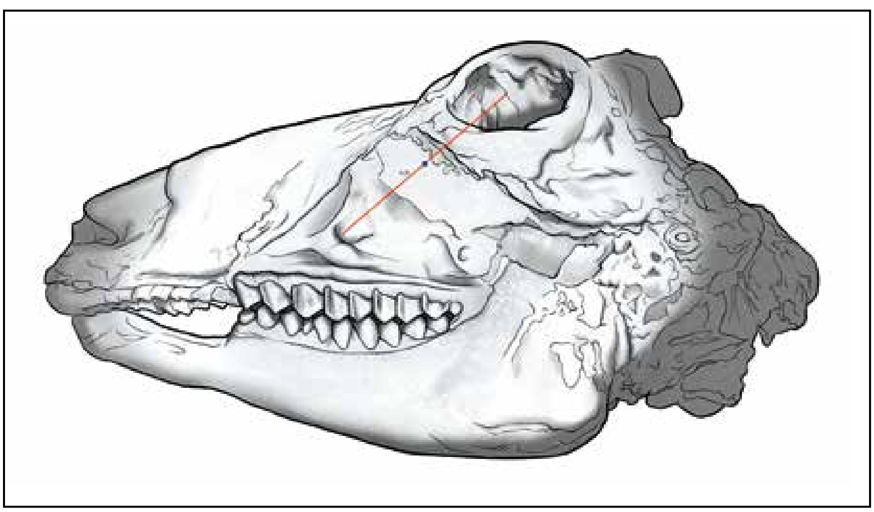

Fig 2 *The goat maxillary sinus is located between the orbital rim and the facial tuberosity (red line). A composite dot was marked halfway between the two landmarks (black dot).*

without compromising the membrane integrity.

The crestal approach is a blind procedure in terms of membrane elevation, which may lead to sinus membrane perforation without the clinician being aware of it. The incidence of sinus membrane perforation via crestal approaches ranges from 24%[22] to 40%[23] by osteotome technique in human cadavers: Specially designed drills[17–19] and burs[20,21] have been used to decrease the risk of membrane perforation.

The present study compared two types of drill designs (an osseodensification bur and an inverse conical-shaped bur) and the corresponding drilling techniques regarding the incidence of the membrane perforation during sinus elevation procedures in a goat model.

Materials and Methods

Fifty fresh-cut goat heads were hemisectioned sagittally (Fig 1). The experiments were conducted with a split-head design divided into 50 sinus sides for the osseodensification bur (OB) group and 50 contralateral sinus sides for the inverse conical-shaped bur (ICSB) group. The fresh-cut goat heads were frozen until 1 day before the experiment. Defrosting occurred at room temperature for 24 hours inside of styrofoam boxes. The goat maxillary sinus is located between the orbital rim and the facial tuberosity (Fig 2). Radio-opacity composite resin dots (Fig 3) about 3 mm in diameter were used to mark the following reference points: the midpoint from the center of the orbital rim and the facial tuberosity. CBCT scans (Fig 4) were taken before the experiments began.

The osteotomy sites were determined based on the CBCT results, where the bone thickness was measured. Unlike the goat model used in a previous study[24] where the sinus was accessed from the crest, the present study approached the sinus from the lateral wall. As a result, the thin bony walls provide easier access to the sinus membrane and excellent microscopic observation.

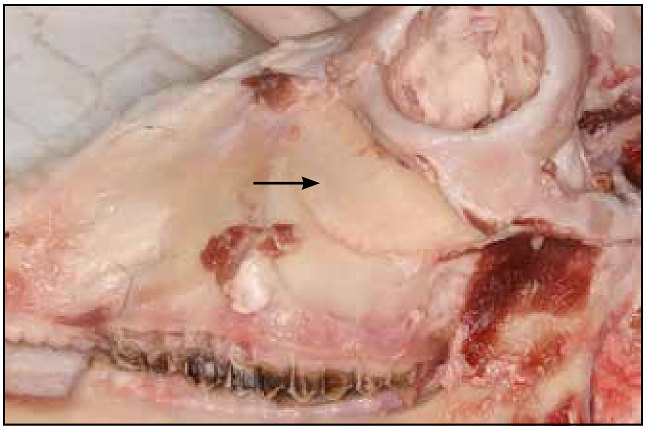

Fig 3 *Radio-opaque composite-resin dots (about 3 mm in diameter) were marked at the midpoint (arrow) from the center of the orbital rim and the facial tuberosity.*

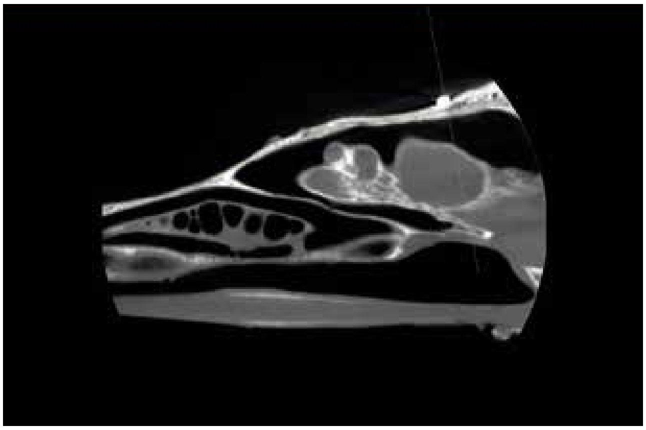

Fig 4 *A CBCT scan shows the reference composite dot and the goat sinus cavity.*

For the osteotomies, the bur used in the OB group (Fig 5) was 3.2 mm in diameter (VS8, BUR-G3 VS3238, Versah), and the bur used in the ICSB group (Fig 6) was 3.3 mm in diameter (SNDR3313T, Osstem). Drilling was performed at 800 rpm, counterclockwise for the OB group and clockwise for the ICSB group, with copious irrigation, following manufacturer's recommendations and guidelines. The osteotomy for both groups was done with the bur advancing past the sinus walls until the sinus membrane was reached, no more than 3 mm beyond the sinus floor. The membrane integrity was then carefully examined under a microscope (Extaro 300, Zeiss; ×30 magnification) (Figs 7 to 9).

Fig 5 *A VS8 bur (Versah) with a 3.2-mm diameter was used for drilling in the OB group.*

Fig 6 *An SNDR3313T bur with a 3.3-mm diameter was used for drilling in the ICSB group.*

Results

Of the 50 goat sinuses, the OB group presented 14 perforations, resulting in a 28% perforation rate, while the ICSB group presented 2 perforations, resulting in a 4% perforation rate (Table 1). In addition, some perforations in the OB group showed a unique pinpoint perforation pattern (Fig 8) that was not seen in the ICSB group. Of the 14 perforations in the OB group, 6 demonstrated a pinpoint perforation pattern, accounting for 42.9% of all perforations in that group. Of the 6 pinpoint perforations, 4 were not detectable unless direct air pressure (Fig 10) was applied, resulting in a

Fig 7 *Clinical view of an osteotomy performed with an ICSB bur. The sinus membrane is intact.*

Fig 8 *Clinical view of a pinpoint perforation type after using an OB bur.*

Fig 9 *Clinical example of sinus membrane perforation.*

Table 1 Perforation Details

Perforation type	n (%)
OB	
Standard perforations	8 (16%)
Pinpoint perforations	6 (12%)
Detectable	2 (4%)
Undetectable	4 (8%)
Total perforations	14 (28%)
ICSB	
Standard perforations	2 (4%)
Total perforations	2 (4%)

OB = osseodensification bur group; ICSB = inverse conical-shaped bur group. Percentages are calculated from the total of 50 goat sinuses per group. Undetectable pinpoint perforation types were identified by applying direct air pressure on top of the osteotomy.

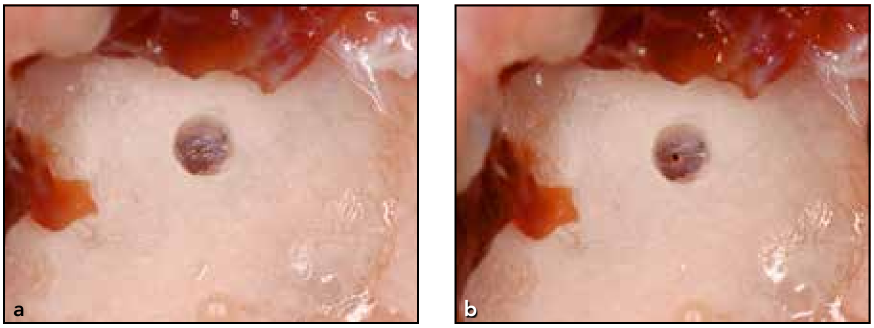

Fig 10 (a) *An intact sinus membrane was found immediately after osteotomy with the OB bur, but* (b) *a pinpoint perforation was seen when air pressure was applied.*

8% perforation rate for that group's total sinuses.

Discussion

The present ex vivo study utilized a goat model to simulate the transcrestal sinus elevation. The thin lateral bony walls were examined rather than crestal bone in order to provide easier access to the sinus membrane and to allow enhanced microscopic observation. The goat specimens were freshly cut and frozen to preserve the biologic and mechanical properties of the tissue. Chan and Titze demonstrated that the mechanical properties of the postmortem soft tissue did not change significantly after 1 month of frozen storage following quick freezing.[25]

The membrane perforation rate was lower in the ICSB group (4%; 2 out of 50 sites) than the OB group (28%; 14 out of 50 sites). The bur designs and drilling protocols may affect the maintenance of membrane integrity. The ICSB bur has a concave tip design (Fig 11) with a relatively round cutting rim, which creates a conical bone or bone chips and pushes the sinus membrane up to decrease the risk of perforation. Oppositely, the OB bur has a convex tip design with a relatively sharp cutting tip, which will cause an indented cutting cone. The OB bur primarily relies on reverse drilling and pumping slurry water and bone to push the sinus membrane up, which pushes bone chips from the alveolar crest. The ICSB bur stoppers may contribute to the control of the drilling depth, decreasing the risk of over-drilling, while the OB burs rely on a visual check of the depth marks, which may reduce precision and cause observation difficulties. The average bone thickness of the experimental lateral walls was 1.38 ± 0.48 mm (range: 0.48 to 2.48 mm), which provided more miniature bone-chip slurry than the clinical scenarios. Therefore, it could be assumed that the lack of a pumping effect due to the thin residual lateral bone in goat samples might increase the risk of membrane perforation.

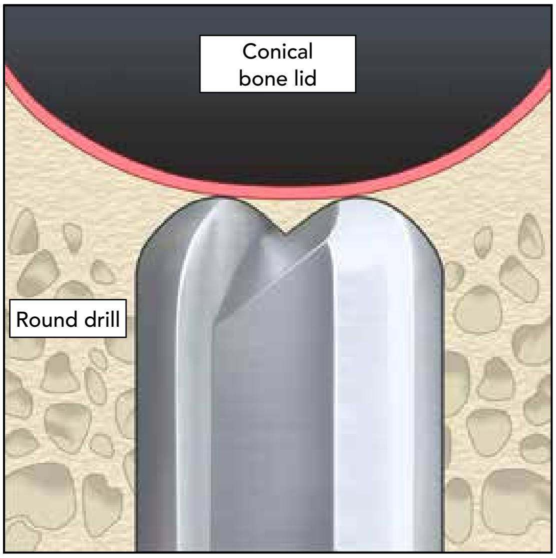

Fig 11 *Schematic design of an ICSB bur with a concave tip and a relatively round cutting rim.*

One study[26] reported a perforation rate of 3.3% with ICSB burs in porcine sinuses. Unlike that porcine study in which the ICSB bur did not go beyond the sinus floor, the ICSB bur in the present study passed through the sinus floor, but not by more than 3 mm (to be comparable with the drilling protocol from the OB group). The two studies still showed compatible results in terms of the perforation rate. A clinical study[19] of 49 crestal elevations done with an ICSB kit exhibited no membrane perforation, and the drilling protocol passed through the sinus floor by 1 mm. The present study followed the protocol of passing the sinus floor by no more than 3 mm, which may have increased the risk of membrane perforation compared to the previous study.

For the OB group, there has not been an ex vivo study published to reveal the perforation rates. A multicenter clinical study[20] of 261 sinus elevation cases indicated no membrane perforations and only eight (3%) implant failures. The present ex vivo study demonstrated a higher incidence of membrane perforation (28%). Among the perforations, there was a unique pinpoint perforation found on six sites in the OB group, four of which were not detectable unless direct air pressure was applied to the membranes. The undetectable perforations could occur in clinical scenarios. The present study required a total exposure of the sinus membrane while the multicenter study did not. Furthermore, in the multicenter study, the mean residual bone height was 5.4 mm, with the majority of the cases having a baseline height greater than 4 mm; the average bone thickness in the present study was less than 3 mm.

Of the two groups in the present study, the pinpoint perforation type was only found in the OB group, owing to the sharp cutting point. A similar type of sinus membrane perforation was categorized as a type I perforation caused by implant drills.[27] Pinpoint perforations are hard to notice in clinical scenarios, as the blood and fluid can hide those small perforations. After osteotomy preparation, the test sites were air-dried and examined under a microscope to identify pinpoint perforations. Four perforations could not be seen unless a direct air pressure was applied from a three-way syringe. Those incipient perforations could be clinically undetectable due to the limitations in visibility and accessibility. The pinpoint perforations accounted for 8% of the perforation rate in the OB group.

The OB group presented a higher membrane perforation rate than the ICSB group, which has not been reported previously. To decrease the risk of membrane perforation with OB burs, it is suggested to refine the current protocols or to modify the bur design. Instead of allowing the bur to pass the sinus floor by up to 3 mm (in existing protocols), it is recommended that this extension be limited to 1 or 2 mm. The recommended operation speed is between 800 and 1,500 rpm, and it may be helpful to use speeds at the low end of that range. OB drills are currently used for sinus elevation as well as ridge expansion, bone compaction, immediate implant placement, and other implant-related implications. Thus, its tip design must be pointed or convex rather than concave.

There were several limitations to the present study: *(1)* It was an ex vivo study examining the lateral wall instead of the crestal bony wall for sinus membrane elevation; *(2)* the average bone thickness of the lateral wall was 1.38 ± 0.48 mm in the goat model used, which is very shallow for the given crestal sinus membrane elevation technique; and *(3)* the experiment utilized only one drill instead of a sequence of drills. Nonetheless, interesting clinical findings were found and presented.

Conclusions

Despite the limitations of the present study, it was found that the ICSB bur group had a smaller sinus membrane perforation rate than the OB group. The OB group presented some pinpoint perforations, which were not identified in the ICSB group.

Acknowledgments

The authors declare no conflicts of interest.

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