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Original Article

Schneiderian membrane perforation upon the advancement of mechanical drills passing through sinus walls: An *ex vivo* animal study

Jerry Ching-Yi Lin [a,b], Ting-Yi Renn [a], Chia-Chen Hsu [a,c*], Wei Jen Chang [a,c**]

[a] *School of Dentistry, College of Oral Medicine, Taipei Medical University, Taipei, Taiwan*
[b] *Division of Periodontology, Harvard School of Dental Medicine, Boston, MA, USA*
[c] *Dental Department, Shuang-Ho Hospital, Taipei Medical University, New Taipei City, Taiwan*

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Crestal sinus elevation;
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Sinus membrane perforation;
ex vivo study

Abstract *Background/purpose:* This *ex vivo* study aimed to evaluate the perforation of Schneiderian membrane upon the advancement of drills incrementally in 1 mm passing through the sinus during the implant site osteotomy with two different drill types and techniques.
Materials and methods: Fifty goat heads with 50 pairs of sinuses were assigned to two groups: osseodensification drill (OD) and inverse conical shape drill (ICSD) to simulate transcrestal sinus elevation. Osteotomy was performed to pass through the lateral sinus wall, advancing the drills incrementally in 1 mm until perforation occurred. The integrity of the Schneiderian membranes was confirmed under a microscope.
Results: The OD group caused sinus perforation after drilling 1 mm beyond the sinus wall, with 8 perforations (16 %) out of 50. The ICSD group only showed perforations after 2 mm of drilling, with 3 perforations (6 %) out of 50. Seventy percent of perforations in the OD group occurred within 3 mm, while 44 % of those in the ICSD group did. Most OD perforations occurred between 2 and 3 mm, while in the ICSD group, they occurred between 3 and 4 mm. No perforation was observed in the ICSD group when drilling up to 1 mm beyond the sinus wall.
Conclusion: Different designs of the drills possessed different tolerance of the advancement of drills exceeding the sinus walls. The ICSD group did not show sinus membrane perforation until the drills extended 2 mm passing through the sinus wall, while the OD group would encounter

* Corresponding author. Dental Department, Shuang-Ho Hospital, Taipei Medical University, No. 291, Zhongzheng Rd., Zhonghe Dist., New Taipei City, 23561, Taiwan.
** Corresponding author. Dental Department, Shuang-Ho Hospital, Taipei Medical University, No. 291, Zhongzheng Rd., Zhonghe Dist., New Taipei City, 23561, Taiwan.
E-mail addresses: 08687@s.tmu.edu.tw (C.-C. Hsu), cweijen1@tmu.edu.tw (W.J. Chang).

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perforation with less than 1 mm exceeding the sinus walls.

Introduction

Sinus elevation has been an important procedure to increase the bone height of the posterior maxilla for implant therapy. Two approaches, lateral and crestal, have been applied to obtain access to the Schneiderian membrane. The crestal approach such as osteotome technique reached the Schneiderian membrane from the crestal direction with the aid of osteotomes.[1–3] The crestal approach has become a standard of care for sinus elevation owing to its better accessibility, less technique sensitivity and decreased postoperative complications. Numerous surgical modifications, devices, tools, kits and burs have been invented to improve the crestal approach, which has made the crestal approach increasingly polpular.[4–15]

Unlike lateral approach, most of the crestal approaches is still of limited accessibility, which may lead to certain possibility of sinus perforation. The incidence of sinus membrane perforation by crestal approaches could be up to 40 %[16] by osteotome technique in human cadavers. Those specially designed drills[10–12] and burs[13–15] have been developed to decrease the risk of membrane perforation.

Amount the sinus kits and devices, the inverse conical shape bur design demonstrated 24 % less incidence of sinus perforation than that of osseodensification bur design.[17] However, it is still uncertain that the relationship between the distance of instrumentation exceeding the sinus walls and the occurrence of sinus membrane perforation in the two different types of drills.

The present study compared two types of drill designs, osseodensification bur and inverse conical shape bur, and the corresponding drilling techniques regarding the incidence of the membrane perforation during the sinus elevation procedure in the goat model.

Materials and methods

Fifty fresh-cut goat heads were used in the present study. The split-head study design was executed with goat heads hemi-sectioned sagittally (Fig. 1). The goat heads were divided into 50 sinuses for the osseodensification drill group: OD (Versah, LLC, Jackson, MI, USA) and 50 contralateral sinuses for the inverse conical shape drill: ICSD group (Osstem, Seoul, South Korea). The goat heads were frozen until a day before the experiment, followed by the defrost process at room temperature for 24 h inside of Styrofoam boxes. The goat species used in the present study indicated the location of maxillary sinus between the orbital rim and the facial tuberosity (Fig. 1). Reference points marked with radio-opacity composite resin dots were placed at the mid-point between the center of the orbital rim and the facial tuberosity (Fig. 2). Cone beam computer tomography (CBCT) (Fig. 3) was taken before the experiments to measure the thickness of the sinus walls.

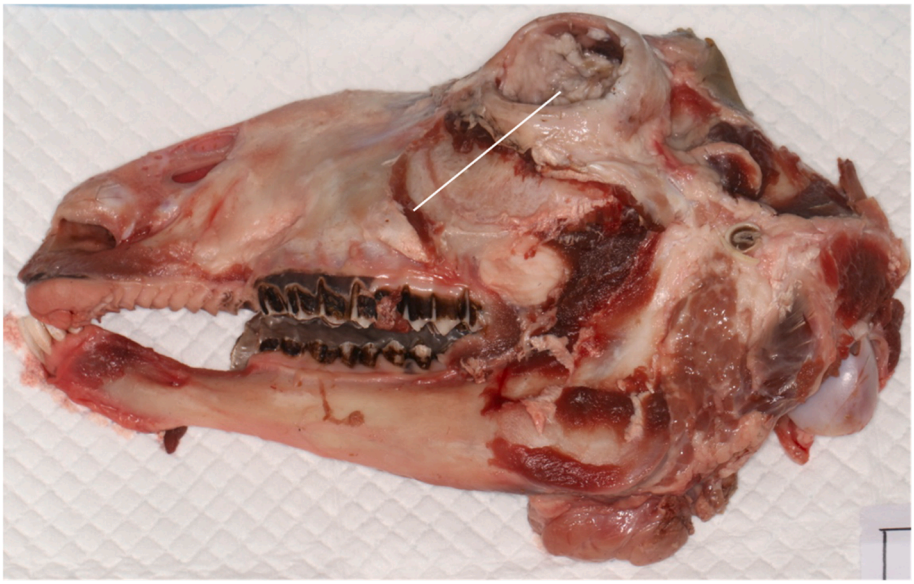

Figure 1 The half goat head model used in the present *ex vivo* study. The goat maxillary sinus is located between the orbital rim and the facial tuberosity. A composite dot was marked at the midpoint between these two landmarks.

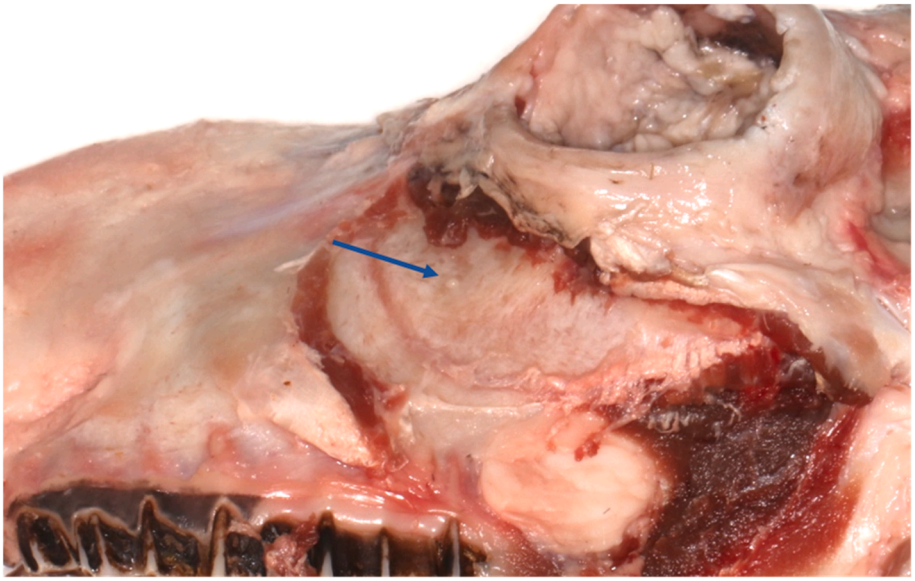

Figure 2 Radio-opacity composite resin dots were marked at the mid-point from the center of the orbital rim and the facial tuberosity.

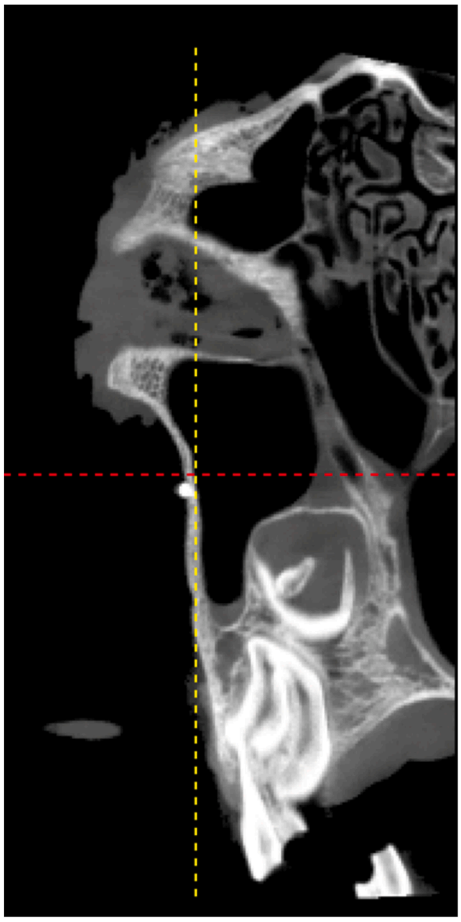

Figure 3 Cone-beam computer tomography (CBCT) indicated the reference composite dot and the goat sinus cavity.

The CBCT data was used to determine the osteotomy sites. The present study approaches the sinus from the lateral wall as the previous study.[17] The thin lateral bony walls facilitate easier access to the Schneidarian membrane and excellent microscopic observation.

The VS3238 drill (Fig. 4) that was 3.2 mm in diameter from the OD kit and the SNDR3313T drill (Fig. 5) that was 3.3 mm in diameter from the ICSD kit was used for the

Figure 4 The osseodensification drill (OD), VS3238 drill, 3.5 mm in diameter.

Figure 5 The inverse conical shape drill (ICSD), SNDR3313T drill, 3.3 mm in diameter.

osteotomy. The drilling was performed at 800 rpm counterclockwise for the OD group with drill stoppers and clockwise for the ICSD group with copious irrigation, following manufacture's recommendations and guidelines. The osteotomy for both groups was done with the drills advancing past the sinus walls until the Schneiderian membrane was reached and perforated. The depths of the drilling advancement were then recorded. The membrane integrity was examined under the microscope (Zeiss Extaro 300 with the magnification of 2.5 × 12, Carl Zeiss Meditec AG, Jena, Germany) (Figs. 6 and 7).

Results

Table 1 indicated the relationship between the drilling depths and the numbers of sinus perforation in the two study groups. Of the 50 bilateral goat sinuses, the OD group encountered membrane perforation sooner at 1 mm (16 %) drill depth passing the sinus wall, while the ICSD did not find membrane perforation until 2 mm (6 %) level. The peak frequency of the membrane perforation occurred at 2 mm and 3 mm (54 % in total) for the OD group, while 3 mm—4 mm (76 %) for the ICSD group. Some membrane could withstand the drill depths more than 6 mm in both groups. For the first 3 mm, the OD group presented 35 samples of membrane perforation resulting in 70 % of membrane perforation rate, while the ICSD group demonstrated 22 samples of membrane perforation indicating 44 % of membrane perforation rate.

Discussion

The present *ex vivo* study demonstrated the risk of sinus membrane perforation upon the osteotomy passing through the sinus walls. Schneiderian membrane may possess certain resistance and tolerance from the instrumentation.[17,18] However, it has not been well-documented regarding the limits of the instrumentation exceeding sinus walls before the occurrence of membrane perforation. The present study showed a delayed perforation pattern upon instrumentation passing through the sinus walls (Fig. 8). The two types of the drills represented two

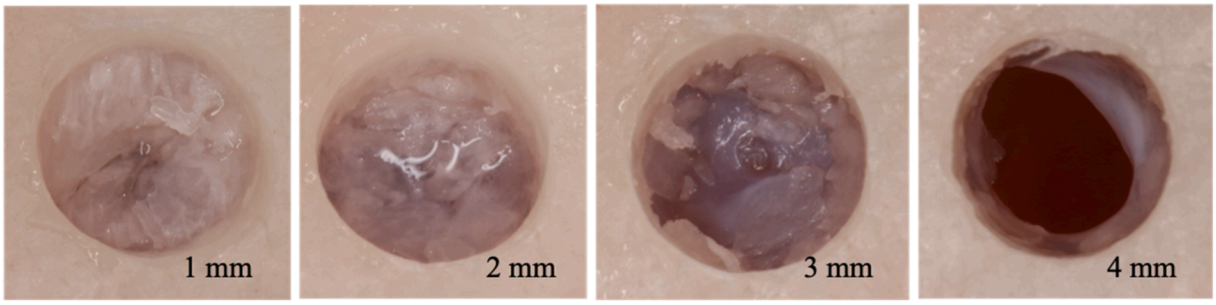

Figure 6 Osteotomy with an inverse conical shape drill (ICSD) and the integrity of sinus membrane in respective to the drilling depth exceeding sinus walls.

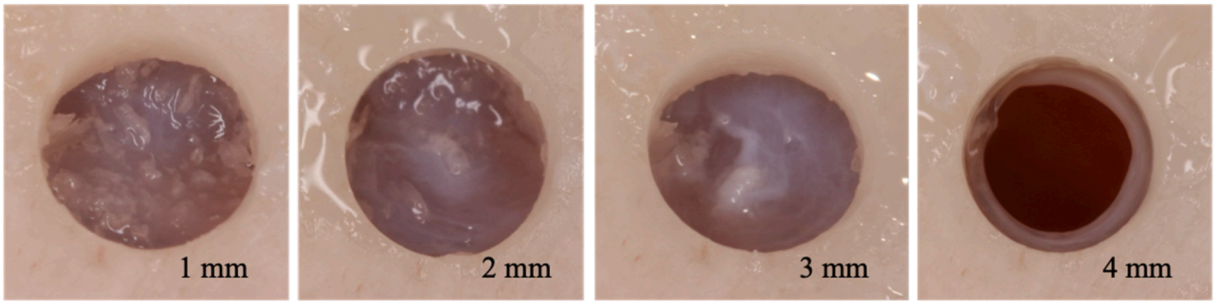

Figure 7 Osteotomy with an osseodensification drill (OD) and the integrity of sinus membrane in respective to the drilling depth exceeding sinus walls.

Table 1 The relationship between drilling depths and the number of sinus perforations in the osseodensification drill (OD) and inverse conical shape drill (ICSD) groups.

Drill depths	OD		ICSD	
0 mm	0	0 %	0	0 %
1 mm	8	16 %	0	0 %
2 mm	12	24 %	3	6 %
3 mm	15	30 %	19	38 %
4 mm	8	16 %	19	38 %
5 mm	6	12 %	6	12 %
6 mm	0	0 %	1	2 %
More than 6 mm	1	2 %	2	4 %
Total	50	100 %	50	100 %

OD: Osseodensification drill; ICSD: Inverse conical shape drill.

different types of mechanisms for sinus elevation. Both designs either OD or ICSD demonstrated relatively less invasive to the Schneiderian membrane. The membrane perforation was not seen immediately after the drills passing the sinus walls.

The OD design represented the sinus elevation with reversing-densifying and a pumping motion, while the ICSD stood for a concave tip design and round cutting rim (Fig. 9), both of which would lead to a conical bone chip pushing the membrane up. The present study results indicated the ICSD design is superior in maintaining Schneiderian membrane integrity to a certain level. Figure 8 revealed a more delayed pattern in the ICSD group than that in the OD group. In other words, the ICSD design showed better preservation for the membrane integrity, which was similar to the previous study.[17] The OD drill utilized the reverse drilling and pumping of the slurry water and bone to push up the sinus membrane. The present *ex vivo* study used the lateral sinus walls for the experiments. The lateral sinus walls in general were thin and lack

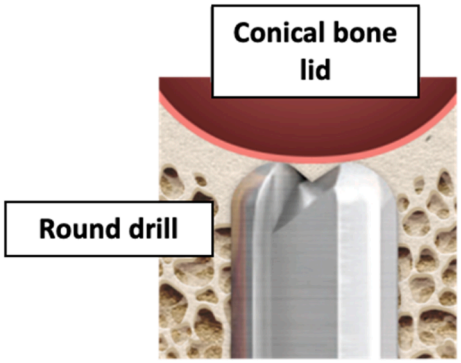

Figure 9 The inverse conical shape drill (ICSD) design is comprised of a concave tip and round cutting rim.

of cancellous bone, which would not create enough slurry bone chips to lift up the membrane safely.

The surgical manual from the manufacture of OD states that the osteotomy exceeding the sinus walls shall be less than 3 mm. Based on the present study, once the drilling depths reached 3 mm exceeding the sinus walls, the accumulated perforation rate came to 70 %. Even the drilling depths were lowered down to 2 mm, the perforation rate was still as high as 40 %. Although the *ex vivo* data may exist certain discrepancy from clinical situation, the study pointed out that the 3 mm rule may not as safe as it was considered. It can be proposed that the risk for membrane perforation with OD protocols increase along with the drilling depths and shall be more conservative. The sinus protocol of the OD group shall be reconsidered.

The result of the present *ex vivo* experiments for the ICSD group matched well with the clinical protocols of the ICSD. No membrane perforation was found for the drilling depths less than 1 mm exceeding the sinus walls. Gatti et al.[12] in 2018 showed a clinical study of 49 crestal sinus lifts performed with ICSD kit yielding no membrane perforation, in which the drilling protocol was 1 mm passing the

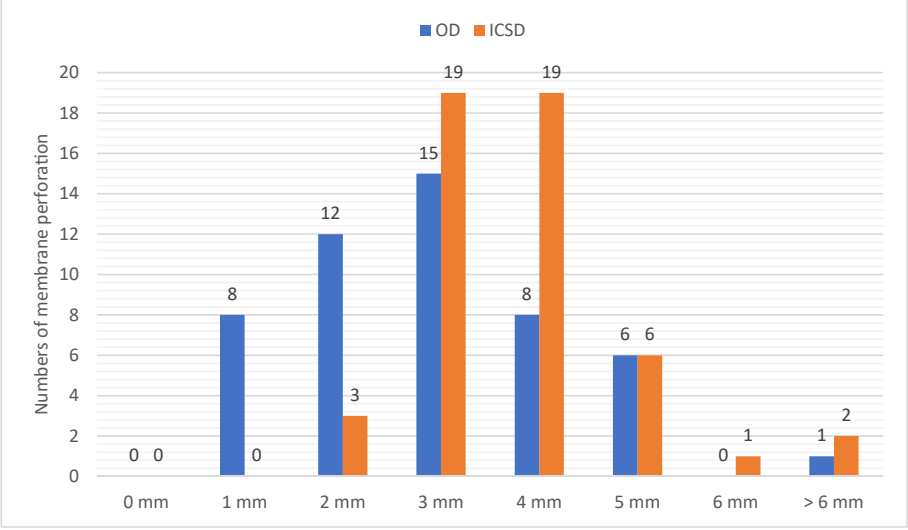

Figure 8 The relationship between the drill depths exceeding sinus walls and the corresponding numbers of membrane perforation from the two types of drills: osseodensification drill (OD) and inverse conical shape drill (ICSD).

sinus floor. When the drilling depths reached 2 mm passing though the sinus walls, the perforation rate increased up to 6 % in the present study. Lin et al.[17] in 2022 discovered 4 % of membrane perforation rate, which was close to the present study for the 2 mm or less drilling depths exceeding the sinus walls.

The present study had certain limitations. The *ex vivo* experiments may not be applied precisely to the clinical realities. The ICSD group utilized drill stoppers for the depth control, while the OD group relied on the visual check. Hence, the ICSD group would have better accuracy and reliability.

Declaration of competing interest

The authors reported no conflict of interest.

Acknowledgments

None.

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