Controlled Hydrostatic Sinus Elevation: A Novel Method of Elevating the Sinus Membrane

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Maxillary sinus elevation surgery has been practiced successfully over the past several decades with good outcomes, but tears and perforations still occur in significant numbers. The presumed cause of these problems is the fact that all methods currently used place "point sources" of lifting pressure on the Schneiderian membrane. A new procedure, controlled hydrostatic sinus lift, is presented herein as a safer, more controlled "lifting pressure" which simultaneously places equal force per square millimeter of bone-membrane interface. Hydraulic pressure in a closed system places equal pressure on all surfaces within the system, thereby eliminating "point sources" of pressure and gently elevating the Schneiderian membrane equally at all points of attachment. This controlled hydrostatic sinus lift procedure is accomplished by using a calibrated, hand-controlled pump and in-line pressure sensor meter. (Implant Dent 2011;20:425–429)

Key Words: closed system, controlled hydrostatic sinus elevation, hydraulic pressure, Schneiderian membrane, dental implant, minimally invasive surgery

Sinus floor elevation surgery has become a well-accepted preprosthetic procedure for the pneumatized sinus cavities and/or vertical interarch alveolar ridge discrepancies.[1–4] The 2 main surgical approaches for sinus floor elevation are external lateral window approach[5–8] and internal transalveolar approach.[9–12] The internal approach is considered more conservative and less invasive than external lateral window approach. The original concept of internal transalveolar technique was designed to use a set of osteotomes of various diameters to create a "greenstick fracture" by hand tapping force in a vertical direction.[10,13,14] The following intrusion osteotomy procedure elevates the sinus membrane by a tapping force to create a "tent." Bone grafting materials, blood clot, and the dental implant may be inserted into the tented space through the osteotomy opening.

The most sensitive aspect of this internal transalveolar osteotome approach is the tapping force which should be sufficient enough to infracture the sinus floor cortical bone but restrained enough to prevent the osteotome tip from traumatizing the Schneiderian membrane.[15,16] Complications may be associated with the tapping force such as benign paroxysmal positional vertigo[17–21] and sinus membrane perforation.

Several surgical techniques have been proposed to minimize the sinus membrane perforation rate by using hydraulic pressure instead of tapping force, the so-called "hydraulic sinus lift" procedure.[22–24] The unregulated hydraulic pressure was applied into the osteotomy site by means of air/water exhaust spray from a high-speed dental handpiece[22] or an uncontrolled water jet from a plastic syringe[23] to detach the Schneiderian membrane from the sinus floor. The applied hydraulic pressure was designed to loosen the membrane. However, without controlling the direction and intensity distribution of the hydraulic pressure, sinus membrane perforations may still occur because all the hydraulic pressure is directed against the apex of the "tent" being created.[22,23] To provide the suitable equal distribution of hydrostatic pressure, the concept of "controlled hydrostatic sinus elevation" is introduced in this article.

MATERIALS AND METHODS

The controlled hydrostatic sinus elevation kit includes pressure sensor meter (Alliance, Boston Scientific, Boston, MA), hand-actuated pump (Inflation System, Boston Scientific), stainless steel Luer-Loc cannula with different opening directions and diameters and connecting parts.

Surgical Protocol

Before the surgery, it is always necessary to complete a full evaluation

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of the sinus cavity with a thorough history, radiographic analysis to assess mucosa thickness, bone height and density, sinus septa locations, and the possible presence of pathology. Usually, radiographic observations using a panoramic radiograph and computed tomographs are used to identify these structures. However, panoramic radiographs are shown to have low reliability in detecting septa which can lead to incorrect diagnosis about presence or absence of septa in many cases.[25,26] Therefore, it seems that CT scan images present a more reliable and accurate diagnostic tool for detecting the maxillary septum.

Surgical Step 1 (To Create Access). The initial osteotomy (a pilot drill of 2 mm in diameter) after flap or flapless procedure is performed to a depth approaching the floor of the sinus cavity but stopping 1 to 2 mm short of the floor (Fig. 1, A). A diamond piezosurgical drill can also be used to just gently perforate the floor of the sinus bone without harming the Schneiderian membrane (Fig. 1, B).[27] The piezoelectric device is designed to cut or grind bone but not damage adjacent soft tissue.[28,29] The integrity of the sinus membrane is then examined by Valsalva maneuver or direct visualization.

Step 2 (Initial Detachment of the Sinus Membrane). The initial detachment of the Schneiderian membrane can be achieved by the following method. After clearing all the air from the tubing, the Luer-Loc cannula with tapered plug-in end (2 mm diameter) is inserted into the osteotomy preparation before touching the sinus floor and pressed snugly using finger pressure (Fig. 2, A and B). The normal isotonic saline fluid is pumped slowly into the closed system, and the gentle pressure will begin to elevate the Schneiderian membrane via the hydrostatic pressure from the hand-actuated pump (Fig. 3). The pressure sensor meter inserted into the closed system will monitor the pressure and also indicate the force necessary to just detach the Schneiderian membrane without tearing. It is imperative that the bone-to-cannula interface be airtight so that there is no lateral leakage of the normal saline solution.

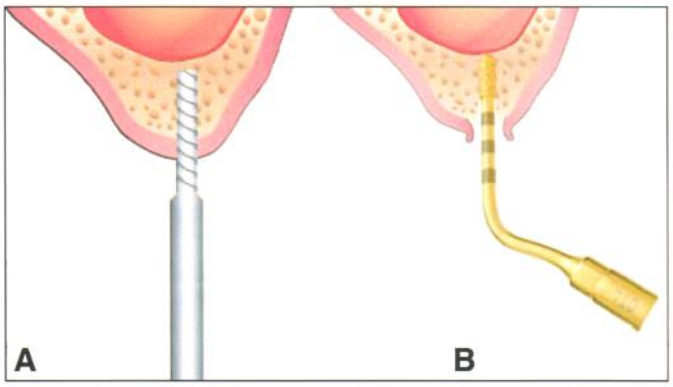

Fig. 1. A, Initial pilot drill up to 1 mm before reaching the sinus floor membrane. **B**, Piezosurgical drill (Mectron Piezosurgery System, Italy) can be used to gently perforate the floor of the sinus floor.

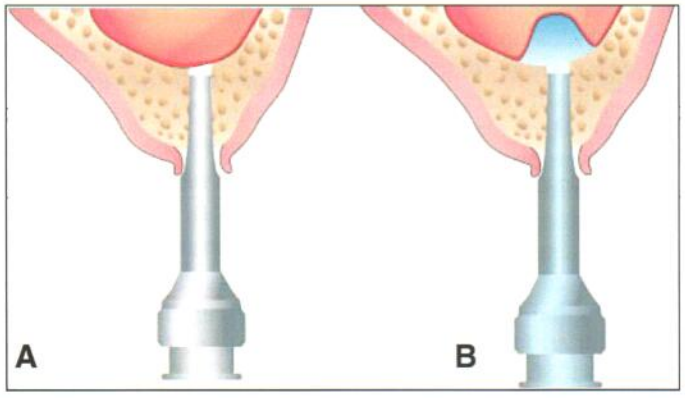

Fig. 2. A, The Luer-Loc cannula with tapered plug-in end inserted into the osteotomy site and should insert 1 mm inferior to the sinus floor but not touch the sinus floor. **B**, Hydrostatic pressure was applied to detach the Schneiderian membrane.

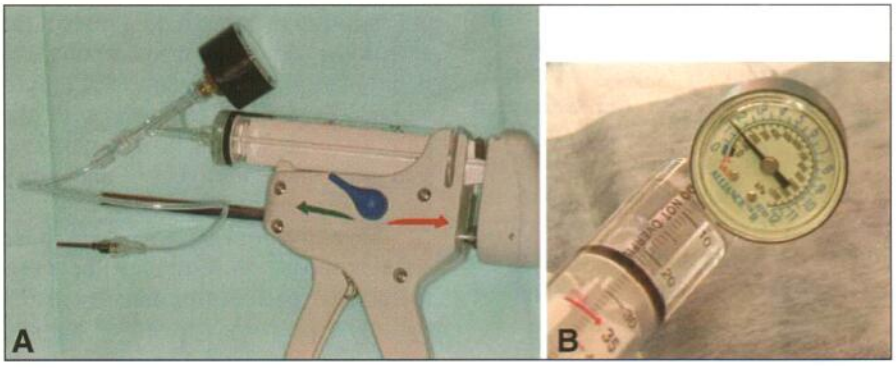

Fig. 3. A, Pressure controlled meter with pump (Alliance Inflation System, Boston Scientific) can provide suitable controlled force. **B**, Pressure meter with sensor to monitor the hydrostatic pressure.

Step 3. Once the desired initial elevation is obtained, a second examination of integrity of the sinus membrane is done. After the initial lift is complete, the surgeon switches to a 3-mm implant drill though the previous osteotomy site. Then, the previous controlled hydrostatic sinus lift procedure is repeated using appropriately a matched larger sized cannula and

tools. The sinus membrane is now lifted to the desired extent, followed by placement of bone grafting materials through the enlarged osteotomy.

Step 4. Bone grafting may proceed through the enlarged osteotomy site.

Step 5. Dental implant may or may not be placed into the osteotomy site depending on the probability of achieving adequate primary stability.

CLINICAL CASE

A 65-year-old man presented to the office for dental implant placement at upper right first molar (No. 3) area (Fig. 4, A). The patient had controlled hypertension and no history of sinus disease. The tooth was extracted due to unrestorable caries 4 months ago. The radiographic analysis and CT scan were performed to evaluate the mucosa thickness, pathology, bone height, bone thickness, and major blood vessels. It revealed an alveolar bone remaining height of 6.5 mm (Fig. 4, B). Nothing remarkable was noted in the maxillary sinus. Local anesthetic was administered (2% lidocaine with 1:100,000 epinephrine × 2 carpules) at No. 3 buccal and palatal site (Fig. 5, A). The surgical site was prepared by elevating a full-thickness flap after a midline incision along the alveolar ridge. These flaps are reflected only far enough to gain access to the central ridge area for adequate instrumentation. The flapless approach may also be used.

The controlled hydrostatic sinus elevation technique was then applied. The initial 2-mm drill was inserted stopping at 1 to 2 mm before reaching the sinus floor. The surgical guide pin was used as a radiographic reference (Fig. 5, B). The piezosurgical machine was used to gently penetrate the sinus floor without tearing the sinus membrane. The integrity of the sinus membrane was examined by Valsalva maneuver or direct visualization. The Luer-Loc cannula with tapered plug-in end was then inserted into the osteotomy site until it was firmly seated and sealed (Fig. 5, C). The hydrostatic pressure meter with pump was then connected to the cannula with flexible tube.

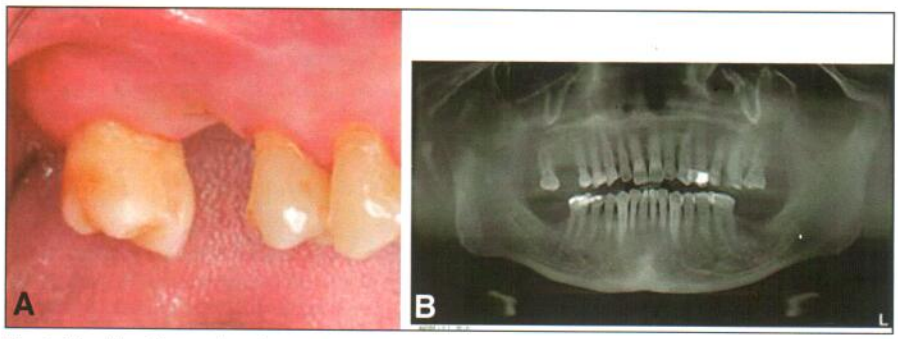

Fig. 4. Baseline information of upper right first molar No. 3. **A**, Intraoral image. **B**, Radiographic image.

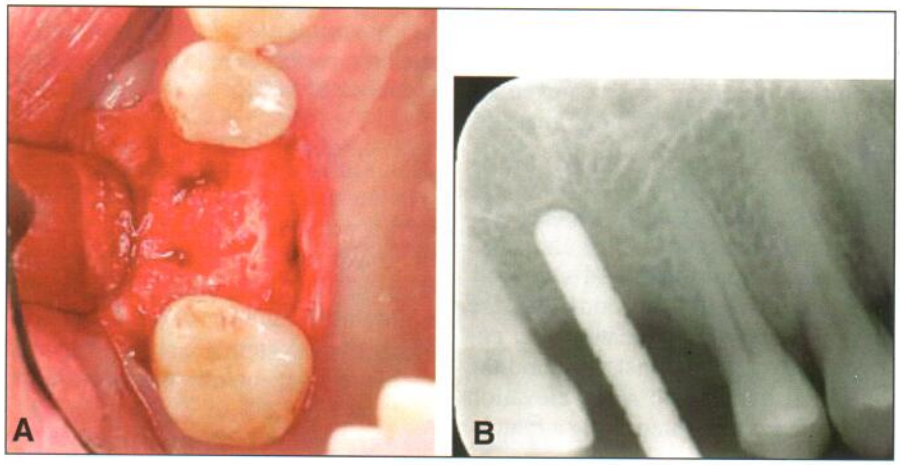

Fig. 5. A, Full-thickness flap. **B**, radiographic guide pin showed that it was close to sinus floor.

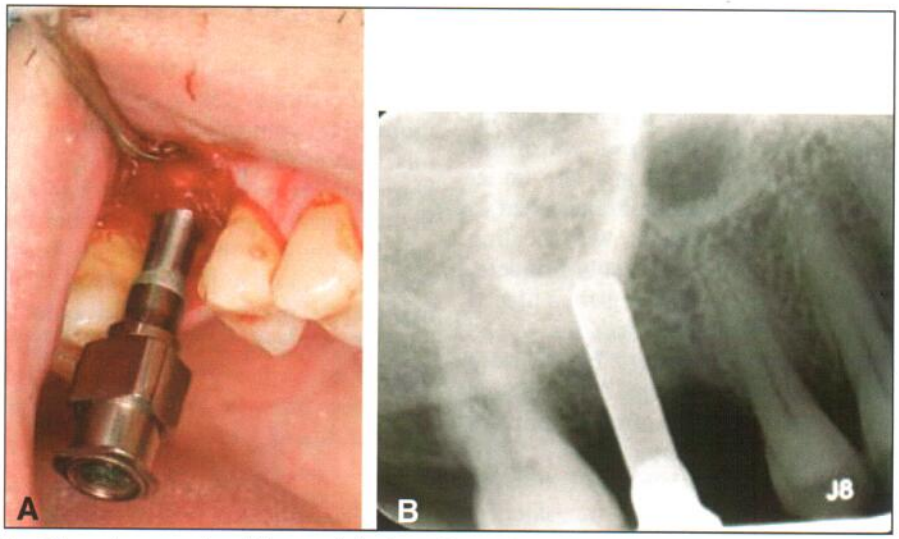

Fig. 6. Luer-Loc cannula with tapered plug-in end inserted. **A**, Intraoral view. **B**, Radiographic image.

Normal saline was then slowly pumped into the sinus cavity under controlled hydrostatic pressure to initially detach the sinus membrane. Once the sinus membrane was initially elevated by hydrostatic pressure, the pressure sensor detected a slight decrease in pressure. The hand-actuated pump then gradually increased the hydrostatic pressure until the pressure sensor once again revealed another pressure drop as the membrane was

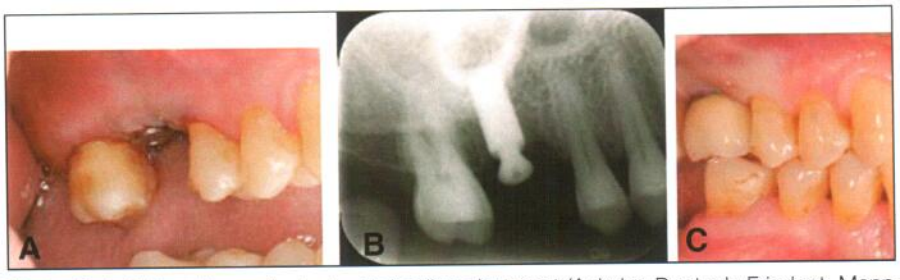

Fig. 7. A, A 4.5 × 11 mm implant with healing abutment (Ankylos Dentsply Friadent, Mannheim, Germany) was placed. **B**, Radiographic image of implant placement. **C**, Fix crown restoration with 4 months loading (restored by Dr. T. S. Zhuo, prosthodontist).

slowly and safely elevated (Fig. 6). This sequence was repeated several times until the desired amount of sinus membrane elevation was achieved.

It is important to note that the initial hydrostatic pressure needed to detach the sinus membrane may vary due to the thickness of the mucosa, the anatomical configuration of the sinus cavity, or simply individual variation. After the initial lift was complete, the previous osteotomy site was then enlarged with a 3-mm twist drill, and the controlled hydrostatic sinus elevation procedure was repeated using a matching size insert tube.

Once the desired elevation was obtained (usually >10 mm), the pressure was then released and the normal saline was removed with the tube. A second Valsalva maneuver or direct visualization test of membrane integrity was now done again. Allograft bone material was then carefully packed into the osteotomy site under the elevated sinus membrane. Next, a 4.5 × 11 mm implant with healing abutment (Ankylos Dentsply Friadent, Mannheim, Germany) was then placed at No. 3 osteotomy site (Fig. 7, A) with primary stability. Flaps were closed by 4-0 sutures. A periapical radiograph was taken after the implant placement (Fig. 7, B).

Patient was given the following prescriptions: antibiotics (amoxicillin 500 mg Q6H for 7 days), a nonsteroidal anti-inflammatory (ibuprofen 400 mg Q4–6H as needed), and chlorhexidine mouth rinse. Minimal postoperative pain and swelling was reported. Sutures were removed 10 days after surgery. No sinus complications or other postoperative sequelae were reported or observed. After 3 months healing, the implant was determined to be osseointegrated and was subsequently restored with a fixed provisional crown (Fig. 7, C).

DISCUSSION

Current sinus elevation procedures, using an external open-window approach and internal osteotome approach, have become effective but highly technique-sensitive procedures. Recently, a systematic review reported incidences of membrane perforation ranging from 0% to 21.4%.[16] In a human cadaver maxillary sinus elevation study using osteotome technique, the membrane perforation was observed in 24% of the surgical sites.[30] Tapping force during sinus floor elevation with osteotome technique may also cause postoperative vertigo (benign paroxysmal positional vertigo). In the new innovative controlled hydrostatic sinus elevation procedure, reported herein, every square millimeter of the Schneiderian membrane is under an equal amount of the hydrostatic force because it is in a closed system. The hydrostatic pressure is under careful control of the surgeon and constantly monitored by pressure meter to avoid the excess pressure that may perforate the membrane.

CONCLUSION

The controlled hydrostatic sinus elevation procedure allows smooth, evenly applied, force application through gentle fluid pressure in a closed system to elevate the Schneiderian membrane. Future clinical trials are needed to evaluate the effectiveness of this technique on a broader scale other than this case report.

DISCLOSURE

Dr. Daniel W. K. Kao: "Patents pending, but no money paid to me or my institution."

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