Background: The atrophic posterior maxilla is a challenging site to place dental implants. Lateral window or crestal approaches are common surgical techniques to overcome the vertical deficiencies of the atrophic posterior maxilla. Sinus augmentation using the lateral window procedure has been predictable for several decades. However, this procedure may result in patient morbidity such as postoperative swelling, pain, and a long edentulous healing period. The crestal approach using a surgical mallet and osteotome is less invasive than the lateral approach, but it has some limitations such as postoperative vertigo, membrane perforation from bone packing to sinus membrane, and limited vertical augmentation due to difficult accessibility. This case series report demonstrates sinus membrane elevation using hydraulic pressure and piezoelectric ultrasonic vibration. This technique results in minimal patient morbidity and offers an alternative to lateral window maxillary sinus augmentation.

Methods: Preoperative radiographs or computed tomograms were taken before surgery to evaluate bone quantity in posterior maxilla. The sinus floor was broken with a specially designed ultrasonic insert with ultrasonic vibration, and hydraulic pressure was applied to elevate sinus membrane evenly simultaneously. A surgical mallet was not used to break sinus floor in any case. Bone graft was not an absolute prerequisite in this report. Implants were placed simultaneously or delayed depending on situations. Postoperative radiographs were taken to evaluate sinus augmentation results in all patients.

Results: All cases in this report show successful vertical augmentation with implant survival. Patients showed minimal or no postoperative pain and swelling.

Conclusions: The crestal approach to maxillary sinus augmentation using hydraulic pressure and ultrasonic vibration is simple and safe procedure with minimal patient morbidity and can be alternative technique to lateral approach.

KEY WORDS: Maxillary sinus, bone graft, dental implants, piezoelectric surgery

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INTRODUCTION
Missing dentition in the maxillary alveolar ridge brings challenges in implant placement due to rapid sinus pneumatization and ridge resorption. In order to place implants of adequate height, ridge augmentation is often necessary. The lateral window approach is usually the technique of choice for ridge augmentation in the maxillary posterior area, especially in cases of minimal residual bone. The lateral window approach has been recognized as a predictable method. However, some patients may reject the lateral window approach due to surgical fear and postoperative pain, swelling, and a long edentulous healing period. Furthermore, surgeons with limited surgical experience tend to avoid this method.

To overcome the disadvantages of the lateral window approach in maxillary sinus augmentation, variable crestal approaches, such as osteotome technique, piezoelectric internal sinus elevation (PISE), hydraulic sinus condensing (HSC) technique, internal sinus manipulation (ISM) procedure method, and crestal window technique (CWT), have been introduced. Most of these techniques rely on bone compaction in order to elevate the sinus membrane. Too much pressure of bone compaction may lead to membrane perforation during or after surgery. ISM and CWT techniques use small instrument to manipulate the sinus membrane, but membrane perforation and delayed surgical time can occur due to limited visibility and accessibility. The aim of this report is to demonstrate an innovative surgical procedure to elevate the sinus membrane crestally with hydraulic pressure and piezoelectric ultrasonic vibration before bone condensation without manipulation of crestally approached instruments.

SURGICAL TECHNIQUE
The hydrodynamic piezoelectric internal sinus elevation (HPISE) technique is a crestal approach using ultrasonic micro-vibration and hydraulic pressure. The HPISE tip uses a specially designed tip that attaches to a piezoelectric ultrasonic unit (Surgynbone®, Silfradent srl, Sofia, Italy or compatible device) and allows water to pass through the tip to elevate the membrane (Figure 1). After local anesthesia using lidocaine (1:100,000 epinephrine) in the surgical site, a full thickness flap is reflected to expose the alveolar ridge. Flapless surgery may also be performed depending on the width of the alveolar ridge. As a first step, a 2.2mm wide carbide round insert (S022®, BukBu Dental Co, Daegu, Korea) with external irrigation is used to break sinus floor (Figure 2). After breaking the sinus floor with the round tip, a 2.8mm wide cylindrical carbide insert (HPISE insert®, BukBu Dental Co, Daegu, Korea) is used to enlarge the osteotomy site and elevate the sinus membrane using hydraulic pressure (Figures 3, 4). The HPISE insert has 4mm working tip height, and depth indicating lines are marked by 2mm intervals. Hydraulic pressure to the sinus membrane from internally irrigated sterile saline causes membrane detachment from the sinus floor and membrane perforation is very rare. After breaking the sinus floor cortex using ultrasonic vibration, hydraulic pressure is applied for 10-20 seconds to detach sinus membrane from sinus floor. After this stage, surgeons can observe up and down movement of sinus membrane whenever patients take a breath.

Bone graft is dependent on surgeon’s personal preference. If the required sinus elevation is minimal (less than 5mm), the dental implant may be placed without bone graft. If additional verti-
cal augmentation is required, bone graft material should be used. Collagen sponge or fibrin rich block with concentrated growth factors (CGF®, Medifuge, Silfradent srl, S.Sofia, Italy) was used as an alternative to bone graft in this report. The authors’ preferred bone graft is gel-conditioned allograft (Orthoblast II®, Isotis Orthobiologics Inc, Irvine, USA) or the mixture of gel-conditioned allograft with Ca-P nonocoated anorganic bovine bone (Bio-Cera™, Oscotec Co, Chunan, Korea) or mineral allograft (Allots®, Bio-Tis Co, Seoul, Korea). The mixture of bone graft is carried with an amalgam carrier and is delivered beneath the elevated sinus membrane through the osteotomy site (Figure 5). When gel conditioned bone is used alone, direct injection of the gel conditioned bone into new compartment is recommended. Bone compaction can be attained by using the ultrasonic vibration of the piezoelectric device (Figure 6). This procedure controls pressure to the bone graft when bone packing is performed, thereby reducing the possibility of membrane perforation during bone compaction. The implant may be placed simultaneously or delayed (Figure 7). When an implant less than 4mm wide is placed, the HPISE insert is the last instrument to make the osteotomy prior to implant placement. Under sizing the osteotomy ensures better initial stability of the implant. When a wider implant is placed, intermittent drilling is often required to accommodate the wide body implant. For this particular procedure, it is recommended that the osteotomy be undersized by one drill size to ensure adequate primary stability of the implant.

**CASE REPORTS**

**Case 1**
A 37 year old woman who wanted an implant supported fixed prosthesis visited our department. The patient’s medical history was not significant. Pre-operative plain radiographs showed residual bone height of 4-7mm at sites #3 and #4. A high sinus septum was seen in the radiograph (Figure 8). Local anesthesia was administrated and a full thickness flap was retracted to expose the alveolar bone. A 2.7mm wide twist drill was used to make the osteotomy approximately 3mm short of the sinus floor. The sinus floor was broken with the HPISE insert, and hydraulic pressure was applied for a few seconds in both #4 and #5 sites (Figure 9). When applying saline through the osteotomy socket of #4, the saline came out through the osteotomy socket of #5, indicating that sinus membrane was elevated over the septum. The mixture of Orthoblast II and Bio-Cera was grafted in the new compartment under the elevated sinus membrane at #4 using an amalgam carrier, but bone grafting was not performed at site #5 (Figure 10). Two 4.5 mm x 11mm implants (SPI implant, Thommen Medical Co, Waldenburg, Switzerland) were placed simultaneously, and guided bone regeneration using bone substitute and collagen membrane (Tutoplast Pericardium®, Tutogen medical GmBH, Germany) was performed to augment the narrow ridge (Figure 11). The postoperative computed tomogram showed approximately 10mm vertical elevation using hydraulic pressure alone at site #5. Similar sinus augmentation was achieved at the #4 site using bone graft material. Unlike conventional osteotome mediated sinus elevations, the sinus membrane was elevated evenly at both the medial and lateral aspects as seen in conventional laterally approached augmentations (Figure 12). A more radiopaque image was seen at site #4 (where bone graft was used) versus site #5 where no bone graft was used. Implant uncovering was delayed to wait for orthodontic treatment completion. The
implants were exposed after 8 months healing. A radiograph of the final prosthesis showed favorable bone augmentation at both sites, regardless of bone grafting or non-bone grafting (Figure 13).

Case 2
A 39 year old female patient presented with missing tooth #3. The width was sufficient for implant placement but there was insufficient height (approximately 7 mm) for a conventional dental implant. A minimally invasive sinus lift technique using HPISE was chosen to augment the sinus. Local anesthesia was administered and a conventional flapless osteotomy was made with a twist drill to approximately 3mm from the sinus floor (Figure 14). The HPISE insert was then used to advance the osteotomy to and through the sinus floor. Hydraulic pressure was applied a few seconds to gently lift the membrane. Collagen Foam (Ace Surgical, Brockton, MA, USA) was packed through the osteotomy into the sinus, but bone graft was not used in this case. A 5.0 x 12mm implant (Cowell Medi Implant Co, Busan, Korea) was then placed and torqued to approximately 40Ncm (Figure 15). A healing abutment was placed and the patient was allowed to heal for 4 months before impressions were taken for a porcelain-to-noble crown (Figure 16). The patient reported no pain during or after the procedure.

Case 3
A 60 year old woman with no significant medical history was referred to our department for sinus augmentation. Cone beam computed tomog-
raphy (CBCT) showed residual bone height of 1mm at site #14 and 5mm at site #15 (Figure 17). The round insert was used to penetrate the sinus floor at sites #14,15 and then the HPISE insert was pushed up to the sinus floor to elevate the sinus membrane using hydraulic pressure (Figures 18, 19). After application of hydraulic pressure, up and down movement of sinus membrane was observed during patient respiration. Fibrin block with concentrated growth factors (CGF) was inserted under the elevated sinus membrane to accelerate bone formation, a mixture of Orthoblast II and Bio-Cera was grafted through the osteotomy, and bone graft was packed with the HPISE insert using microvibration (Figures 21, 22). The postoperative cross-sectional view of CBCT images revealed approximately 15mm of sinus augmentation (Figure 23). Two 12mm length implants (Den- tium Implant Co, Seoul, Korea) were placed by a referral doctor after 3 months healing. The initial stability of implants was favorable (Figure 24).

**Case 4**

A 39 year old male patient presented with missing teeth #3 and #4. Non-specific past medical history was revealed. The bone heights at sites #3 and # 4 were approximately 4 mm and 8mm, respectively (Figure 25). The sinus floor was broken with the HPISE insert and hydraulic pressure was applied for a few seconds to elevate
gently sinus membrane at site #3. Hemostatic collagen sponge (Euroklee S.L., Cerdanyola del Vallés, Barcelona, Spain) was grafted under the elevated sinus membrane at site #3. Bone substitute (Ostim, Heraeus Kulzer, Hanau, Germany) was grafted and two 11.5mm length implants (Frontier, Global Medical Implants SL, Barcelona, Spain) were placed. About 13mm of vertical sinus augmentation was achieved, and sinus augmentation was continued to the apical area of the #4 implant (Figure 26). Implants were uncovered after 6 months of healing and a porcelain fused to metal crown was cemented after 4 weeks use of a provisional prosthesis (Figure 27).

Case 5
A 69 year old female patient visited at our department. Her chief complaint was masticatory difficulty due to an ill fitting denture. She wanted implant supported fixed prosthesis, but she was very apprehensive of sinus augmentations using a lateral approach. The cross section view of the CBCT image revealed residual bone height of approximately 5mm at sites #2, #3, #14, and #15 (Figures 28, 29). To reduce postoperative discomfort, a crestal approach using the HPISE technique was chosen. The HPISE insert was pushed up to break sinus floor and to elevate the sinus membrane. Orthoblast II was injected in the new compartment under the elevated sinus membrane through the osteotomy sites of #2 and #3 (Figures 30, 31). The sinus membrane was elevated using hydraulic pressure at #14 and #15, and CGF alone was inserted under the elevated sinus membrane (Figure 32). Five 3.7 mm x 13mm HA coated implants (Tapered Screw Vent implant, Zimmer Co, CA, USA) were placed. Postoperative cross sectional view of CBCT images showed approximately 10mm of vertical sinus augmentation in the right posterior maxilla using bone graft and in the left posterior maxilla without bone graft (Figure 33). Postoperative discomfort was very minimal. Cross sectional view of CT after 4 month healing revealed bone formation around all implants in the sinus (Figure 34). After 6 months healing, all implants...
were uncovered. The final porcelain fused to metal prosthesis was cemented after 5 months use of a temporary prosthesis (Figure 35).

**DISCUSSION**

The lateral window approach is a predictable surgical method for augmentation of atrophic posterior maxillae, but complications associated with the lateral window technique have been reported.

Compared to the lateral window approach, the crestal approach has the advantage of being minimally invasive, which contributes to less postoperative discomfort. Multiple crestal techniques have been reported to overcome the disadvantages of the lateral window approach. Most of the crestal approaches use a surgical mallet and osteotome to break the sinus floor. Several clinicians have reported postoperative positional vertigo related with osteotome mediated sinus floor elevations (OMSFE) due to trauma to the inter ear from striking the surgical mallet. In addition, OMSFE is a blind technique, so sinus augmentation is limited. The OMSFE technique has lower success rates when residual bone height is 4mm or less (when compared to cases with 5mm or more residual bone height). The PISE and HSC technique are innovative crestal methods where a surgical mallet is not required to break the sinus floor. These techniques are free from postoperative vertigo, but elevation of the sinus membrane depends on bone compaction because hydraulic pressure from external irrigation is not enough to elevate the sinus membrane. The crestal window technique overcomes the blind nature of conventional OMSFE, but the application is limited because this technique is indicated when wide diameter implants (>5mm or more) are available. In addition, many instrumentation are necessary to get a sufficient amount of sinus augmentation.

The HPISE technique uses ultrasonic piezoelectric microvibration and hydraulic pressure from internal irrigation. The piezoelectric device using ultrasonic vibration only cuts hard tissue which allows it to come in contact with the membrane without tearing it. Even and gentle elevation of the sinus membrane is possible due to hydraulic pressure from internal irrigation before bone packing. Therefore, bone compaction is not a prerequisite for sinus elevation in the HPISE technique unlike conventional crestal approaches. Some studies have recently reported successful sinus augmentation from lateral window approaches and crestal approaches with only membrane elevation. New bone formation with patients’ own venous blood, absorbable gelatin sponges and CGF in a fibrin-rich block as alternatives to bone grafts for sinus augmentation have been reported in clinical studies. Some studies reported fibrin rich block with CGF accelerated new bone formation. New bone formation in the sinus with collagen sponge and CGF as alternatives to bone grafts with the HPISE technique was evident in the present report.

**CONCLUSION**

The HPISE technique is a predictable sinus augmentation method that does not involve striking a mallet to break the sinus floor. This technique reduces the possibility of benign positional vertigo, membrane perforation, and postoperative patient discomfort. This technique does not rely on instrumentation or bone compaction to elevate the sinus membrane. HPISE is an alternative surgical method to the lateral sinus augmentation technique and can be used with or without bone graft material as demonstrated in the 5 cases shown in this report and 9 total cases in this series.

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