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An 8-Year Retrospective Study: 1,100 Patients Receiving 1,557 Implants Using the Minimally Invasive Hydraulic Sinus Condensing Technique

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Background: For many clinicians, inadequate alveolar bone height and anatomical features of the maxillary sinus complicate sinus lift procedures and placement of endosseous implants. We present a new internal crestal approach that addresses these issues.

Methods: Sinus burs and condensers of increasing width are used in conjunction with pliable atraumatic bone grafting mixture and hydraulic pressure from a surgical handpiece. The risk of a membrane perforation is minimized when the surgeon's tactile skill is administered in a two-stage process to first loosen and then graft bone particulate under the Schneiderian membrane. Threaded implants can then be placed in the same visit and secured via primary closure.

Results: A retrospective investigation of 1,100 cases showed that eight implants failed and 14 required longer healing periods in patients with alveolar ridge heights varying between <1 to 5 mm.

Conclusions: Our experience suggests that hydraulic sinus condensing is a predictable and minimally invasive alternative for prosthetic rehabilitation of maxillary anterior and posterior regions in the presence of anatomical restrictions to implant placement. *J Periodontol* 2005;76:482-491.

KEY WORDS

Dental implantation, endosseous; hydraulic sinus condensing; maxillary sinus/surgery; review of reported cases; septum; sinus condenser; slope; surgical procedures, minimally invasive.

Inadequate alveolar bone height below the maxillary sinus is a frequent anatomical restriction to the prosthetic rehabilitation of the upper jaw by means of endosseous implants. Within the sinus cavity itself, additional restrictions complicate optimal positioning of implants. These restrictions include sinus floor slope, the presence of septa, and the presence of nasal cavity. Previous reports¹⁻⁷ have indicated that lifting the sinus by means of autogenic or allogenic bone grafts are predictable approaches that can provide sufficient bone volume for implant placement.

There are two basic sinus lift techniques: the buccal window⁸ approach and the internal⁹⁻¹¹ approach. In the buccal window approach, implantation can be performed in tandem with the sinus lift, or it can be delayed for a few months to allow for ossification of the grafted site.¹² In the internal approach, the implant site is prepared to the maximum available height of the maxillary bone and a greenstick fracture of the sinus floor is accomplished using osteotomes¹⁰ or threaded implants.¹³ This method allows for the insertion of longer implants.

We present an 8-year retrospective study of 1,557 implants in 1,100 patients as validation of an innovative technique that we have named hydraulic sinus condensing. Our approach has proven to be effective even in cases where deficient alveolar ridge heights are only ≤ 1 mm. Only eight implants failed at the early integration phase during the study period, resulting in a 99.99% success rate. No correlations were found between the failed implants and the surgical method. The majority of the patients who experienced failures were handicapped by <1 mm of cortical bone or were smokers, and second attempts in these cases proved successful.

Fourteen implants required longer than normal healing periods, with the time to restoration extended from the typical 4 months to about 10 months. Overall, however, we have found that most patients heal rather quickly when grafted regions are sealed via primary closure. A recent histological analysis confirmed nearly complete osseointegration of our favored bone graft mixture 5 months postoperatively.

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A sinus condensing kit* was developed especially for this procedure. It consists of round diamond sinus burs with 1, 2, and 3 mm diameters. Titanium-coated sinus graft condensers are supplied in 2, 3, 5, and 6 mm diameters. The sinus condensers are marked at depths of 3, 5, 8, and 10 mm. Using these tools in combination with hydraulic pressure supplied by a surgical handpiece, clinicians can safely separate the Schneiderian membrane from the sinus floor and prepare the area for immediate implant placement in a fashion that takes advantage of anatomical features normally viewed as restrictive.

PROCEDURE

Following a general review of his or her health, each patient is clinically and radiographically examined. In cases where multiple implants are necessary, a presurgical prosthetic plan and template fabrication are employed to determine the location and angulation of implants. Patients are premedicated with an antibiotic beginning 2 days prior to surgery and continuing for at least 8 days postoperatively.

The oral facial region is prepared and draped. A local anesthetic with vasoconstrictor is then infiltrated and a crestal incision is made. When planning for a 5 mm or similarly wide implant, an osteotomy is initiated with a 3 mm round diamond sinus bur (Fig. 1). Drilling ceases about 1 mm short of the sinus floor. The surgeon then downsizes to a 2 mm sinus bur for the purpose of forming a narrower conical shape at the end of the osteotomy. This step in the drilling process is crucial to the formation of the pinhole through which graft material will be pushed to initially loosen the Schneiderian membrane.

Constant pressure is applied to the foot pedal of the high-speed handpiece to apply hydraulic pressure to the osteotomy while drilling. While rotating, the 2 mm sinus bur is gently tapped through the cortical bone of the sinus floor just hard enough to form a pinhole (Fig. 2). Hydraulic pressure is introduced to the surgical site at this stage, providing enough force to begin atraumatically dissecting the membrane from the sinus floor. To date no incidences of air embolism have resulted from the use of air and water pressure. To ensure that none occur, every attempt should be made to increase the water flow to its highest setting on the handpiece and allow pressurized water pressure to enter the pinhole slowly, before the bur is tapped all the way through. A delicate touch at this stage also safeguards against membrane perforation.

Once the membrane is loosened, hydraulic pressure is ceased. The membrane will be at rest but slightly detached. It will not remain in an elevated position until permanent graft material is introduced.

The patient is now ready for the primary stage condensing of the sinus. The preferred graft mixture consists of a demineralized freeze-dried bone matrix† combined with a smaller amount of small-particle,

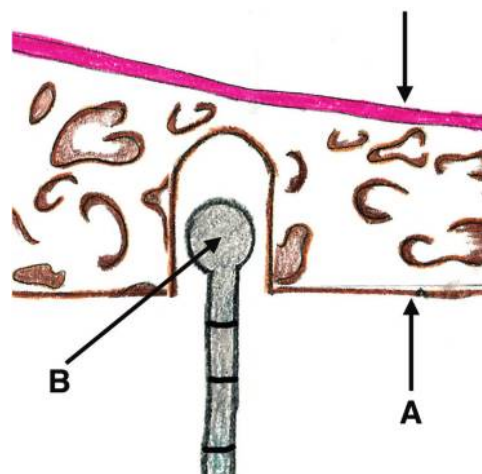


Figure 1.

With 5 mm (A) of sinus floor thickness, use a 3 mm round diamond bur (B) to start the osteotomy.

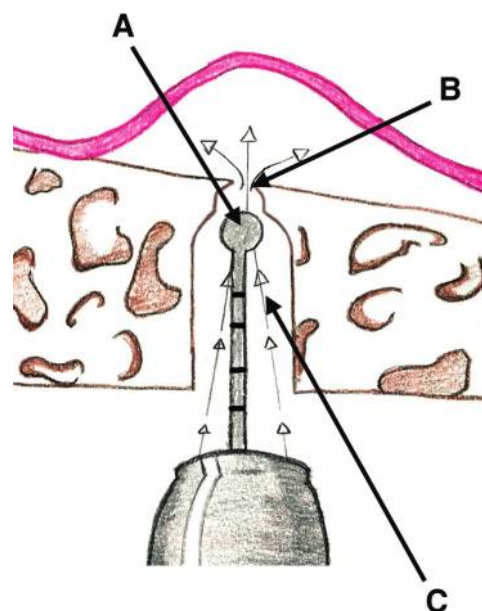


Figure 2.

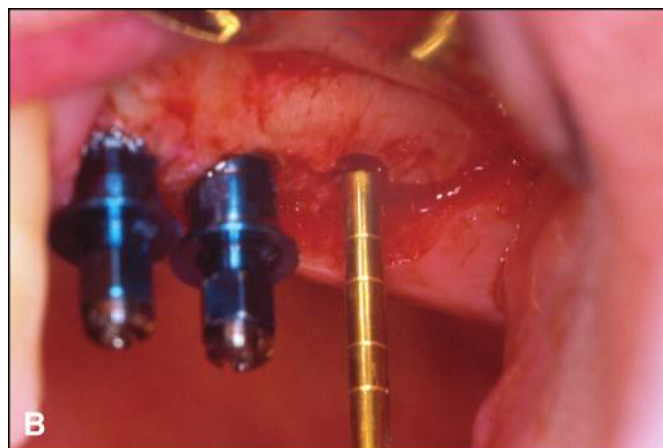
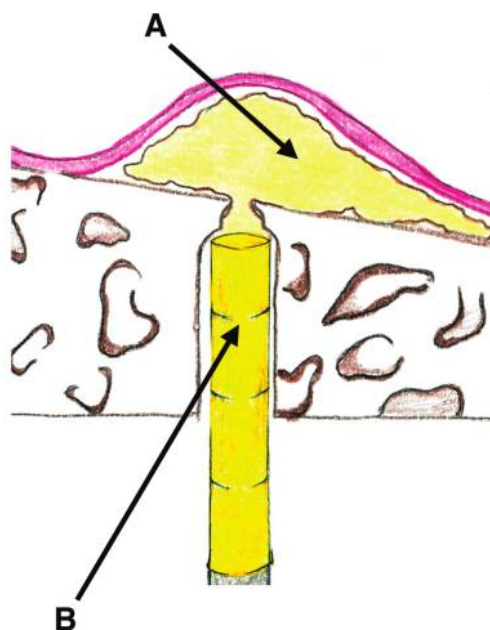
Tapping pinhole access to the sinus. The 2 mm round bur (A) forms a conical shape (B) at the end of the osteotomy. Consistent hydraulic pressure from the handpiece (C) through the pinhole inflates the Schneiderian membrane.

spherically shaped, peptide-coated product.‡ The latter product facilitates radiopacity for x-ray purposes, and its rounded shape produces less trauma when

* H&H Co., Ontario, CA.

† Grafton Demineralized Bone Matrix, BioHorizons, Birmingham, AL.

‡ PepGen P-15 particulate, Dentsply Friadent CeraMed, Lakewood, CO.



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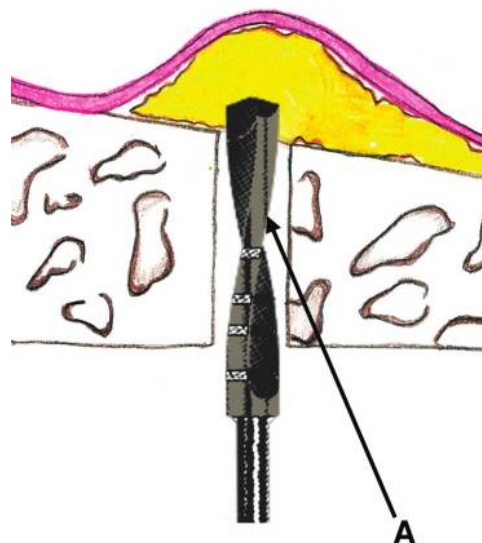
Figure 3.

A) Gently push the material (A) through the pinhole with a 3 mm condenser (B) to initially loosen the membrane. The conical end of the osteotomy prevents the condenser from entering the cavity. **B)** Clinical photo illustrating primary condensing.

condensed against soft tissue. A bone graft mixture is packed through the pinhole and pushed against the membrane using a 3 mm sinus condenser (Figs. 3A and 3B). The applied pressure will begin to loosen the membrane, while the conical 2 mm shape at the end of the osteotomy blocks the 3 mm condenser from entering the sinus cavity. We use only 1.0 cc of graft mixture to stretch the membrane upward because its purpose at this stage is merely to balloon the membrane upward. Some of this primary condensing graft material will irrigate out during subsequent drilling.

Once the initial lift is complete, the surgeon switches to a regular 3 mm implant drill and bores through the 2 mm conical shape. This opens full diameter access to the sinus cavity. The graft mixture already condensed under the membrane now acts as a cushion surrounding the drill bit to safeguard against punctures or tears (Fig. 4). Following this step, additional drilling and condensing occurs, using wider bits and condensers in diameters that are appropriate for the size of implant to be used.

The secondary lift introduces graft mixture for the permanent sinus augmentation. We have experimented with different product mixtures in different ratios, and generally prefer a combination of one or more bovine-derived mineralized bone materials[§] with at least 50% of the aforementioned peptide-coated particulate. If the surgeon wishes, a peptide-coated product enhanced by a hydrogel carrier^{||} may be substituted for the par-

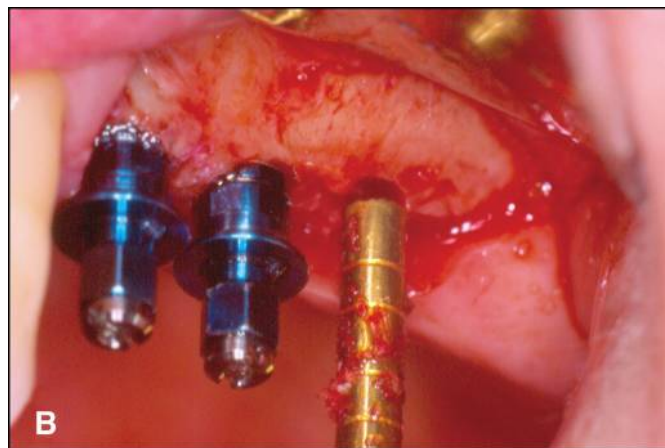
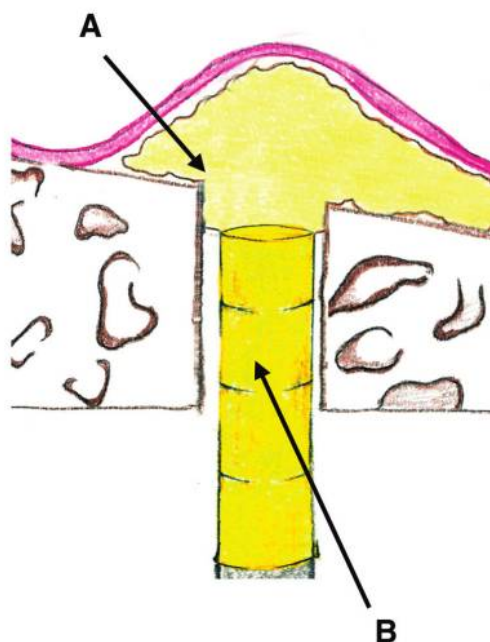
**Figure 4.**

Widen the osteotomy with a 3 mm implant drill (A). The bone graft mixture will insulate the drill bit from the membrane.

ticulate. Use an appropriately sized condenser to pack the bulk of the material into the stretched membrane (Figs. 5A and 5B).

§ Bio-Oss, Osteohealth Co., Shirley, NY or OsteoGraft/N-300, Dentsply Friadent CeraMed.

|| PepGen P-15 Flow, Dentsply Friadent CeraMed.



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Figure 5.

A) Use a combination of mineralized bone with at least 50% peptide-coated particulate (A) for the secondary graft. Pack the material in with a wider condenser (B). **B)** Clinical photo illustrating secondary condensing with the wider sinus condenser.

In general, use 1 cc of mixture for each 5 mm increment of sinus augmentation during secondary condensing. The Schneiderian membrane is fragile, and a conservative approach is often best when preparing implant foundation sites that combine simple socket preservation with the riskier anchoring benefits of a sinus lift. Frequently it is easy to predict when a well-grafted socket will make a greater contribution to the stability of the fixture than the sinus augmentation itself. In these cases, the sinus lift can be kept to minimal height in the interest of reducing trauma to the membrane.

Once a sufficient amount of bone graft mixture is condensed under the membrane, a 5 mm implant drill is used to prepare the site for fixture placement. As in the initial drilling procedure, the graft mixture acts as insulation when final implant drilling completes the narrow osteotomy, preventing the bit from perforating the Schneiderian membrane (Figs. 6A and 6B).

The patient is now ready for implants. To facilitate stabilization, we recommend tapered implant models characterized by closely spaced threads (Fig. 7). Figures 8 and 9 illustrate the structural advantages of implants sourced from different manufacturers.[¶] To further safeguard against implant failure we also use wider cover screws (washer screws) when possible. Additional factors contributing to quick, same-day implant stabilization include the elasticity of the sinus membrane, which serves to hold the packed material

in place, the condensing force of the patient's normal breathing, and clotting blood.

Figures 10, 11, and 12 are radiographs demonstrating hydraulic sinus condensing cases in various cases.

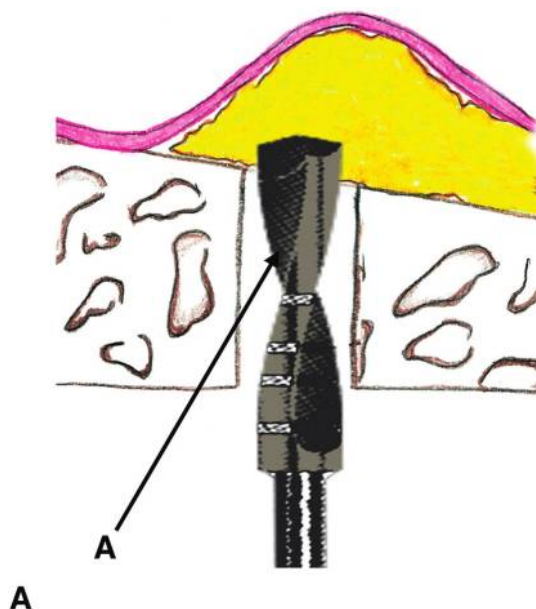
DISCUSSION

In sinus grafting, membrane integrity is a primary condition for and measure of success. Hydraulic sinus condensing effectively preserves the sinus membrane while taking advantage of anatomical features that, in conventional techniques, necessitate a more invasive approach or compromise the clinician's ability to position implants accurately.

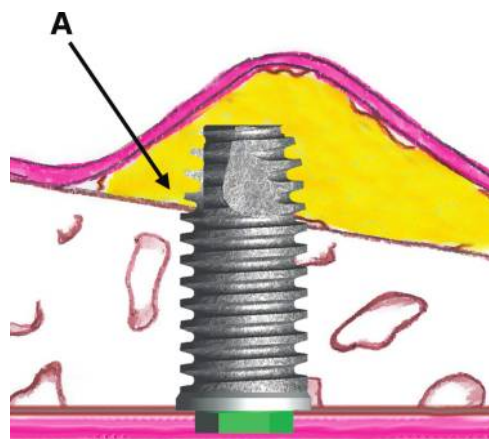
There are several issues to consider when comparing conventional techniques to the method discussed here. We should state that the traumas and failures associated with implants placed in aggressively drilled and overheated bone are, categorically, not an issue with our patients. Our patients are generally referred to us because they have deficient alveolar bone to begin with; thus, drilling is minimized or unnecessary and no overheating of bone occurs. This factor contributes to our near 100% success rate for implantation.

There are numerous trauma reduction and stabilization benefits, however, that issue directly from the use of hydraulic sinus condensing. The first has to do

[¶] Lifecore, Lifecore Biomedical Inc., Chaska, MN; BioHorizons; and Xive, Dentsply Friadent CeraMed.

**Figure 6.**

A) Use an appropriately sized drill (A) to widen the osteotomy for implant placement. **B)** Clinical photo illustrating the final drill.

**Figure 7.**

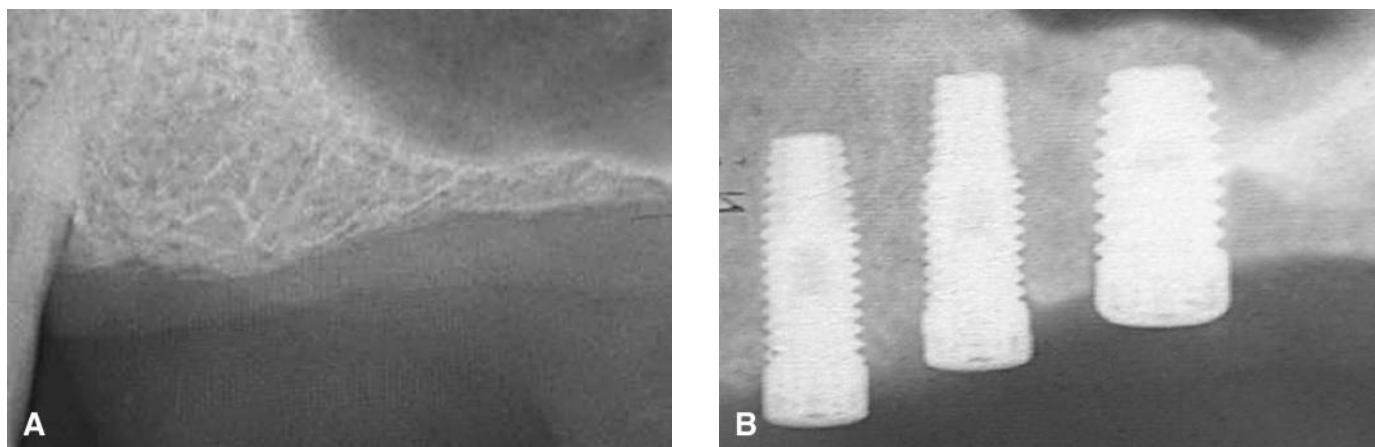
Use implants (A) with closely spaced threads.

with sinus membrane integrity. The lateral approach relies on the opening of an osseous window and is thus a more invasive procedure. Laceration of the Schneiderian membrane using this method can occur quite easily. As an option, the internal crestal approach reduces traumatic risk somewhat by employing osteotomes to simplify the procedure. Nevertheless, achieving control of greenstick fracturing when hammering a mallet against the sinus is very difficult. The use of bulky instruments to separate membrane tissue from bony spines or septa can, once again, result in lacerations. Although osteotomes can be used to expand the maxillary ridge, this advantage becomes superflu-

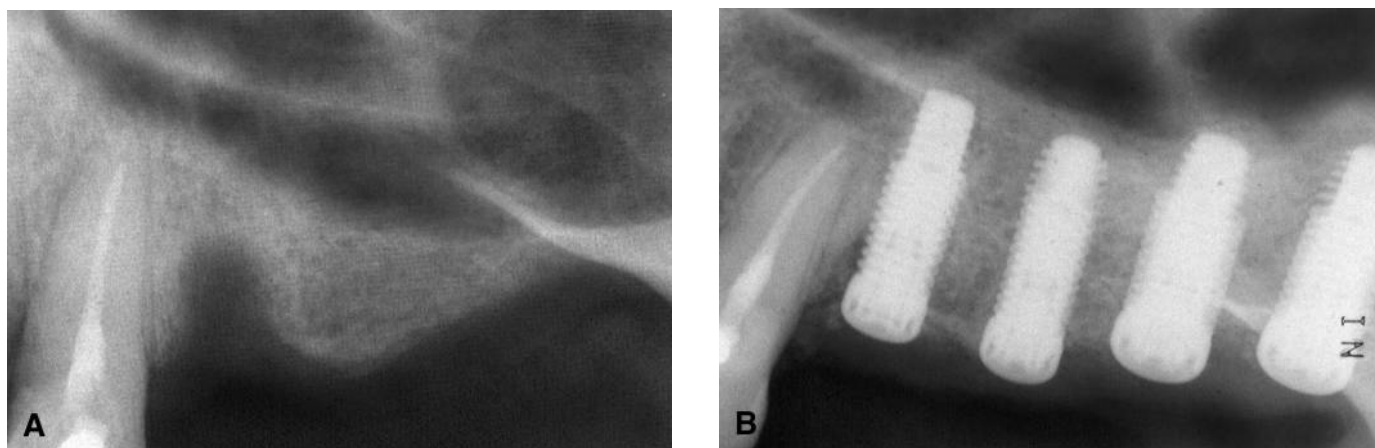
ous in cases where only 1 to 3 mm of crestal bone exists. In such cases expansion is unnecessary because the ridge, comprised primarily of Type 1 bone, already is wide.

Using special sinus burs and condensers in the hydraulic condensing technique can improve the internal crestal (osteotome) approach because the instruments provide a greater margin of tactile control and a more straightforward method for placing implants in deficient maxillary ridges. The internal crestal method harvests native bone from the sides of an osteotomy and pushes it up into the sinus on the concave tip of the osteotome tool via the percussive impact of a mallet. Hydraulic sinus condensing, on the other hand, relies on the more gentle tapping of a rotating sinus bur to create a tiny hole through which hydraulic pressure can be introduced. The technique is atraumatic because cortical bone is perforated rather than fractured. This allows us not only to avoid lacerations, but to place implants even when less than 1 mm of cortical bone is present.

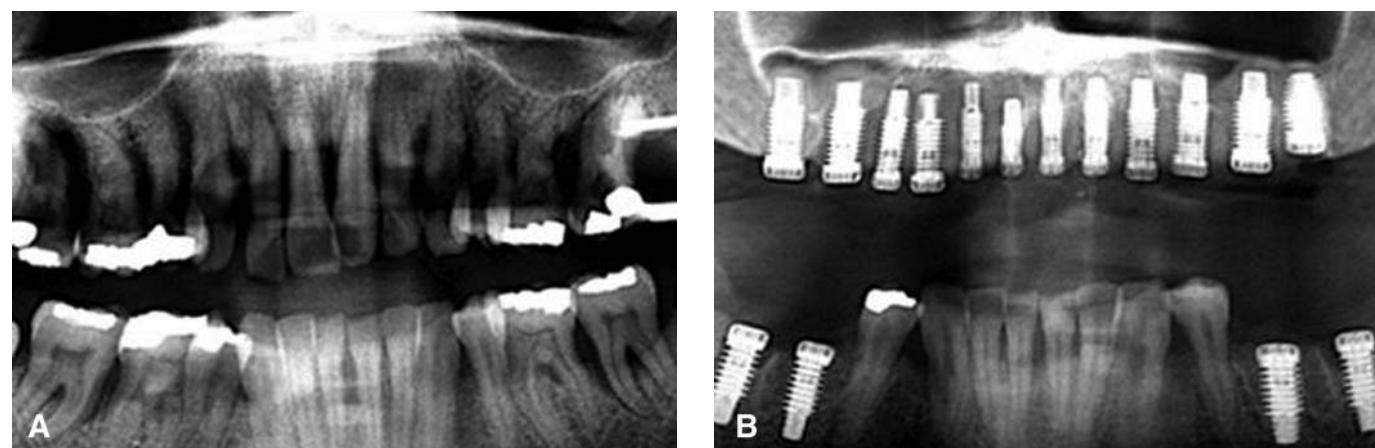
Variations in sinus slope present a second area of difficulty. Sloping sinus complicates the buccal window approach especially when sinus access windows must be decorticated further superior and posterior to reach the cavity and the membrane (Fig. 13). In the internal approach, a sloped sinus often requires additional chiseling on the side of the osteotomy where the cortical bone is thicker (Fig. 14). Also, the difficulty of achieving tactile control may increase when the sinus slope runs in a mesial-to-distal or buccal-to-palatal direction. In contrast, hydraulic sinus condensing makes use of a benign pinhole through which

**Figure 8.**

Before (A) and after (B): Stability achieved with sharply threaded implants.

**Figure 9.**

Before (A), sloping sinus floor and uneven crestal bone height, and after (B): In order to create even crestal height and sinus floor, same-length fixtures were placed at the same crestal level just 1 mm apical to the CEJ of adjacent natural tooth. The fixtures are tenting both the sinus membrane and gingival flap with the aid of a vertical translation technique.¹⁴

**Figure 10.**

Before (A) and after (B): A severe case involving immediate extraction and simultaneous sinus condensing. Stabilization at 16 sites was achieved in the inter- and intraradicular bone and the sinus floor. The patient returned to work almost immediately.

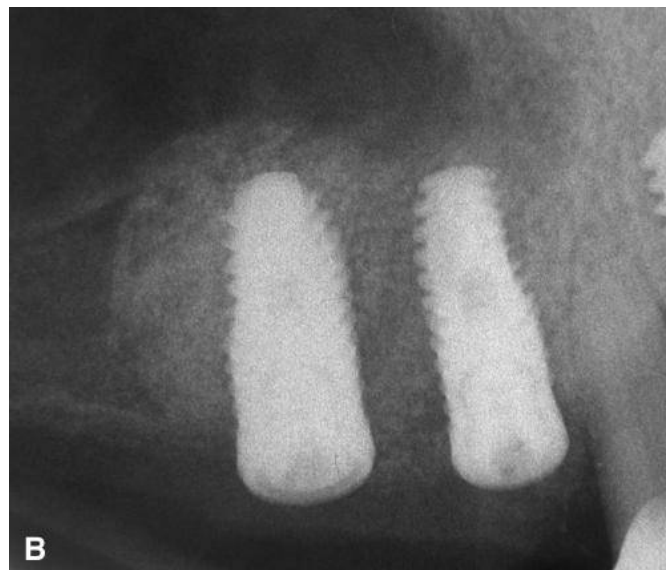
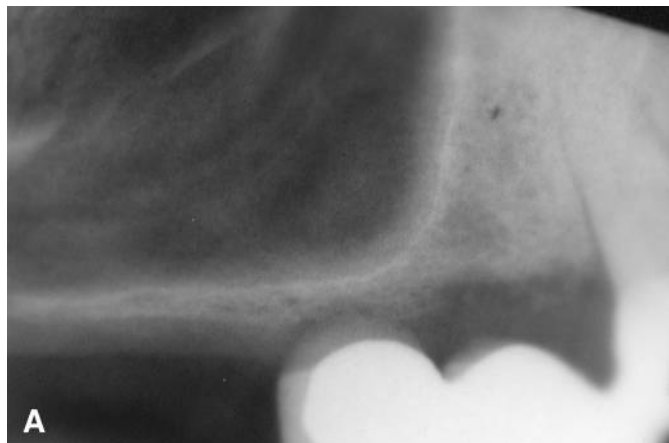


Figure 11.

Before **(A)** and after **(B)**: Membrane on the sloped area of most sinus cavities is less attached and not likely to tear. The pinhole and initial condensing were performed only on the mesial implant at the slope. It is not necessary to make more than one pinhole when loosening the membrane over multiple sites. Stability of the mesial implant was achieved using an implant with sharp coronal-end threads. Distal implant stability was achieved with a tapered implant and wider cover (washer) screw in 1 mm of cortical bone.

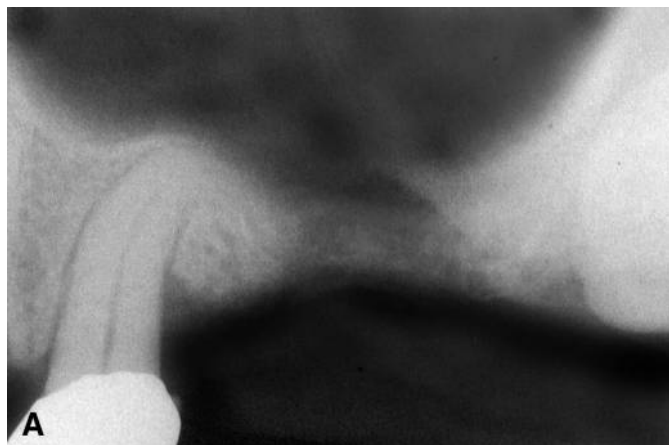


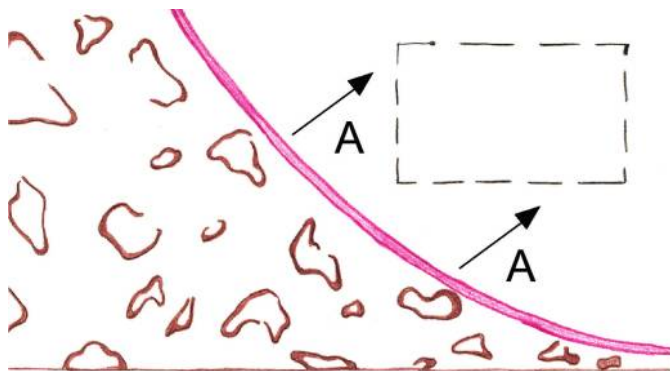
Figure 12.

Before **(A)** and after **(B)**: In cases of severe sinusitis the sinus membrane becomes thicker, reducing chances of perforation. Here, a 15 mm lift was possible with only 1 mm of cortical bone available.

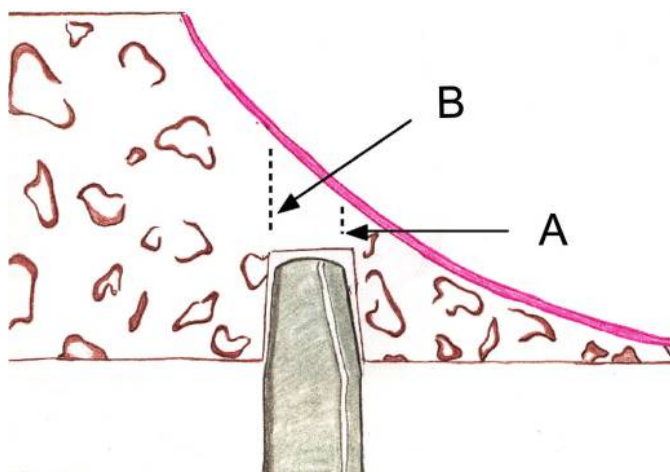
only hydraulic pressure and graft material – not surgical tools – push against the membrane to safely dissect it. Sinus slope thus ceases to be an issue.

A third issue involves the presence of compartmental sinus septum. In conventional surgery this anatomical feature may necessitate additional work and result in increased trauma. It may also force the surgeon to compromise implant positioning decisions. When performing a buccal window procedure, for example, two windows are required to open access to the sinus cavity on either side of perpendicular septa

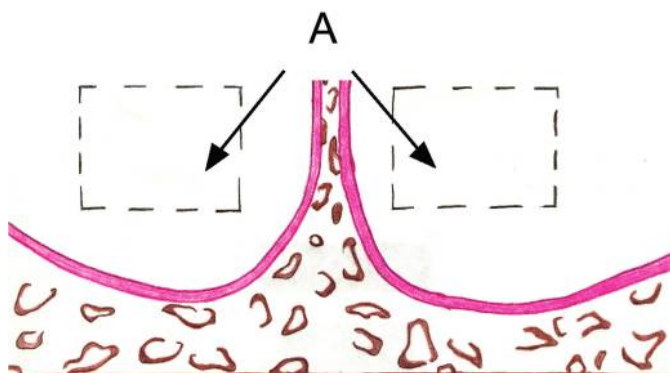
(Fig. 15). In the internal approach, use of osteotomes may encourage the surgeon to position fixtures further mesial or distal to perpendicular bony walls as it becomes difficult to advance the tool under the septum (Fig. 16). Such adjustments can compromise optimal positioning for some patients. With hydraulic sinus condensing, a single osteotomy and pinhole access allow for the introduction of graft material into both chambers abutting the septa. The surgeon can tap the bur through and balloon the sinus up on either side to prepare the site for implant placement directly under-

**Figure 13.**

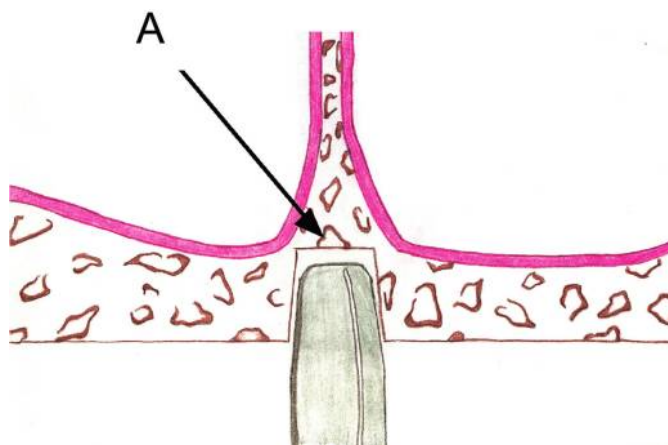
In the buccal window approach, the access window must be placed superior and posterior (A) to compensate for a severely sloping sinus.

**Figure 14.**

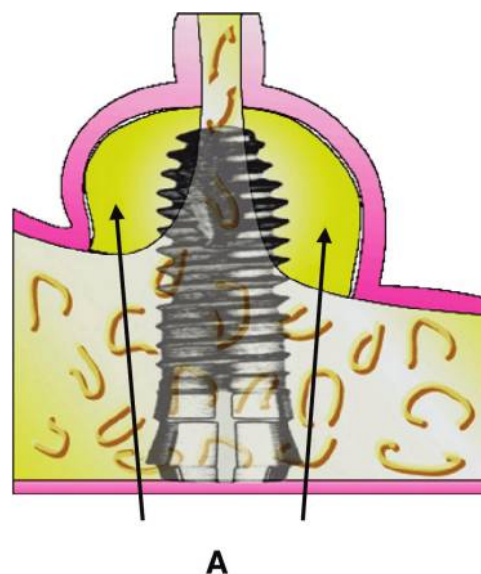
In the internal or osteotome approach, the distal side of the tool (A) enters the cavity first, whereas 3 mm of bone remains on the mesial side (B) of the tool. This necessitates additional chiseling to chip out the thicker side in a sloped sinus.

**Figure 15.**

In the buccal window approach, two access windows (A) are required to avoid septa.

**Figure 16.**

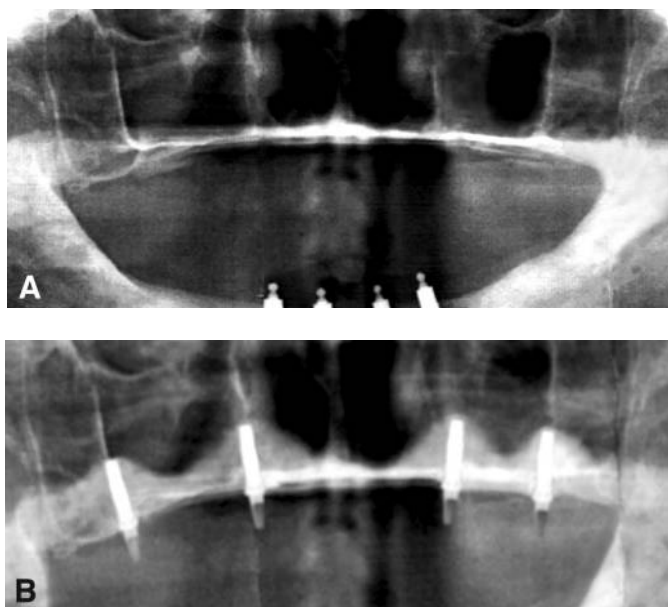
In the internal approach it is difficult to advance the osteotome once it reaches the septum (A) without risking a traumatic fracture. Implants must be placed mesially or distally to avoid this problem.

**Figure 17.**

Implant stability improves when the surgeon can graft under the membrane at the septum-sinus floor junction (A).

neath perpendicular bony walls (Fig. 17). Implants positioned this way anchor into anatomy that is multi-dimensional and, therefore, stronger (Fig. 18). This anchoring method facilitates improved and more immediate fixture stability.

Finally, hydraulic sinus condensing permits implant placement in the presence of complex nasal cavity. Nasal cavity implants are impossible in the buccal window approach and difficult at best when using the internal method, but we have found that the atraumatic nature of hydraulic pressure, accompanied by use of a minimally invasive pinhole using the described method,

**Figure 18.**

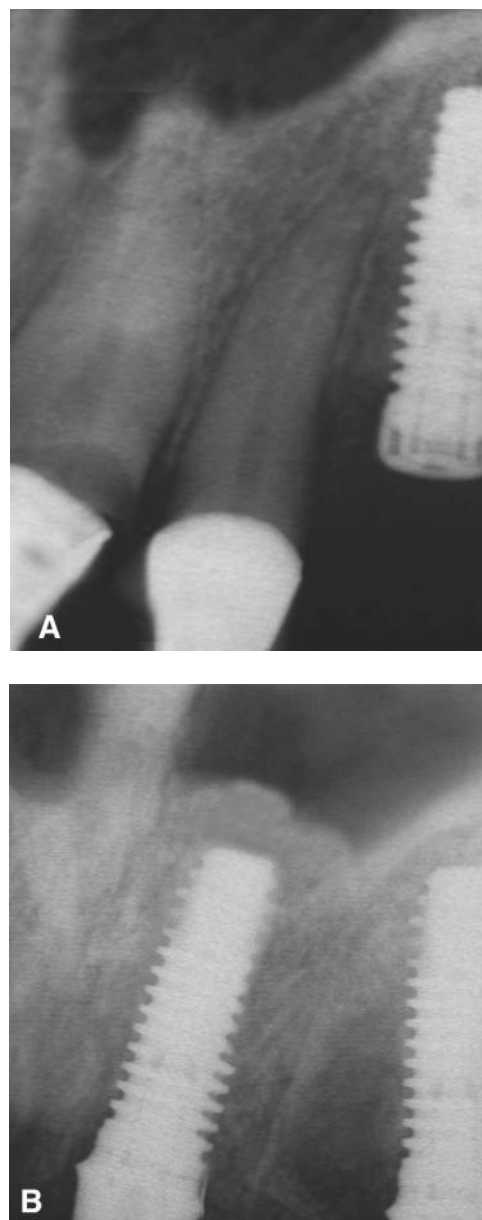
Before (A) and after (B): Enhanced implant stability with the fixture anchored into two bony planes.

circumvents the threat of greenstick-fractured bone shreds. In fact, hydraulic sinus condensing may be a patient's only safe option in cases where the anterior ridge has severely atrophied (Fig. 19).

Questioning the likelihood of air embolisms in this procedure is natural, given our use of air as a component of hydraulic pressure during the initial stage of the surgery. We have not encountered this difficulty in more than 1,100 cases. Hydraulic force introduced to the sinus cavity applies pressure to connective tissue, not blood vessels. Chances are minimal that the membrane will be perforated and a vessel ruptured; however, if this were to occur, it is likely that errant air pressure would enter a nearby sinus cavity, resulting in zero trauma.

Over a period of 8 years we have had to employ our sinus perforation contingency plan in fewer than a half dozen cases. In the event that a membrane is punctured, we switch to a 5 mm implant drill and drill completely through the sinus floor and membrane. We then suture the flap shut and reschedule the patient at approximately 3 weeks. This is sufficient time for a granulation plug to form where the membrane was drilled. Once healed, the patient's implant therapy can be concluded per normal procedure.

We should add that the benefits of hydraulic sinus condensing do not exclude cases referred for reasons of sinusitis or other inflammatory disease. Otolaryngologists refer some patients to our offices specifically for purposes of fortifying the natural barrier between the sinus and oral cavities or to relieve pressure within the sinus. In all such cases our patients have reported

**Figure 19.**

Before (A) and after (B): Extraction of tooth #9 with an immediate nasal floor elevation and implantation.

improvement of their sinus problems, including fewer or no headaches, improved breathing, improved drainage, and elimination of sinus pressure. None of our patients complained of a worsened sinus problem or newly formed sinusitis as a result of the procedure described. Of the eight implants that failed, immediate removal and successful replacement generated no new sinus problems.

CONCLUSIONS

Eight years of routine administration using hydraulic sinus condensing affirm the safety and efficacy of the

procedure. Hydraulic pressure and pliable bone graft mixture, used in tandem, can gently dissect soft tissue from bone in the sinus without danger of perforation. The methodical use of burs and condensers prevents surgical intrusion or perforation when a conically shaped sinus cavity access point is completed with a pinhole and the surgeon employs practiced tactile skill during the condensation stage. Rather than invading the cavity with surgical instruments, pressure is applied exclusively by hydraulic pressure and condensed grafting mixture.

Eight implants failed during the 8-year study period. No correlations were found between these failures and the surgical method. Fourteen implants required longer healing periods, extending the patient's time to restoration from the customary 4 months to about 10 months. In each of these cases the patient was handicapped by <1 mm of cortical bone.

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