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Two Different Clinical Indications Using Hydraulic Sinus Condensing® (HSC) Technique: Ten Years Follow-Up

By Leon Chen, DMD, MS, Jennifer Cha, DMD, MS, Hsin-Chen Chen, MD, Otolaryngologist

A minimally invasive surgical technique called Hydraulic Sinus Condensing® (HSC), using sinus bur with water pressure to drill through the crestal bone and loosen the sinus membrane with water pressure at the same time, was introduced at the annual meeting of American Academy of Periodontology in 1998. Since then, this technique has evolved to many modified techniques with the same concept (drill through the bone), such as trephine, peizo, and Reamer. The procedure is versatile and can be performed in conjunction with immediate extraction and implant placement, or transgingival, often known as flapless implant placement. For these indications, many patients have reported that HSC has been shown to provide quick relief of respiratory deficiencies or sinus-related pressure. This technique provided a minimal postoperative discomfort for medically compromised patients and avoided multiple surgeries. A 10-year follow-up CAT scan is included for long-term success of the procedure.

Dentists often encounter resistance from patients when protracted or invasive reconstructive therapies are prescribed to correct maxillary sinus deficiencies in preparation for dental implants. Cases hampered by a lack of clinical precedent can result in a sequence of referrals, with the patient being passed from one practitioner to another. Clinicians may even shelf a difficult case indefinitely.

While conservatism has its place in dental practice, patients may continue to suffer as a result of indecision. We have evaluated the benefits of a new, minimally invasive sinus elevation method as it compares with two established sinus elevation techniques: These include the long-practiced buccal (lateral) window procedure and the osteotome (crestal) approach. Dr. Woo assesses the buccal window approach as the most

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widely practiced, and the osteotome method as the most conservative.[6] With proper administration of HSC, a case can be made for liberalizing some of the beliefs that serve to limit the pool of sinus elevation and dental implant candidates. Successful resolution of issues associated with cumbersome treatment protocols, trauma, and pain management are benefits of the HSC method.

This article discusses two indications for which HSC is ideally suited. For each case type, we will discuss our reasons for implementing the procedure and its associated benefits. We categorize patients according to thickness of available cortical bone and whether certain anatomical features, to be discussed in the next article, are present. For a given implant site, cortical bone thickness is evaluated by measuring from the highest point of the alveolar crest to the lowest point of the sinus floor. In common practice, most clinicians avoid sinus elevations followed by immediate implantation for patients with < 5 mm of cortical bone. These patient types are designated as Class 3 or Class 4 patients, and our patients who receive HSC and immediate implantation generally fall into these two categories. Class 2 describes another category of patients whom a fair number of clinicians would judge as suitable for sinus-lift therapy with immediate

Clinical Sinus Classification	
Class 1	> 10 mm cortical bone
Class 2	6 mm to 10 mm cortical bone
Class 3	< 5 mm cortical bone
Class 4	No cortical bone present. Soft tissue only.
Classes 1SL, 2SL, 3SL or 4SL	Patients with a sloped (SL) sinus floor
Classes 1SP, 2SP, 3SP, or 4SP	Patients with one or more sinus septa (SP)

implants. Significantly fewer clinicians would recommend sinus augmentations for Class 1 patients.

We do not suggest that HSC should be a replacement for existing, proven surgical conventions. Rather, it is offered as an alternative to clinicians who would prefer to treat patients that too often have been turned away. Certain restrictions, of course, do apply to all available sinus-elevation options, including HSC. Unresolved facial growth, for example, eliminates HSC and implant therapy as an option for males younger than age 18 or females younger than age 16 (although a segmented approach in these cases, while traumatic, is conceivable). Also, due to the exclusively tactile nature of the blind HSC method, it may not be the right choice for surgeons who prefer a visual orientation. In such cases, the buccal window procedure is an obvious alternative.

Still, contraindications such as heavy smoking, sinusitis, or diabetes, need not be viewed as unconditionally prohibitive to the sinus-elevation solution presented here. Future articles in this series will discuss how infection and certain features of sinus anatomy, typically viewed as obstructive to the maxillary sinus lift procedure, can, in fact, be turned to the surgeon's advantage.

Case One — Multiple Extraction of Immediate, Implant Placements, GBR, and Sinus Lift Simultaneously — (four Surgeries in one)

In July 1998, a 45-year-old heavy-smoking female referred to the Dental Implant Institute of Las Vegas presented to us as a Class 3 sinus floor with generalized advanced periodontitis and irreversible atrophy throughout the anterior-posterior maxilla and in the lower molars. The subject required fixtures in maxillary tooth numbers 3-14 and in 18, 19, 30, and 31 of the mandible (*Figure 1*).

Starting on the right side, the

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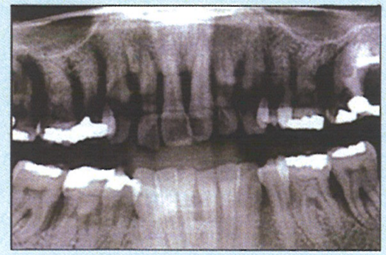

Figure 1: Periodontitis affecting maxillary and posterior mandibular dentition

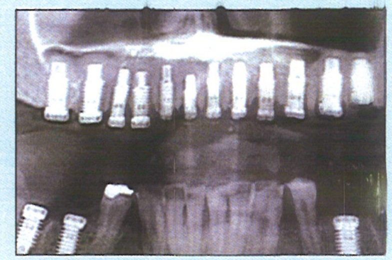

Figure 2: 16 implants immediately placed at the time of extraction and sinus lift

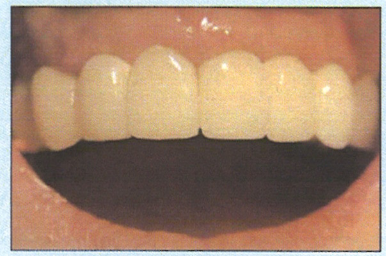

Figure 3: 12-month postoperative — full mouth restoration

Figure 4: Four implant sites to be approached transgingivally; the sinus floor is as thin as 1 mm with presence of slope and septum

upper molars and premolars were removed first. Sinus floor augmentation via HSC followed. To set up the procedure, a single pinhole was tapped through the sinus floor using a 2-mm sinus bur on the distal side of the site. Experience has shown that the first premolar provides the best reference for pinhole orientation when preparing multiple implant sites in a sinus floor that slopes in a mesial direction. In patients with a distally sloped sinus floor, the second molar provides the best pinhole reference.

When preparing multiple sites for implants, one might assume that vertical osteotomies with straight sides fail to provide sufficient room for moving the sinus condenser distally or mesially so that bone graft mixture can be packed under the membrane either behind or in front of the point of entry. But the preparatory osteotomies at each planned site are always drilled out to a diameter of 4 mm or 5 mm during the second stage of the procedure. These widened osteotomies provide enough room to condense bone particulate into the sinus at an angle. Skilled use of hydraulic force during the initial membrane loosening stage, followed by the use of 2-mm or 3-mm sinus condensers in osteotomies widened to 4 mm or 5 mm, makes it possible to graft bone in the desired direction over more than one implant site, provided that all the sites are located in a single-sinus chamber. Torque the fixture in and it will aid the even distribution of the bolus of graft material that has been condensed.

Following HSC in the right maxillary, implants were placed. The left-side maxillary was then elevated, socket grafted, and implanted. The canines were left intact at this stage to serve as references. The decision to use or not use stents is best made on a case-by-case basis; no stent was used in this instance.

Following implantation of the left-side maxillary, the lower molars were extracted and implanted. Next, we extracted and implanted the anterior upper teeth (which were not needed for HSC). Finally, tooth numbers 6 and 11 were extracted and implanted. The patient left the office with 16 implants, a fortified sinus, and a temporary denture

Figure 5: Implant sites landmarked with biopsy punch

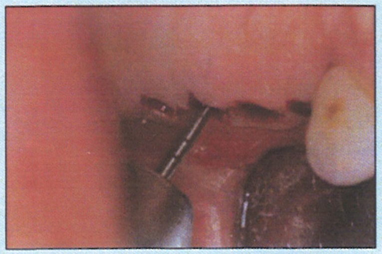

Figure 6a: Utilizing #2 Sinus bur to break the cortical floor, the water. Pressure from handpiece will simultaneously loosen the sinus membrane

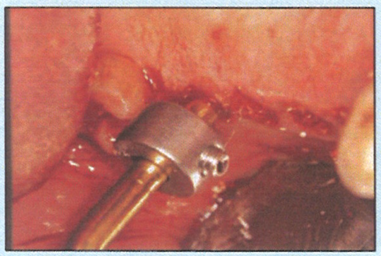

Figure 6b: Condensing graft materials with Chen sinus condenser

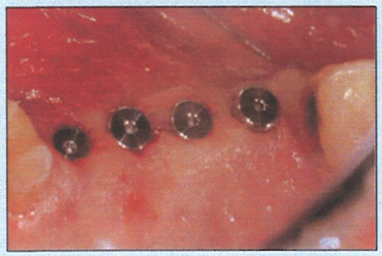

Figure 7a: Transgingival fixtures placed at the time of sinus lift

(*Figures 2 and 3*). Fixed prostheses with individual crowns were used in the permanent restoration.

Though this case was somewhat atypical, it illustrates how HSC can be a viable plan of action for patients who have had advanced periodontitis resulting in considerable decay. Since it is not necessary to access the sinus cavity on a tooth-by-tooth basis when preparing multiple osteotomy sites, the sinus elevation and socket graft usually can be completed in the same appointment. This allows the patient to return to a normal schedule almost without pause. Immediate fixture stabilization can be achieved through the combined effects of condensed allograft materials under the Schneiderian membrane, patient respiration to further compact the Schneiderian membrane, blood clot around the socket graft and fixture, and translate the gingival tissue for primary closure.

Case Two — Flapless Implants/Sinus Lift Simultaneously

In March 1997, a 56-year-old male came to the Dental Implant Institute of Las Vegas with a Class 3-SP-SL sinus floor and a two-pack-per-day smoking habit, fitted with a partial denture, and presented as a candidate for implants at tooth numbers 2, 3, 4, and 5 (*Figure 4*). The patient was highly sensitive to epinephrine and was taking Coumadin® daily; his referring physician would not permit interruption of the anticoagulant therapy. In order to fulfill the subject's desire for implants, it was necessary to perform the sinus elevation quickly under conditions of homeostasis to manage blood flow.

One advantage working in the subject's favor included a wide alveolar ridge, which is characterized by a low sinus position and serves to eliminate the possibility of undercutting on the buccal side. The patient also benefited from the presence of 5 mm of keratinized tissue.

We elected to approach the sinus cavity from crestal transgingivally. Blood flow management was achieved with the use of a carbon

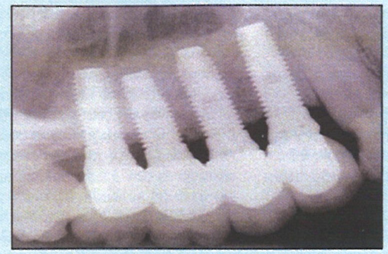

Figure 7b: Restoration six-months postoperative

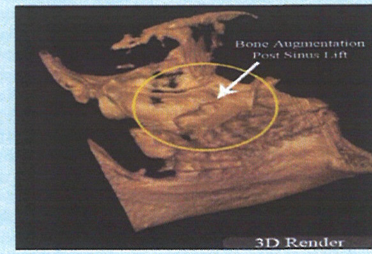

Figure 7c: Shows 9-years later, 3D CAT Rendering showing 2 bony domes (see area marked by circle)

dioxide laser. The utility of such lasers in cases calling for extra delicacy is well documented in the literature.[8,9,10,11,12] A biopsy punch was used to landmark four implant sites (*Figure 5*). One carpule (54 mg) of Carbocaine® 3% (mepivacaine hydrochloride) with-epinephrine was infiltrated on both the buccal and palatal sides of the treatment area. Following the previously discussed HSC drilling procedure, a single pinhole was drilled through the ridge with a sinus bur at tooth number 4. We then condensed DBX®a through the pinhole to loosen the sinus membrane (*Figure 6a*). Because there was approximately 2 mm of soft tissue over a 3-mm sinus floor, the 5-mm depth marking on the sinus condenser served as an important reference.

Once the membrane was loosened, 5-mm osteotomies were drilled at the marked implant sites. The aforementioned bone-graft mixture was then condensed at each location (*Figure 6b*) and implants were placed. By using the carbon-dioxide laser and approaching the sinus transgingivally, we gained excellent control of blood flow and performed the HSC procedure with no postoperative swelling (*Figure 7a*). *Figure 7b* shows the graft six months postoperative and *Figure 7c* shows a CAT scan nine years later.

This type of indication is common. Soft tissue healing often may be compromised by smoking habits, inflexible medication regimens, or systemic conditions. In these cases, it is useful to amend the HSC procedure by employing a cauterizing laser. This is especially true if the patient suffers from a hereditary blood disorder. Minimally invasive transgingival approach can be utilized for patients with medically compromised conditions such as diabetes or patients who are heavy smokers. This surgical approach allows these types of patients to be able to have implant surgery with sinus elevations.

Summary

The use of hydraulic force to condense bone particulate into the maxillary sinus is a predictable and less invasive method of site preparation for many, but not all, dental implant candidates. It is our approach in the primary indication for HSC — patients with advanced periodontitis in whom insufficient cortical bone at the alveolar ridge of the posterior maxilla stands as a detriment to effective implantation. A second indication for HSC accounts for those patients who suffer blood disorders or have sensitivities to certain medications, such as vasoconstrictors, and in whom it is crucial to manage bleeding during surgery. In these cases, changes in the armamentarium used for the procedure can effectively accommodate special needs. These clinical cases were followed for 10 years to show the continued success of the HSC technique. ■

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Calcium Sulfate Use in Dentistry

By Dr. Mamidwar, DDS, MD, MS

Calcium sulfate hemihydrate (CS), known as plaster of Paris, is a fascinating material with unique physical and chemical properties. Although it has been used as a bone-graft material for more than a century, we are just beginning to understand its biologic properties and are, thus, just beginning to understand its potential. This material exists in many forms and variations, and materials intended for biomedical use must be carefully produced. Thorough knowledge of the physical properties of this material and its biological mechanisms must be obtained for clinicians to achieve optimum results when using it as a bone-graft/repair material, barrier membrane and hemostatic/angiogenic agent, or in other unique, developing ways. For example, recent studies indicate that it is fully soluble in vivo and causes significant bioactivity through calcium release, pH change, and local carbonate apatite precipitation. It can be used as a cement or in preset granular form and has significant antibiotic/drug release properties. Additionally, newer forms of CS, such as timed-release CS composites, have excellent potential as fully soluble bone repair biomaterials.

CS and Bone Graft/Repair

In past studies, CS cements have been observed to act as fillers in bone sites to prevent soft tissue growth until bone has regenerated. However, some studies have reported that this material has been observed to resorb too quickly before bone can regenerate. It is very likely that failed attempts to use this material as a bone filler have resulted from improper use or use of inconsistent and uncharacterized material. A medical practitioner using CS cement as a bone-filler material must have complete knowledge of its properties.

The properties of this material suggest that certain rules should be followed when it is used as a bone filler:

Choice of material

- Only the dense forms of the material should be used as a bone filler.
- This material must be completely tested for impurities by manufacturers and should consist of a consistent range of particle size to control setting properties.

Choice of implant site

- The mechanical properties of CS cement suggest that its use as a bone filler is appropriate as long as it is not used in load-bearing applications.
- When possible, it should be used in enclosed bony sites where it can be adequately packed and properly set.

Form of CS cement used and setting agent

- Whenever possible, pre-set material should be used as implants since CS cement set in contact with blood can exhibit variable setting properties and dissolve more quickly than preset material.
- When setting the cement in a bleeding bone site, the clinician should take every precaution to suppress bleeding, which interferes with setting.
- When setting the cement in a bleeding bone site, the clinician should use accelerants to speed setting and prevent blood infiltration of the unset cement.

Overall, CS worked very well as a bone-graft material.

Bone defect sites usually show significant bleeding. In these situations, blood proteins can interfere with setting. There is also evidence that CS cements set in the presence of blood dissolve more quickly. Thus, whenever possible, preset CS cement implants should be used since these will always dissolve more slowly and consistently than those set in the presence of blood. Also, it is always advantageous to work in as dry a bone site as possible in order to achieve proper setting. Working with a slightly "dry" cement (using slightly less water or setting agent than needed) works well in these environments because some moisture is usually absorbed from the environment to complete setting. Better setting in these situations is also produced through the use of accelerants, such as NaCl or K_2SO_4, which cause the material to set before significant blood proteins can infiltrate the cement. One method of clinical use suggests 1) packing the site with CS hemihydrate powder with gauze to produce hemostasis, 2) removing the gauze, 3) using NaCl for formation of a slightly dry cement, 4) packing the operative site as densely as possible with this cement using a layered approach (referred to as the stratification method), 5) overfilling the site, if possible (if soft tissue coverage allows), and 6) applying 4% K_2SO_4 to the surface to almost immediately set the surface of the defect and stabilize the CS filler.[1-2]

CS as Barrier Membrane and Hemostatic/Angiogenic Agent

Guided-tissue regeneration barrier membranes play an important role in healing of the bone defects by maintaining space for osteogenesis. Several studies have shown that calcium sulfate works as an effective barrier. Payne et al studied, in vitro, the barrier properties of three different commonly used materials (polytetrafluoroethylene, polylactic acid, and calcium sulfate).[3] Human gingival fibroblasts were cultured on these barrier materials and on

control surface (a polystyrene culture plate). A cell-migration assay showed that there was significantly greater migration of fibroblasts on control surfaces compared to any of these barrier membranes ($p < 0.05$). More interesting was the finding that mean migration distance of fibroblasts over calcium sulfate was greater than that on PLA. SEM studies showed that there was more cell migration and spreading on calcium sulfate as compared to ePTFE or PLA. Calcium sulfate was also more conducive to cell survival. Based on these findings, it was concluded that calcium sulfate has excellent potential for use as a guided-tissue regeneration barrier membrane compared to ePTFE or PLA.

Other investigators conducted animal studies on the use of CS as a barrier material, and concluded that it worked as a barrier membrane in the defect area and allowed bone regeneration during healing.[4,5] Kim et al also studied the use of CS as a barrier in a randomized, controlled human clinical study.[6] Twenty-six patients with periodontal infrabony defects were treated. Half of those patients were implanted with allogeneic, demineralized freeze-dried bone matrix (DBM)/calcium sulfate composite with a CS barrier. The remaining half received gingival flap surgery alone and served as a control. Significantly better bone regeneration was observed in patients treated with DBM+CS combination than in the control patients.

It is clear from the results of all these studies that CS is effective as a resorbable barrier material. ePTFE is one of the most commonly used barrier membranes, but is nonresorbable and must be removed at a later time. Additionally, infection rates are higher with nonresorbable barriers. Thus, CS offers significant advantages over routinely used barrier membranes. In a paper on endodontic surgical technique, Kim and Rethnam noted that CS also has hemostatic properties.[7] This is not surprising considering that calcium ion is a known coagulant.

Recent studies showed evidence of increased angiogenesis in defects filled with CS compared with those filled with autograft. Strocci et al studied the growth of blood vessels in the defects filled with CS and covered with an ePTFE barrier (group 1), CS alone (group 2), and autograft alone (group 3).[8] Microvessel density in all these defects was evaluated at the end of four weeks. Mean comparative numbers of microvessels in group 1 were 9.88 ± 4.613; in group 2, microvessel density was 7.92 ± 1.998; and in group 3 the values were 5.56 ± 1.895. Mean difference between group 1 and 2, group 1 and 3, and group 2 and 3 were statistically significant. These findings showed that CS is highly angiogenic, even when compared with autograft. Although the reason behind this phenomenon has not been definitively demonstrated, this important finding partly explains the efficacy of CS for bone grafting purposes. It is well known that blood vessels are necessary for bone healing, and, among others, Schmid et al have shown the close correlation between the development of new blood vessels and bone formation.[9]

CS as a Delivery Vehicle

CS also works as an effective vehicle for delivery of growth factors and drugs. Several studies have shown that CS can be effectively used as a drug delivery vehicle. Antibiotics such as tobramycin have been delivered locally using calcium sulfate. Beardmore et al have shown that tobramycin-impregnated calcium sulfate was useful in preventing development of infection in bone defects.[10] In an infection-prone bone-defect model in goats, no infection was observed in defects filled with tobramycin-impregnated calcium sulfate or defects filled with a combination of demineralized freeze-dried bone matrix and tobramycin-impregnated calcium sulfate. However, infection developed in seven of the eight goats where the defects were filled with demineralized freeze-dried bone matrix alone and in six of the seven goats where the defects were left empty. This study proved the effectiveness of calcium sulfate as an antibiotic delivery vehicle.

Doadrio et al studied the effect of using calcium sulfate-based cements as drug-delivery vehicles on the physico-chemical properties of calcium sulfate itself.[11] Their studies showed encouraging results. There was no effect on the physico-chemical properties of calcium sulfate because of its combination with cephalexin, a first-generation cephalosporin. Setting properties were not affected, and neither were the dissolution properties. Release of cephalexin was directly related to the rate of dissolution of drug-carrying cement. Calcium sulfate released cephalexin faster because of its fast dissolution. However, cephalexin release from hydroxyapatite/calcium sulfate cement was controlled because of its slower dissolution. Presence of hydroxyapatite reduced the dissolution rate of composite and hence the release of cephalexin.

Rosenblum et al showed that fibroblast growth factor (FGF) was released at controlled rates from set CS cement disks, and that the FGF release was directly related to the dissolution rate of the CS cement.[12] In a recent publication, Intini et al showed that a combination of CS and platelet-rich plasma was not only an effective bone-repair material but that it had osteoinductive properties similar to bone-morphogenetic proteins.[13] Most bioactive molecules, in particular those that can be dissolved into water- or salt-containing solutions, can be incorporated into set CS materials. These results suggest that CS can act as a simple and effective delivery vehicle for release of bioactive molecules into bone-defect sites.

Summary of Mechanisms Involved with CS and Bone Repair

CS has been shown to stimulate bone growth in controlled defect studies. Its unique biologic properties are probably based on its in vivo dissolution. There are at least four proposed mechanisms by which CS could stimulate bone regeneration:

1) Space filling/prevention of fibrous tissue ingrowth. At its most basic level, CS fills space in a bone defect, preventing the ingrowth of soft tissue and retaining the space for bone regeneration. In vivo, in a bone defect filled with solid CS, the CS dissolves at about 1 mm per week from the outside inward. This dissolution can significantly outpace the formation of new bone but, nonetheless, acts to reserve space for new bone.

2) Calcium Phosphate Precipitate. After using CS as a bone-repair material for over 115 years, we are beginning to understand that CS has properties that were not appreciated or understood until the last 15 years. Calcium ion release by the CS causes high-local calcium ion concentrations in surrounding bone tissues. High calcium ion concentrations cause significant cellular changes, including increased alkaline phosphatase activity and gene expression favorable to bone formation.

3) Carbonate apatite precipitation. One of the observed effects of CS dissolution is the local precipitation of carbonate-substituted apatite. This precipitate forms at the surface of the CS material as it dissolves, is left behind in the tissue as the CS dissolves beneath it, and acts as a trellis for osseoconductive ingrowth of new bone.

4) pH Change and Calcium Ion Release. There are other important aspects to be considered as CS dissolves in the body. In vitro, as the CS dissolves, the local pH decreases. This result is probably caused by a combination of sulfur ion release and the precipitation of carbonate apatite. It may also explain why the observed precipitate forms in intermittent bands in vivo instead of forming a more consistent mass. In vivo, the local pH drop would be expected to interrupt apatite precipitation until local body fluids are buffered to a pH that again allows precipitation to again proceed, probably resulting in cyclic pH changes. This local drop in pH may lead to a chain of events that may also contribute towards development of bone in the defect. ■

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