Localized Sinus Elevation and Osteocompression with Single-stage Tapered Dental Implants: Technical Note

Marcel G. Le Gall, DDS[1]

In the atrophic posterior maxilla, placement of longer (at least 10 mm) and wider diameter implants may significantly improve long-term results, but sinus grafting is often necessary to provide sufficient bone volume for implant support. The crestal approach to sinus augmentation requires penetration of the sinus floor with surgical instruments that are often difficult to control; there is a high risk of damaging the schneiderian membrane. Fabricating a round cutting rim at the apical end of a single-stage tapered implant can provide a controlled method of gently penetrating the sinus floor prior to grafting and placement of the definitive implant. In soft type 4 bone, the single-stage tapered implant design can help to enhance initial stabilization through lateral osteocondensation of the receptor site. Localized sinus elevation with osteocompression utilizing single-stage tapered implants may offer a simplified approach to the complex clinical challenge of successfully restoring the atrophic posterior maxilla.
INT J ORAL MAXILLOFAC IMPLANTS 2004;19:431–437

Key words: *dental implants, schneiderian membrane, sinus augmentation, sinus elevation*

Implant placement in the posterior maxilla is often complicated by deficiencies in the volume and quality of available bone. Sinus elevation via a crestal approach has been used successfully for more than 2 decades to facilitate placement of longer implants.[1,2] The technique generally involves the use of a mallet with a series of tapered and cylindric instruments, such as osteotomes, to widen and condense the lateral walls of an osteotomy, followed by the upward fracturing of the sinus floor with the instruments. A variation of this technique involves preparation of an osteotomy to 1 mm below the sinus and careful use of a trephine drill to cut a cap through the sinus floor. In either case, additional particulate graft material may be inserted into the elevated sinus to increase the volume of available bone. Dental implants are sometimes immediately placed, or the access channel may be filled with particulate graft material and allowed to heal as part of future implant site development.

Although improvements[2,3–15] to osteotome designs have expanded their clinical efficacy in condensing, removing, and/or preserving soft bone material in maxillary and sinus implant reconstructions,[12–14] the indications and use of these instruments remain limited and technique sensitive, even for experienced clinicians. In sinus membrane elevation, the depth of osteotome insertion can be difficult to control; there is a high risk of sudden membrane puncture and penetration into the sinus cavity with the instrument. Use of a trephine drill to penetrate the sinus floor also may damage the schneiderian membrane.

This article presents a technique for localized sinus elevation and lateral osteocompression of low-density bone utilizing a single-stage (transmucosal)

[1]Private Practice Limited to Dental Implants and Occlusion, Lorient, France.

Correspondence to: Dr Marcel Le Gall, 42 rue de la Belle Fontaine, 56100 Lorient, France. Fax: +33 2 97 64 73 31. E-mail: mglegall@wanadoo.fr

Fig 1 Double self-tapping threads to the apical end of the implant and 2 different surgical protocols are designed to facilitate placement in high- or low-density bone. Note the convex bottom.

tapered screw implant system (Tapered SwissPlus; Zimmer Dental, Carlsbad, CA) and a custom surgical instrument.

CLINICAL PROCEDURES

Implant System

Description. The implant has a single-stage design. It consists of an intraosseous, tapered, self-tapping screw with a microtextured surface and a machined, transmucosal neck with a slightly fluted emergence profile (Fig 1).[15,16] Two tandem external threads originating on opposite sides of the apex enable placement with higher torque and fewer rotations than conventional screw-type implants with a single thread pattern.[17–20] Indeed, in dense bone the torque applied during the last revolution can reach 100 Ncm,[21] easily surpassing the 40 Ncm commonly recommended for immediate or early loading.[22] An external bevel and internal, antirotational connection form the abutment interface.[15] Other features of the system have been described previously.[15,18,21,23] The implant receptor site is prepared conventionally using a series of straight drills in progressive diameters, but the final drill diameter differs according to the density of bone in the surgical area.

Dense Bone Surgical Protocol. In dense and moderately dense bone (types 1 to 3),[24] the final straight drill is a step design that prepares a narrower diameter in the apical region of the osteotomy. Approximately one third to half of the tapered implant body can be placed before the self-tapping threads engage the walls of the receptor site, which can facilitate placement in locations with limited vertical access, such as the posterior mandible. This feature, combined with the double thread pattern on the implant body, considerably limits the number of revolutions required to seat the implant, thereby reducing the risk of overheating the bone. After placement, intimate bone contact is well distributed over the entire length of the implant body, and the surgeon can tactilely discern the firm anchorage achieved. Under these conditions, immediately loading of the implant poses very little risk, provided caution is used to avoid any initial occlusal overload.

Soft Bone Surgical Protocol. In low-density bone (type 4), sequential preparation of the osteotomy culminates with a final straight spade drill that is 0.2 or 0.3 mm smaller in diameter than the tapered apical end of the implant, depending on the implant's diameter. During placement, the self-tapping apical threads of the implant fully engage the lateral walls of the receptor site and gradually condense the bone to a maximum of 0.6 or 0.7 mm at the crest of the ridge, depending on the implant diameter. Research has shown that when a receptor site is prepared slightly smaller (minimum 100 µm) in diameter than the implant, the force-fitting stresses generated during placement will increase placement torque and implant stability.[16,17] In ridges with adequate width, this technique is designed to produce axial and lateral densification of the soft bone and achieve maximum thread engagement along the entire implant body for immediate stability. In narrow ridges, bone densification and lateral deformation may be performed simultaneously during implant placement, but care must be taken to avoid tearing the crest of the ridge. It is sometimes advisable to expand the ridge using a tapered osteotome prior to placing the implant.

Localized Sinus Elevation

Indications. In cases where at least 5 mm of vertical bone height is available to stabilize the implant in the posterior maxilla, lateral bone densification and elevation of the sinus can be achieved with placement of a single-stage tapered implant that is up to 4 mm longer than the available bone height. Narrow-diameter implants less than 10 mm in length are generally contraindicated for the posterior maxilla because of the high stress concentrations in the region. Single-stage tapered implants with a 4.8-mm-diameter platform are exclusively recommended for this application because of their ability to mechanically enhance immediate stabilization. The narrower-diameter (3.7-mm) implant body can help increase lateral osteocompression at the crest of the ridge by placing the implant to the base of its flared neck. When ridge width allows placement of the wider- (4.8-mm) diameter implant body, the increased lateral osteocompression and longer coronal threads can help stabilize the implant in soft

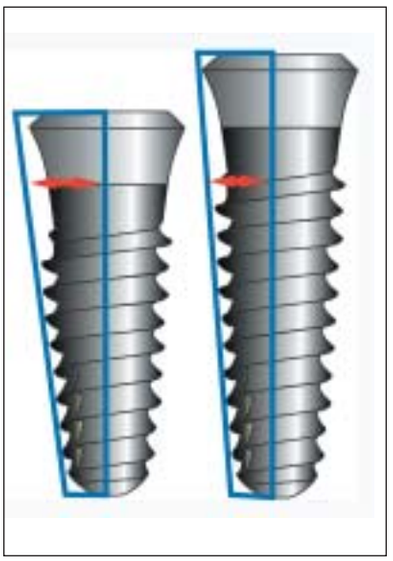

Fig 2a *(Left)* A longer implant *(right)* than the one to be placed *(left)* is used for the custom surgical instrument. Using a narrower implant as an instrument *(arrows)* will help preserve the lateral bone for osteocompression by the definitive implant.

Fig 2b *(Above)* The custom surgical instrument is fabricated by cutting a concavity with sharp edges into the convex bottom of the implant. Depending on the case, 1 custom instrument may be necessary for each size of implant body (3.7 mm and 4.8 mm).

type 4 bone and thereby limit the required depth of neck insertion.

Diagnosis and Treatment Planning. Prior to surgery, assessment of the patient's medical and dental histories and present health status is recommended to identify any potential health concerns. A diagnostic workup allows evaluation of the volume and location of available bone as well as the esthetic and functional needs of the patient. Impressions followed by the fabrication of working casts to be articulated helps the clinician plan how many implants to use and in what positions to place them, as well as consider the bearing surface,[25] crown-root ratio, occlusal relationship, and potential complications. This process facilitates the creation of a prosthetic waxup and fabrication of a surgical template to guide the surgery relative to the planned prosthesis. A signed patient consent form is obtained prior to surgery.

Custom Surgical Instrument. In some cases, elevation of the schneiderian membrane can be greatly facilitated by first using a custom surgical instrument to gently cut through the sinus floor. The custom surgical instrument is fabricated by modifying the apical end of a single-stage tapered implant that is 2 to 4 mm longer than the definitive single-stage tapered implant that will be placed (Fig 2a). A thin rotating disk is used to flatten the convex bottom of the implant, and a concave cup similar to that of a cutting osteotome is cut into the implant bottom with a round carbide bur (Fig 2b). If desired, the thin rotating disk can be used to cut serrations into the top edge of the prepared concave cup.

Surgical Protocols. After anesthetizing and preparing the patient for surgery, a partial- or full-thickness flap is elevated to expose the surgical site. If necessary, the crest of the ridge may be flattened with an osteotome and mallet or by cutting with an appropriate drill under copious irrigation. The sequential osteotomy procedure for low-density bone is used to initially prepare the site. Completion of the surgical procedure depends on the vertical height of available bone, the condition of the sinus floor, and the density of the available bone (Figs 3 and 4).

Vertical Bone Height ≥ 10 mm. For sites with a bone height of at least 10 mm, where the sinus floor is flexible and poorly defined and bone of type 1, 2, or 3 is available, an implant 2 mm longer than the actual height of available bone can sometimes be used alone to elevate the schneiderian membrane. The osteotomy is sequentially prepared to a depth of 1 mm to 0.5 mm below the schneiderian membrane, as determined tactilely and radiographically (Fig 3a). The longer implant is manually screwed into the receptor site using slight pressure (Fig 3b). The lateral osseous compression created by the tapered implant body and support provided by the large threads facilitate slight elevation of the sinus floor, which is still attached to and irrigated by the schneiderian membrane (Fig 3c). This technique allows for minute control of the sinus floor elevation and can be easily monitored by digital radiography during the procedure.

Vertical Bone Height ≥ 5 mm. In cases where the vertical bone height is at least 5 mm, the surgical procedure described may be used with either a flexible or rigid and well defined sinus floor and bone of any type. When augmentation and placement of an

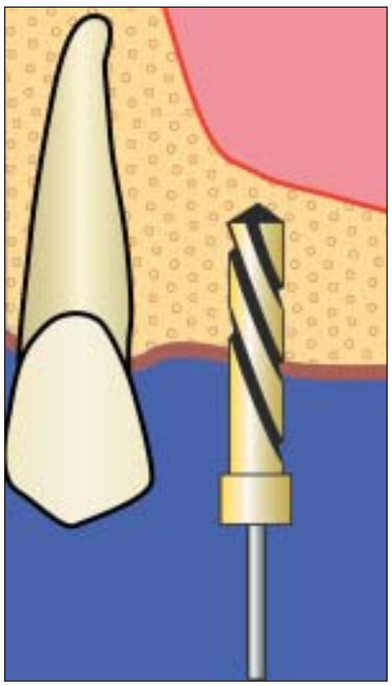

Fig 3a An osteotomy is prepared 1 to 0.5 mm below the schneiderian membrane in sites with a flexible sinus floor and types 1 to 3 bone.

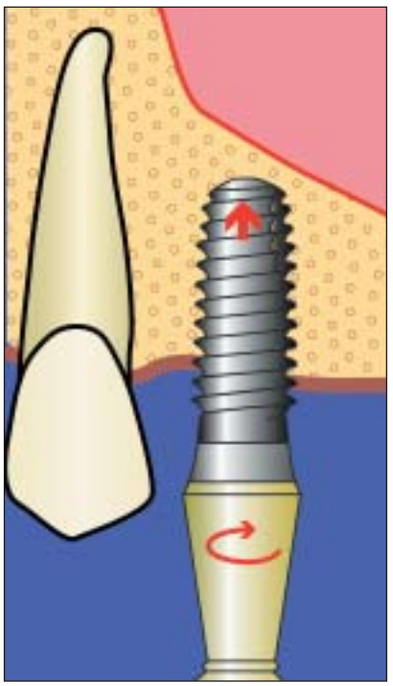

Fig 3b An implant 1 to 2 mm longer than the available bone height (at least 10 mm) can be used to elevate the sinus.

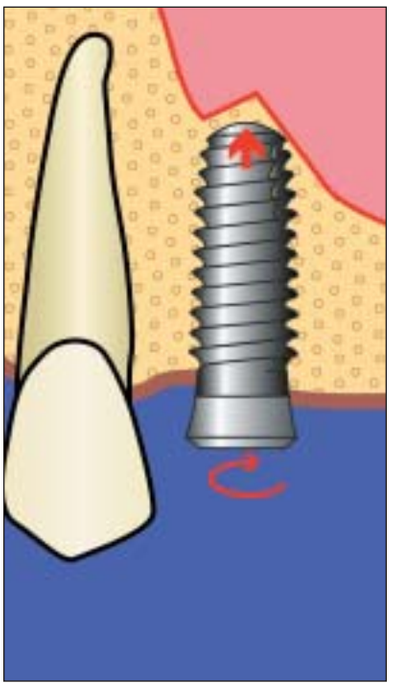

Fig 3c As the implant is screwed into place, its convex bottom lifts the schneiderian membrane and underlying bone.

implant up to 3 mm longer than the actual height of available bone is desired, the osteotomy is sequentially prepared to a depth of 1 mm below the sinus floor (Fig 4a). The custom surgical instrument is progressively screwed into the osteotomy until a cap is just cut through the floor of the sinus, as determined tactilely and radiographically (Fig 4b). The instrument is removed to prevent damage to the sinus membrane. In cases where type 4 soft maxillary bone and/or a resistant sinus floor prevent the implant from obtaining sufficient support to fracture the floor of the sinus during placement, a malleted osteotome technique can be utilized to fracture the sinus floor.

Vertical Bone Height of < 5 mm. In cases where the vertical bone height is less than 5 mm, the surgical procedure described may be used with either a flexible or rigid and well defined sinus floor and bone of any type. A staged approach consisting of sinus grafting followed by secondary implant placement 6 months later is recommended to optimize primary implant anchorage. Either a crestal or a lateral window technique (Caldwell-Luc operation) may be used.

Completing the Surgery

If additional graft material is desired, the partially seated implant or partially seated custom surgical instrument is removed. Particulate graft material is introduced into the receptor site and pressed into the elevated sinus region with a cylindric surgical instrument that is smaller in diameter than the receptor site (Fig 4c), or by the bottom of the implant or custom surgical instrument as it is screwed into the receptor site again. Care should always be taken not to completely seat the custom surgical instrument. When a sufficient quantity of graft material has been placed, the definitive single-stage tapered implant is screwed into the receptor site to its normal placement depth (Fig 4d). If slight lateral play remains after seating the implant or if there is limited vertical access, it may be necessary to screw the implant further into the bone to the base of the implant's flared neck, which can help stabilize the implant by increasing lateral osteocompression at the crest of the ridge.

After implant placement, healing screws are attached to the implants. The soft tissues may be closed with interrupted nonresorbable sutures

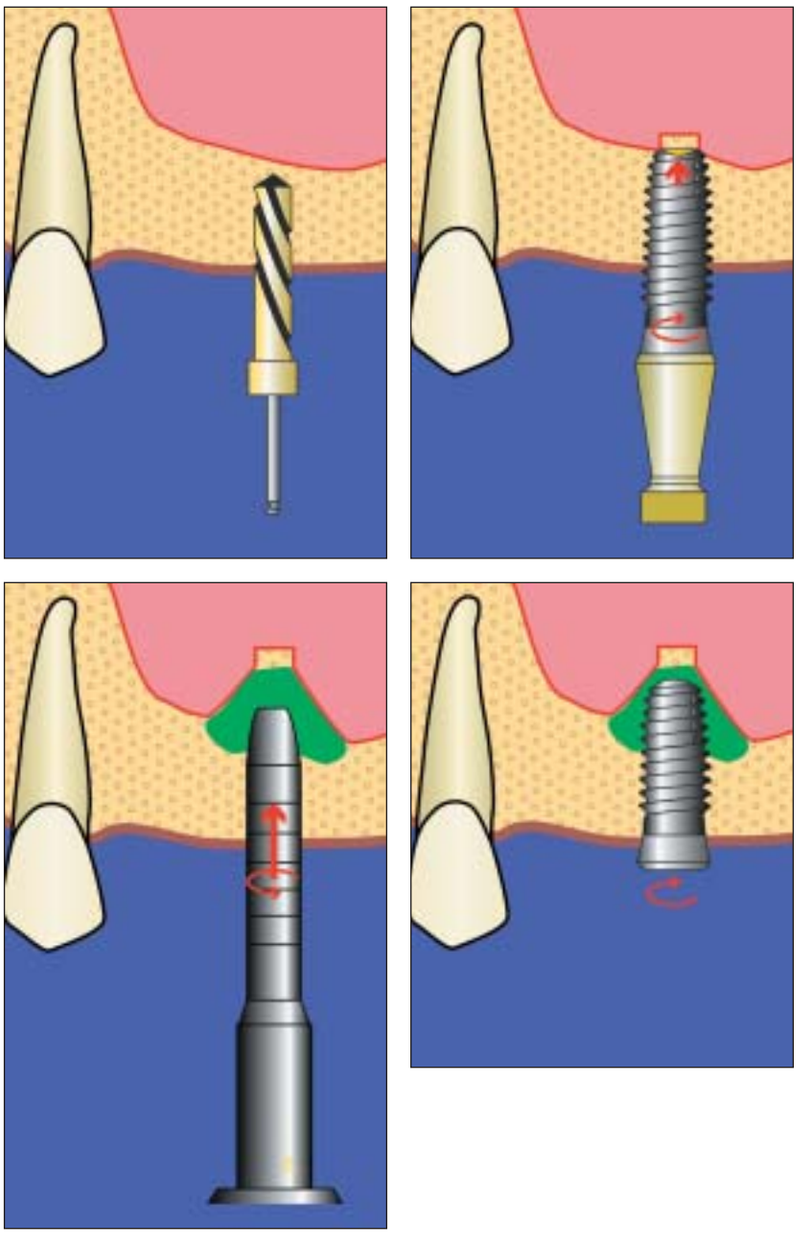

Fig 4a *(Left)* An osteotomy is prepared to 1 mm below the sinus floor in sites with a rigid sinus floor and types 1 to 4 bone.

Fig 4b *(Right)* The custom surgical instrument is carefully threaded into the receptor site to cut a cap through the floor of the sinus. It is then removed.

Fig 4c *(Left)* An osteotome or other cylindrical instrument is used to elevate the bone cap.

Fig 4d *(Right)* The tapered implant is placed into the receptor site.

around the necks of the implants for 1-stage surgery, or over the tops of the implants for 2-stage surgery, which will depend on the depth of implant placement according to the gingival biotype.[26]

Postoperative Treatment

Prophylactic antibiotic therapy commencing on the day of surgery and continuing 5 to 7 days postoperatively is recommended. Patients should be instructed to try not to blow their noses for at least 3 days after surgery, and to cough or sneeze with an open mouth. The use of anti-inflammatory medications during the same period may also help to limit edema and bruising, and analgesics may be used to control pain or discomfort. Sutures are generally removed 1 week postoperatively, and standard clinical procedures are followed to prevent prosthetic loading. After 6 months of healing, the implant can be clinically restored with well-balanced contacts and guidance on the posterior teeth.

DISCUSSION

In the posterior, atrophic maxillary ridge, longer and wider implants are needed to enhance long-

term survival, which often requires bone augmentation beneath the sinus so that implants 10 mm or longer can be placed.[2] The technique of localized sinus floor elevation has expanded prosthetic options by enabling the placement of longer implants into these atrophic maxillary segments without the postoperative morbidity associated with onlay and interpositional (Le Fort I osteotomy) grafting.

The procedures for localized sinus elevation presented in the present article involve the modification of a single-stage tapered implant to serve as a cutting instrument for controlled penetration of the sinus floor. It is important to underscore the fact that once the implant has been modified, it is no longer considered a dental implant but rather a custom surgical instrument that is removed after use. Clinical procedures could be greatly enhanced through the commercial fabrication of a comparable surgical instrument. The ideal design would be 14 mm in length, with the tapered body and double threads of the implant, but with a permanent, milled implant mount section, which would eliminate the potential for screw loosening during use. It would be fabricated from surgical-grade stainless steel with a smooth surface to facilitate cleaning and sterilization prior to use and have a concave apex with a circular cutting rim.

While all single-stage tapered implants of a given body diameter have equal dimensions at their coronal and apical threads, the progression of taper from the maximum to the minimum body diameter is proportional to the implant length. Hence, the maximum diameter of a 10-mm-long implant body is greater than the 10-mm-length of a 14-mm-long implant, because of the more gradual taper of the longer implant. Utilizing an implant that is 2 to 4 mm longer than the definitive implant to be placed allows the instrument to be screwed into the osteotomy to the length of the proposed implant without maximum lateral osteocompression of the osteotomy walls. When the custom surgical instrument is removed and the definitive implant is placed, the lateral osteocompression is expanded to the definitive implant's maximum diameter for enhanced stability.

The original formulation of the 2-stage surgical technique was fueled by concern that any loading of the implant during the primary stages of bone healing might prevent osseointegration or result in fibrous encapsulation of the implant.[27] External small threads were engineered to stabilize the implant by engaging cortical bone, preferably in both the crestal and basal locations of the receptor site. In low-density bone, however, the cortical layer may only present as a thin shell or may be completely undifferentiated. Researchers have reported that increasing bone density through osteocompression and creating a tight interface between the implant and bone can greatly enhance immediate implant stabilization, especially in the soft bone of the posterior maxilla.[5,16,18,21,27,28]

Although the amount of bone that comes into direct apposition with screw-type implants gradually increases with follow-up time, removal torque for screw-type implants is dependent on the amount of compact bone, rather than the total amount of bone, between the implant threads. The low-density-bone surgical technique presented here, coupled with the self-tapping, double-thread pattern and slightly tapered form of the selected implant, is designed to compress the lateral walls of the receptor site during placement and reduce the number of required rotations for seating the implant.[21] Immediate, intimate contact can thus be achieved along the entire length of the implant body, which may reduce the need for remodeling at the hard tissue interface.[21] For bone of higher density, these features can provide excellent mechanical resistance to facilitate immediate loading.[27,28] In comparison, the greater number of required rotations to seat straight screw-type implants with single thread patterns often results in slight play between the implant and bone at the level of the first few coronal threads, while the most stable interface is limited to the apical region of the implant.

In addition to thread engagement and body design, surface roughness may help to provide a frictional interface with the receptor site and assist in mechanical retention by facilitating bone ingrowth during osseointegration.[16] Numerous investigators have reported that surface roughness can positively influence cellular and tissue responses to implants, and that a positive correlation exists between implant surface roughness and the degree of initial and long-term mechanical fixation.[16,21] While the surface finish of screw-type implants can range from relatively smooth (eg, machined) to relatively rough (eg, titanium plasma-sprayed), the implants described in the present article have a fairly uniform, moderately microtextured surface that has been found to osseointegrate even under immediate, full occlusal loading conditions in partially edentulous patients.[29]

In grafting the elevated sinus, some clinicians first insert a collagen sponge to enhance resistance to graft displacement in the event of a small schneiderian membrane tear and to serve as a barrier between the sinus and graft material. Other clinicians prefer to maximize the amount of particulate

graft material inserted into the sinus region and rely on the integrity of the schneiderian membrane to maintain the graft. The gentle sinus elevation procedures described in this article facilitate the latter, although either technique may be used.

CONCLUSION

Technologic and surgical advancements over the last 3 decades have expanded the applications of dental implant therapy far beyond its original indications. Localized sinus elevation with osteocompression utilizing 1-stage tapered implants represents a simplified approach to the complex clinical challenge of successfully restoring the atrophic posterior maxillary jaw. Beyond the new proposals presented in this article, an essential key of the success or failure of an implant is the way that mechanical stresses are transmitted to the peripheral bone.[30] The optimal regulation of functional forces developed during deglutition and mastication[24,31] is then the last prerequisite for long-term success.

ACKNOWLEDGMENT

The author thanks Robert Riley, CDT, and Michael M. Warner, MA (Zimmer Dental), for their assistance.

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