ADVANCES IN BONE MANIPULATION: PART 2 OSTEO-MOBILIZATION FOR HORIZONTAL AND VERTICAL IMPLANT SITE DEVELOPMENT.

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INTRODUCTION

Re-establishing appropriate alveolar dimensions allows a "restorative-driven" implant position to achieve long-term stability, esthetics and function. The benefits of bone manipulation procedures are often a minimally invasive, trans-gingival and single-intervention dental implant reconstruction for the benefit of our patients. The previous article (*Selected Readings in Oral and Maxillofacial Surgery*, Vol. 18, #4) described osteo-condensation, which preserves bone, improves bone quality, manipulates the desired implant position and increases implant primary stability; and trans-alveolar sinus elevation (TASE) techniques that gain intra-sinus vertical alveolar height at residual defects or extraction sites for implant placement. Modified TASE techniques were also discussed for larger vertical elevations. This article will discuss osteo-mobilization techniques for restoring alveolar width and combined osteo-mobilization and TASE procedures for restoration of alveolar width and height for esthetic dental implant reconstruction.

Tooth loss results in esthetic compromise, reduced function, malocclusion and bone loss for which patients seek reconstruction with dental implants. Alveolar atrophy follows tooth loss, with progressive bone loss (horizontally, vertically or both) and reduced bone quality.[1-3] (Fig. 1A,B) Although application of osseointegration has greatly advanced dental reconstruction,[4-7] adequate bone quality and quantity are essential for initial and long-term implant success.[7-9]

Reconstruction with dental root-form implants often requires augmentation of the implant site to restore alveolar contours. (Fig. 1B) Vertical and horizontal alveolar dimension loss has been managed with various modifications of: guided bone regeneration,[10-13] block and particulate grafting,[13-17] ridge expansion,[18-25] distraction osteogenesis,[26-27] composite micro-vascular free flaps,[28] and the use of biologics and biomemetics,[29-34] to restore height and contour. These methods often require multiple or staged procedures with prolonged healing intervals, increased cost and post-operative discomfort. Reconstruction with dental implants has advanced as a long-term treatment option, with enhanced functional and esthetic outcomes using faster, less invasive and more predictable treatment options.[35-41]

An alternative to these conventional implant-site development procedures is a group of **bone manipulation** techniques that mobilize vital bone with plastic bending, shaping or condensation of tissue as a bone flap or a bone-periosteal flap.[18,20,23,42-44] These result in contour or dimensional changes, while preserving bone integrity and viability. The concept is to manipulate the residual bone to create an intra-bony cavity with a wider base

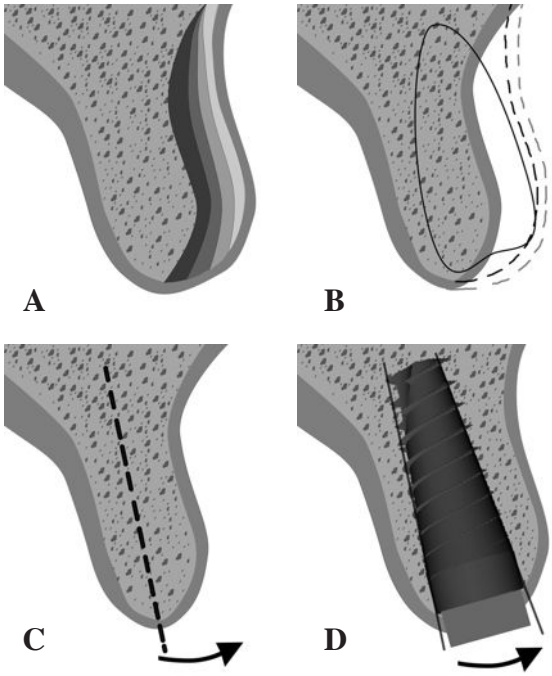

Figure 1. Graphic representation of progressive horizontal bone loss resulting in reduced bone volume that could compromise "restorative-driven" implant positioning. **A.** Progressive horizontal bone loss, **B.** Progressive horizontal bone loss complicating implant positioning, **C.** Bone incision for osteo-mobilization, **D.** Osteo-mobilization with facial/buccal bone manipulation to allow a "restorative-driven" implant position.

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or taller roof (i.e. a "four wall bony defect") that heals like an extraction site, with access of mesenchymal stem cells and the normal wound healing mechanisms.[44] (Fig. 1C,D) These techniques can be broadly categorized as **osteo-condensation**, **trans-alveolar sinus elevation (TASE**) and **osteo-mobilization**.

Osteo-condensation and trans-alveolar sinus elevation (TASE) were reviewed in Part 1 (*Selected Readings in Oral and Maxillofacial Surgery*, Vol. 18, #4).[45-53] Bone manipulation techniques are most commonly utilized in the maxilla due to the spongy, less cortical nature of the maxillary bone.[23,42,54-61] The edentulous posterior maxilla poses additional challenges with progressive sinus pneumatization, horizontal and vertical bone loss, and reduced bone quality.[62] (Fig. 2) Bone manipulation techniques increasingly have application in the mandible with the technological advances of office-based Cone Beam Computed Tomography (CBCT), Piezosurgery®, and specialized instrumentation and implant design.[21] The advantages of these techniques are: limited use of graft materials, simultaneous implant placement, reduced discomfort, and faster native bone healing.

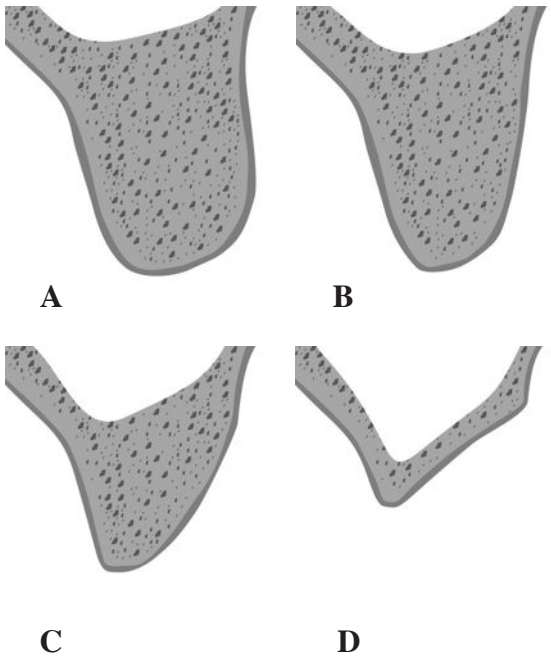
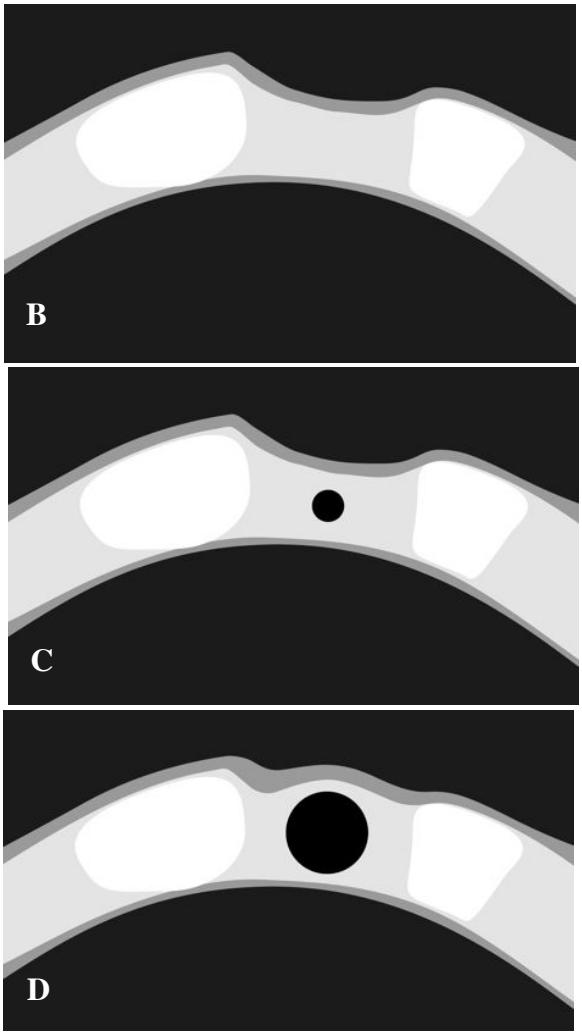


Figure 2. Graphic representaton of progressive bone loss and sinus pneumatization. **A.** Healed post-extraction site in the posterior maxilla, **B**. Horizontal buccal bone loss with slight increase in vertical sinus height, **C & D**. Progressive patterns of combined horizontal buccal and vertical alveolar bone loss with increasing pneumatization of the sinus. This can result in a severely reduced bone volume that cause positioning challenges for implant reconstruction.

Osteo-condensation best describes these minimally invasive osteotome techniques in which osteotomes of increasing diameter compress or condense the spongy bone of the maxilla to develop the implant site.[56] They are useful in cases of mild horizontal bone loss because they preserve and enhance the residual bone rather than remove bone, as would be the case with drilling.[54,56-61] Summers also described the "ridge expansion osteotomy," with full thickness flap exposure and preparation with a 2 mm drill, the implant site could be "expanded slightly at the cortices" with osteo-condensation by compressing the intervening bone with osteotomes.[54] (Fig. 3B,C) The compression increases the bone density, bone to implant contact, and slightly increases the horizontal ridge width. (Fig. 3C) A modification of this technique uses rotary mechanical expanders to accomplish the osteo-condensation, reducing the patient manipulation.[24,25] The **ridge expansion osteotomy** is the transitional step from osteo-condensation to osteo-mobilization. (Fig. 4)

Osteo-mobilization describes a group of bone manipulation techniques that rely on precise bone osteotomies of the residual

Figure 3. Osteo-condensation with tapered osteotome expansion (ridge expansion osteotomy). **A.** A set of tapered osteotomes. (NobelBiocare®, Yorba Linda, CA), **B.** Graphic representation of coronal section showing horizontal bone loss, **C.** Graphic representation of coronal section showing full thickness flap exposure and 2 mm pilot drill, **D.** Graphic representation of coronal section showing use of progressive tapered osteotomes to condense and manipulate the crestal bone, increasing the horizontal dimension.



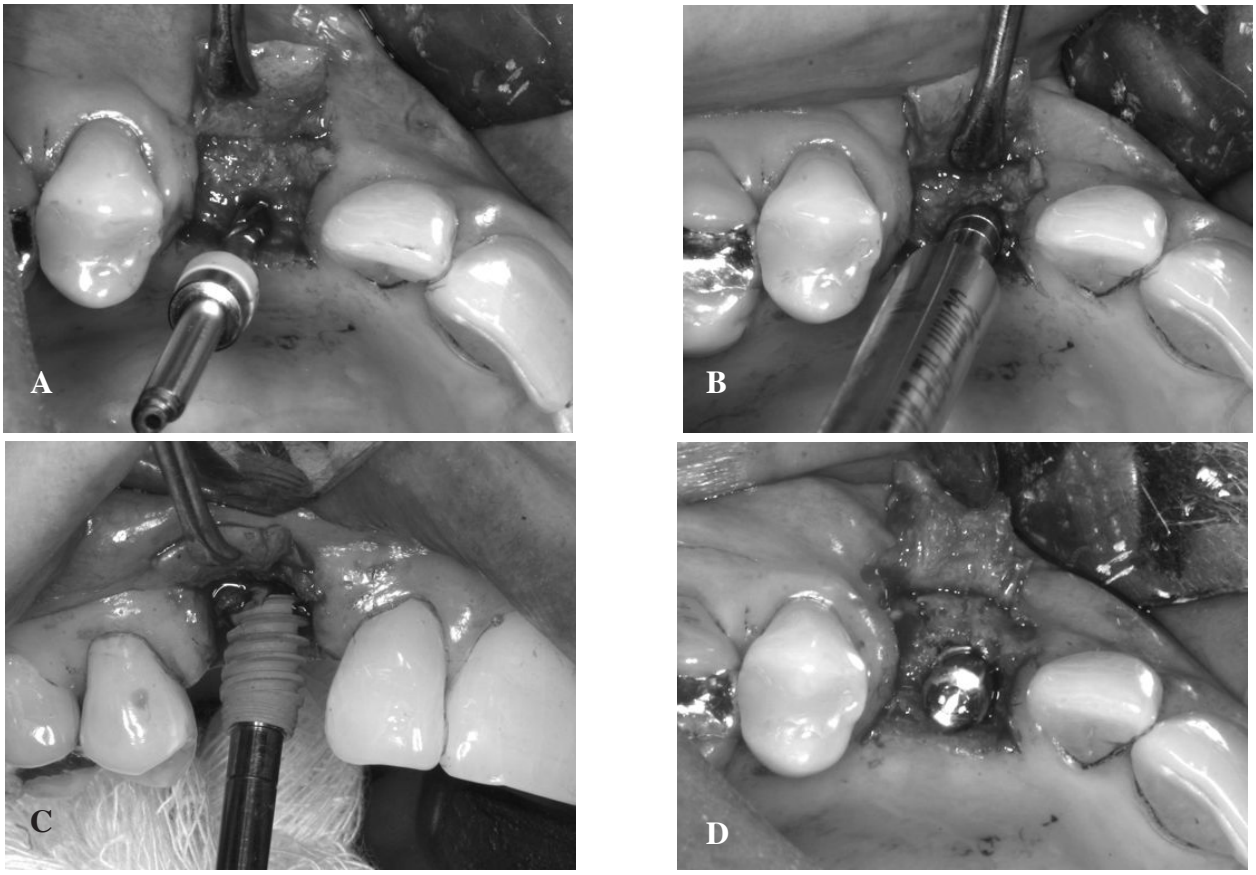


Figure 4. Full thickness flap exposure osteo-condensation with axis re-orientation and buccal bone manipulation for restorative-driven implant position. **A.** Palatal incised full thickness flap design for planned apical repositioning. A 2 mm twist drill is used for the initial osteotomy in a palatal position at the anticipated location of the final palatal implant margin, **B.** Osteo-condensation and buccal bone manipulation with progressive tapered osteotomes, **C.** Implant insertion with axis re-orientation to ideal position, **D.** Implant and healing cap placed with expanded crestal bone intact and adequate volume.

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alveolus to allow progressive intra-operative manipulation and mobilization, combined with expansion techniques to increase the alveolar horizontal dimension. They produce an expansion defect that opens like a book at it's binding. The defect is tapered, with its widest dimension at the ridge crest.[18,20,23] This often restores the alveolar volume and arch contour to near-normal dimensions.[20] (Fig. 1C,D) The technique, in it's most basic form, has been described as ridge splitting, using a full thickness muco-periosteal flap for access. Ridge widening is completed with out-fracture of the buccal cortex, often with partial or complete loss of attachment. Grafting, fixation of the fractured buccal segment or both is completed using guided bone regeneration principles, with or without implant placement, and primary soft tissue closure.[19,22,63,64,68,69] The buccal segment often acts as a free graft with minimal or no blood supply. In the mandible a full thickness flap is most commonly used with mechanical screw type expanders.

Ridge expansion (also referred to as "bone spreading") mobilizes the buccal cortical plate from the stable palatal cortex, maintaining the continuity of the expanded buccal segment as a viable bone flap or bone-periosteal flap.[18,20,23,43,44,65] In the maxilla it is best approached using a partial thickness flap or a limited crestal access with a flapless approach.[65] Expansion techniques include the use of osteotomes with several modified designs and distraction or rotary "screw mechanical expanders".[18,20,23-25,42,54,61,66]

Controlled assisted ridge expansion uses substantial bone mobilization with maintenance of a thick supra-periosteal dissection to preserve vascular supply.[66] The osteo-periosteal island flap sections the buccal plate with intact overlying periosteum or intact gingival mucosa. The osteo-periosteal flap provides complete mobilization of the buccal plate. The bone and the intervening gap is grafted.[67]

Techniques with substantial bone flap mobilization or fracturing require apical native bone for primary implant stability. Preservation of the vascular supply with an intact bone-periosteal flap allows direct healing of the inter-bony gap by normal intra-bony healing without grafting.[44] Surgical exposure of the wound via a soft tissue flap and the residual blood supply to the bone flap are major distinctions in these procedures,[44,65] and can account for the varied reports of application, success and complications with ridge expansion procedures.[18,20-22,42-44,55,59,61,63-66,68-70]

ANATOMIC CONSIDERATIONS

Prior to osteo-mobilization, evaluation of facial, dento-facial and dento-gingival parameters and esthetics must be completed.[71] Treatment planning considerations should include smile assessment, attached gingival tissue (width and biotype), vestibular depth and muscle or frenal tissue attachments.[72-74] Appropriate implant placement and management of any esthetic or soft tissue compromise, are necessary to prevent problems during initial healing or long-term stability of the prosthetic reconstruction.[40,74-78] Preparatory or simultaneous soft tissue procedures (i.e., laser frenoplasty, vestibuloplasty, augmentation with connective tissue grafting or pedicle flaps) are often necessary.[79-81]

In the anterior maxilla, flapless or split-thickness exposures preserve the crestal blood supply, providing a more predictable hard- and soft-tissue level after healing. In the event that there is insufficient soft tissue quality or quantity after expansion and implant insertion, the site can be augmented with a closed or open flap connective tissue graft.[82-84] In the posterior maxilla, split thickness flap development is a more clinically challenging dissection than a full thickness flap, but it allows retention of the periosteal blood supply to the bone flap.

The posterior mandible is the most challenging to manage with a split-thickness dissection. The periosteum is thinner and more friable, and it seldom stands up to retraction and manipulation of the osteo-mobilization procedure. Therefore, a full thickness flap approach is preferred in the mandible, where lateral augmentation and final tissue levels are less critical. The viability and thickness of the cortical buccal bone flap then determine if additional bone augmentation is necessary.

Osteo-mobilization procedures require a residual ridge 4 mm to 5 mm in thickness and adequate height. If the ridge has a significant undercut or lacks a medullary component there are greater risks of fracture during or after elevation and of expansion or bone resorption during healing. Varying degrees of undercut and "step off" to adjacent tooth roots indicate reduced bone volume and possible buttresses of the buccal plate. These can reduce mobility and increase the risk of fracture.[23]

Bone condensation and expansion of 1 mm to 2 mm is less demanding but becomes more difficult with progressive atrophy, bi-cortical bone or reduced bone compliance. Expansion at the canine is manageable with moderate bone volume and compliance but becomes more difficult with progressive atrophy and reduced bone compliance. Areas between the canine and central incisor, and posterior to the molar region can be managed in continuity with osteo-mobilization of a multi-tooth edentulous segment. However the canine "buttress" around the corner of the arch typically requires a planned vertical bone release to avoid possible vertical fracture at the contour height of the planned implant site.

Bone quantity and quality vary greatly in the edentulous maxilla and require careful clinical and radiographic analysis.[85-87] At sites that have been recently grafted or that have osteoporotic bone there can be altered or inconsistent bone compliance, increasing the risk of buccal or palatal wall fracture, a reduced vascular supply, or reduced primary stability and load-bearing capacity.[23,88-90] Office-based cone-beam CT technology allows preoperative analysis of ridge dimensions, sinus anatomy and bone density.[88] The degree of complexity of expansion sites can be visualized in a CT analysis. (Fig. 5)

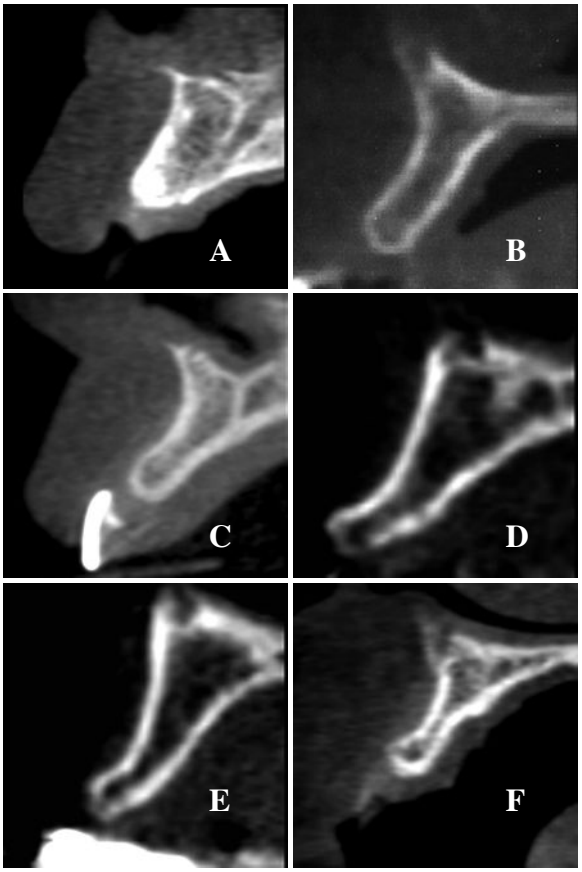


Figure 5. CBCT images of increasing degrees of horizontal bone loss, labial undercut, reduced marrow volume and cortical bone margin thickness. **A.** Mild horizontal dimensional loss after grafting for site preservation, **B.** Mild horizontal loss with minimal undercut and good marrow-cortical bone anatomy, **C.** Mild horizontal bone loss with increasing undercut and reduced marrow space, **D.** Moderate horizontal bone loss with moderate undercut and reduced marrow space, **E.** Moderate to severe horizontal bone loss with moderate undercut and reduced marrow space, **F.** Severe horizontal bone loss with severe undercut and reduced marrow space with thick "bi-cortical" bone.

SURGICAL CONSIDERATIONS

Osteo-mobilization procedures in the maxilla require surgical experience with traditional osteo-condensation and TASE techniques. (See *Selected Readings in Oral and Maxillofacial Surgery*, Vol. 18, #4.) Progressive implementation of osteo-mobilization techniques for horizontal site development begin with less demanding procedures such as split grafting.[67] Ridge splitting techniques are more demanding, and osteo-mobilization of a bone flap or bone-periosteal flap are more complex. These procedures can be completed as a staged approach, however, they have their greatest advantage with simultaneous implant placement.[20-22,42-44,54,56,63,64,70]

After comprehensive medical, clinical and radiographic assessment, and development of the treatment plan, the patient receives standard preparation with chlorhexidine mouth rinses and antibiotics. Intravenous anesthesia and local anesthesia are administered with the patient in a semi-reclined position. Operating from a sitting position, an armrest offers a stable base to control force application. Support of the patient's head is important for osteotome procedures. The osteotome is guided by the surgeon's right hand while the left hand palpates the ridge and palate for continuous feedback. The surgeon directs repeated tapping of the osteotome by the assistant. (For more details see *Selected Readings in Oral and Maxillofacial Surgery*, Vol. 18, #4.) Tactile, visual, and auditory cues require careful attention to avoid sudden fracture of the buccal bone or loss of vertical reference. Patient, progressive, and repetitive bending and relaxation is necessary to produce the desired expansion result.

A surgical template is helpful for determining initial site development dimensions, inter-implant positioning and vertical position reference. (See *Selected Readings in Oral and Maxillofacial Surgery*, Vol. 17, #6.) However, the template may obstruct access for instrumentation in a majority of the procedures. Therefore, the template may need to be removed during osteo-mobilization. As the buccal bone is manipulated facially the expansion defect is opened with apical and three-dimensional adjustments with Piezosurgery® or rotary instruments. The template is reinserted for intermittent reference of the inter-implant and vertical positions and gives a dento-gingival reference for the desired final vertical and bucco-palatal positions.

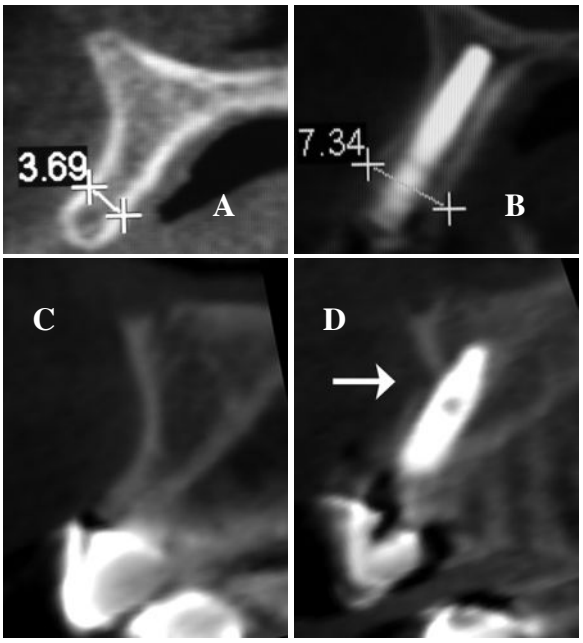


Figure 6. Pre-operative and post-operative CBCT of ridge expansion (RE) demonstrating horizontal dimensional change and fracture. **A.** Pre-operative and **B.** Post-operative images of RE demonstrating horizontal dimensional change, **C.** Pre-operative and **D.** Post-operative images of RE with severe facial undercut and fracture at the apical one-third of the buccal plate (arrow).

The implant's design is important for fitting the defect that is produced by progressive alveolar crest expansion. A tapered implant can enhance and support the expansion yet avoid vertical fracture of the buccal plate, either at the height of contour or at the apical one third (area of greatest undercut).[20] (Fig. 6) Implant primary stability is a requirement for integration, and bone flap stability is required for maintenance of vascularity and viability.[44]

Periosteal preservation is more critical in the esthetic zone due to reduced bone volume and the esthetic risk of bone and soft tissue recession. A palatal split-thickness incision allows movement of attached tissue buccally, maintaining or improving vestibular depth and the width of the zone of attached tissue around the implant. (Fig. 7) The residual palatal partial-thickness periosteal layer can be left exposed for healing by secondary intention.

Both partial thickness flaps and flapless approaches demand more technical care and time during surgery. Even though surgical time is reduced with experience, the time demand remains. A limited flap exposure gives the flexibility (in case of an unfavorable fracture) needed to convert the procedure to a full thickness approach, with extension and release that is appropriate for grafting with conventional GBR techniques.

Implant positioning is most challenging in the mesio-distal and facial dimensions and with excessive facial angulation. Facial angulation or facial positioning can compromise buccal hard- and soft-tissue volume and increase the risk of recession. In these situations, grafting the expansion gap with a split graft can be effective for site development, followed by secondary implant placement.[70] A split graft can be also beneficial when the labial plate is too thin or develops a significant fracture.

Soft tissue management with pedicle flaps, finger flaps and free connective tissue grafting allow near primary closure to the gingival or periosteal margin. Additionally, in patients with a thin biotype (See *Selected Readings in Oral and Maxillofacial Surgery*, Vol.14, #6; Vol. 18, #1.) or when there is an esthetic need for additional tissue thickness or to develop a "root eminence," sub-epithelial connective tissue grafting can be completed though a closed tunnel with crestal access.[82-84]

Mechanical rotary expanders have the advantage of minimal patient manipulation. They are most applicable in expansion with osteo-condensation with minimal expansion of 1 mm to 2 mm. The horizontal dimensional change and use of a full thickness flap are similar to the ridge expansion osteotomy in the maxilla described by Summers.[24,25,54] These techniques are the least demanding clinically and are easily applied in the mandible and at selected sites in the maxilla.

The use of osteo-condensation for expansion procedures often results in clinically visible fractures and minimal facial bone thickness of the expanded buccal segment. These may require an over-graft GBR technique and primary closure. (See Case Study 1, p. 26) The advantage of this technique is maintenance of native bone on the implant surface and straight-forward implementation of rotary mechanical expanders for surgeons experienced with GBR techniques.

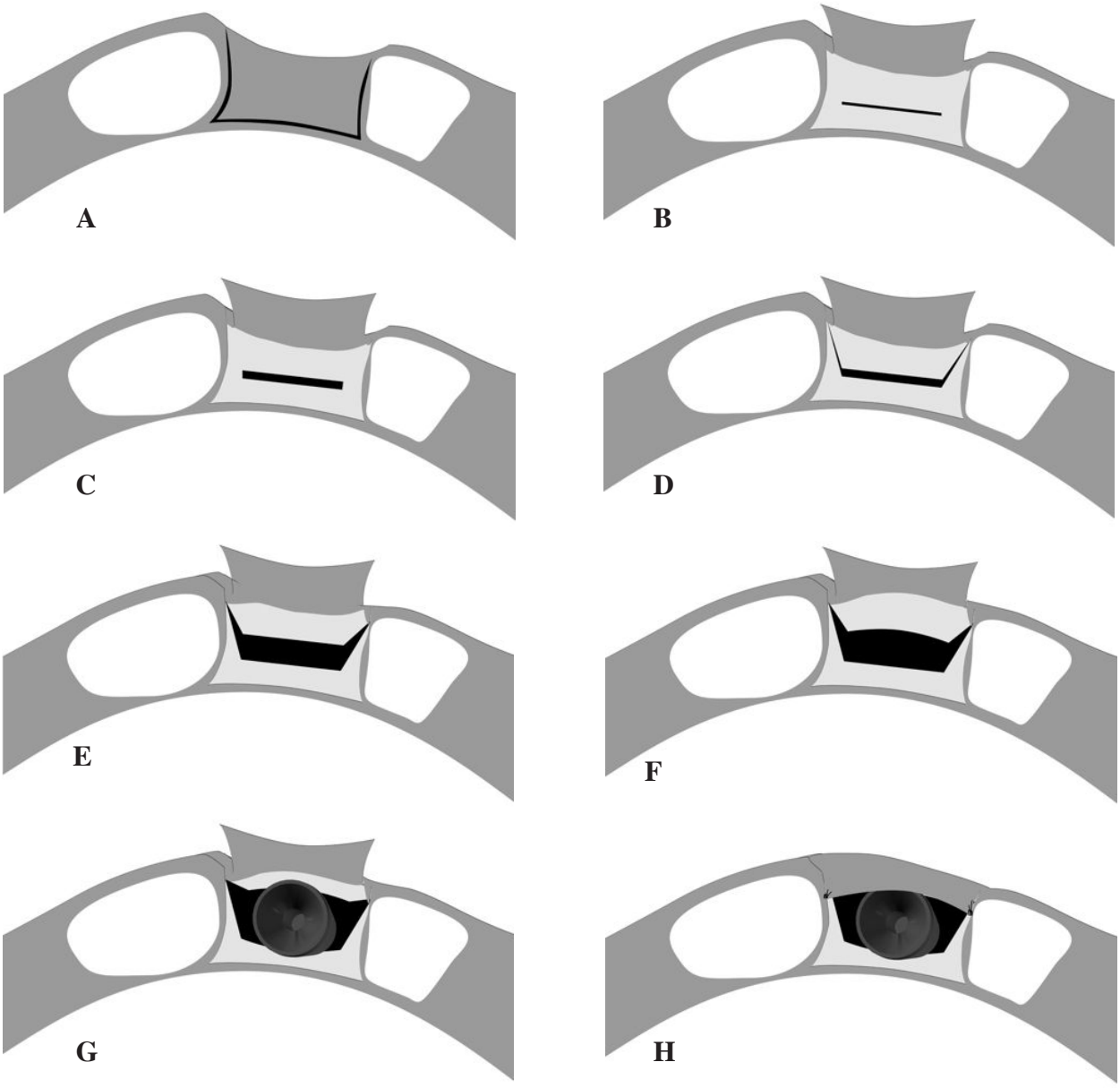


Figure 7. Graphic representations of horizontal views of the anterior maxilla showing a split thickness ridge expansion with intrabony osteotomy, internal lateral beveled bone incisions, trans-gingival tapered implant placement with apical repositioned flap. **A.** Palatal incision for a buccal-based, split thickness flap, **B.** Horizontal Piezosurgery® bone incision, **C.** Osteo-mobilization with spade expanders, **D.** Internal beveled bone incision with a #64 "Beaver" blade, **E.** Osteo-mobilization with spade and bi-bevel expanders, **F.** Osteo-mobilization with D-shaped and tapered osteotomes, **G.** Tapered implant placed with collagen in the intact intrabony gap, **H.** Apical repositioning of the facial flap with lateral beveled soft tissue releasing incisions.

Mechanical rotary expanders can also be used with osteo-mobilization for horizontal multi-tooth defects in the mandible. Via full thickness exposure, bone incisions and osteotomies with Piezosurgery® and rotary expansion allow correction of mandibular horizontal deficiencies, with osteo-mobilization of a viable bone flap. Bone flaps thinner than 2.0 mm to 2.3 mm generally do not require a GBR over-graft. Additionally, a recent implant design (NobelActive®; NobelBiocare , Yorba Linda CA) incorporates an aggressive cutting thread and expanding body that functions like a rotary expander. This implant can reduce the amount of initial osteo-mobilization needed at surgery. (See Case Study 2. p. 28)

Use of a full thickness flap is simpler for access, however, the risk of bone resorption is increased by the potential loss of the periosteal vascular supply. If the residual buccal plate is thin, consists of only cortical bone, has partial dehiscence or is fractured, over-grafting with GBR principles would then apply. With the addition of particulate graft and barrier for containment, closure can be with a trans-gingival protocol or with primary soft tissue closure for the healing interval. This "over-grafting" technique cannot be applied over periosteum of a split-thickness flap. Therefore, a strategic choice is initially necessary, based on a preoperative assessment of the appropriate treatment pathway. (Table 1)

When a two-stage healing protocol is utilized, near primary closure to the gingival or periosteal margin is completed passively.[20,23] At uncovering, there can be additional soft tissue augmentation to enhance the trans-gingival interface. Experienced surgeons can use trans-gingival placement when there is excellent initial implant stability and an intact bone flap with optimal thickness. With increasing surgical experience, narrower ridge widths, smaller flaps and reduced wound exposure can enhance the minimally invasive benefits of these procedures. A light-cured periodontal dressing (Barricaide™ Densply-Caulk Milford, DE) can aid in protection of trans-gingival wounds during the initial post-operative period.[23]

Traditional TASE procedures have a limit to the amount of sinus elevation before the risk of a membrane tear becomes unacceptable.[91-93] (See *Selected Readings in Oral and Maxillofacial Surgery*, Vol. 18, #4 for more details.) TASE procedures require a residual 5 mm to 7 mm of ridge height with adequate horizontal bone dimension for insertion of a 10 mm implant.[46-53] Several modified TASE

TABLE 1: MANAGEMENT OF COMPLICATIONS

Site	Flap Design	Wound Healing	Management of Complications	Technique
Mandible or Maxilla	Full Thickness	GBR principles	Overgraft	Mechanical Screw Expanders or Osteome
Maxilla	Partial Thickness	Local regeneration	Split graft	Osteotome
Maxilla	Mini-Flap/Flapless	Local regeneration	Overgraft or split graft	Osteotome

techniques in combination with ridge expansion allow successful placement of implants in the posterior maxilla with reduced risk of sinus perforation and greater elevation.[23,42]

Combining ridge expansion with localized management of the sinus floor (LMSF) or contiguous sinus floor elevation (CSFE), with reduced residual alveolar height and native bone support on the implant surface, requires a longer healing interval of 6 months.[23,42] An additional consideration is use of transitional loading on a reduced occlusal platform or a splinted provisional prosthesis to progressively load the posterior maxillary bone.[23,42] Implant placement can be simultaneous, with submerged healing, or trans-gingival when excellent initial implant stability is present.[23] The advantages of these techniques are simultaneous implant placement, shorter treatment time, less discomfort, and restoration of the buccal arch dimension for a restorative-driven implant position.

In patients with wound healing compromise, such as diabetes, the vascular bone flap is less susceptible to overlying soft tissue dehiscence than block or particulate grafts. Systemic medical problems in which vibration might cause traumatic displacement of tissues or a plaque need careful consideration and medical consultation. Post-operative vertigo is a rare, and usually self-limiting, complication of osteotome techniques and may require management with an Epley maneuver.[94,95] The use of a mechanical rotary expander for site development is less traumatic for patients who require local anesthesia without intravenous anesthesia or who are unable or unwilling to endure the manipulation of an osteotome procedure.

PROCEDURES

Osteo-mobilization with ridge expansion has broad application for patients with mild to moderate horizontal bone loss and adequate vertical alveolar height above the inferior alveolar nerve or anterior to the sinus. The ridge is sectioned with Piezosurgery® or a #64 “mini” beaver blade (Fig. 9E). The buccal bone pedicle is progressively manipulated facially with specialized osteotomes or mechanical rotary expanders to restore ridge dimensions. Tapered implant placement then follows a natural emergence to a restorative-driven crown position. (Fig. 1C,D)

Osteo-mobilization for Horizontal Deficiency in the Mandible with Full Thickness Flap Exposure

The technique in it’s most basic form has been described as ridge splitting, using a full thickness muco-periosteal flap for access, and ridge widening is completed using either mechanical expanders of distraction or rotary screw design.

Flap Design

A full thickness flap incision provides maximum mobilization and the potential for apical repositioning for trans-gingival healing. Complete the incision palatal to the ridge crest to maximize the amount of attached tissue. Exaggerate the mesial and distal corners to increase the flap length for optimal fit with apical repositioning. (Fig. 8) (See Case Study 2, C&D, p. 28)

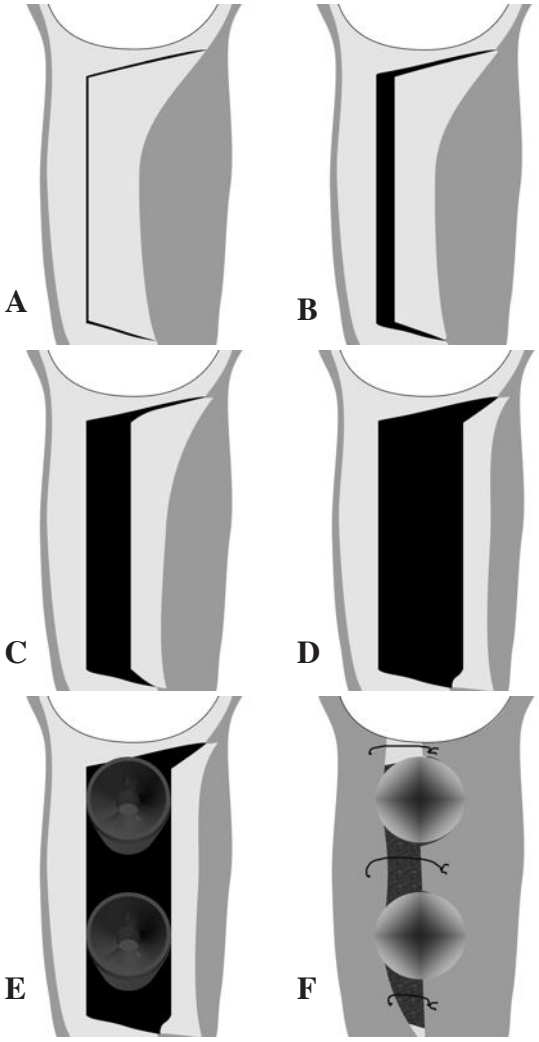


Figure 8. Graphic representations of the posterior mandible showing a full thickness flap for ridge expansion with intrabony osteotomy, internal lateral beveled bone incisions, trans-gingival tapered implant placement with apical repositioned flap. **A**. Lingual incision for a buccal-based, full thickness flap, demonstrating a narrow alveolar contour and completion of horizontal, anterior and posterior beveled bone incisions (through the buccal cortex) with Piezosurgery®. **B., C.** & **D.** Progressive buccal bone mobilization with increasing diameter rotary expanders and apical preparation, **E.** Tapered implant insertion, **F.** Apical repositioning of the facial flap with lateral beveled soft tissue releasing incisions.

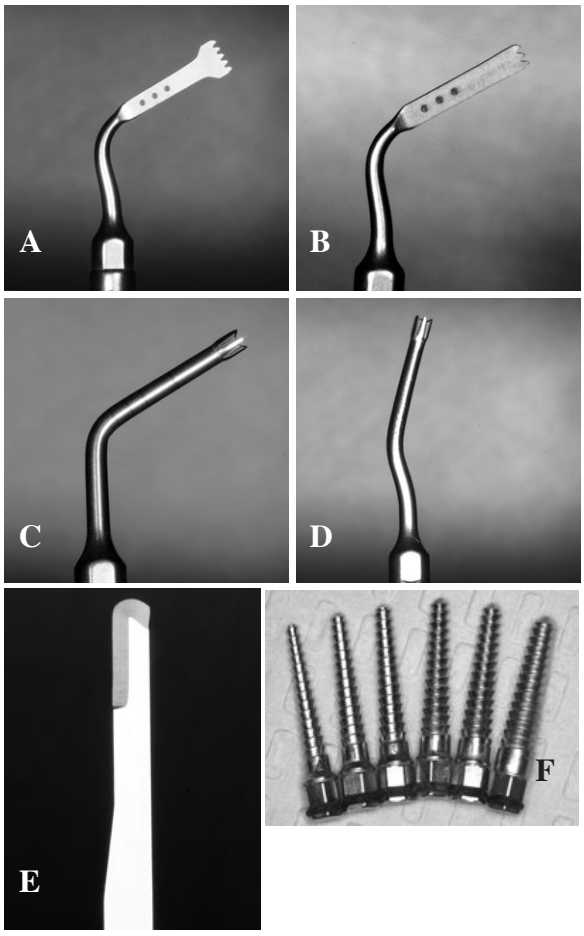


Figure 9. Examples of osteo-mobilization instruments for implant site preparation. **A.** Piezosurgery® insert OT7S4, **B.** Piezosurgery® insert OT7S3, **C.** Piezosurgery® insert IM2P, **D.** Piezosurgery® insert IM2A, **E.** #64 "Mini" Beaver blade (#S6400, Sable Industries,Vista, CA), **F.** Rotary mechanical expanders(Meisinger USA, Centennial, CO), from left to right, 2.7 mm, 2.9 mm, 3.1 mm, 3.3 mm, 3.5 mm, 4.0 mm.

Bone Incision

Using Piezosurgery® instrumentation with insert OT7S-4 (Fig. 9A) reduces the time for alveolar sectioning. This technological advance makes a fine cut of 0.35 mm with minimal lateral thermal injury to the bone.

The residual ridge should have a minimum 4.0 mm to 5.0 mm of thickness to leave the expanded bone flaps with adequate thickness for regeneration. Section the alveolus parallel to the buccal cortex, maintaining a minimum 2 mm thickness to a depth of 7 mm to 9 mm. (Fig. 8B) With a posterior edentulous segment, the posterior extent of the osteotomy extends well past the last implant site and then is beveled out laterally through the buccal cortex. (Fig. 8A) Beveled lateral bone release incisions are usually necessary at the anterior dentate margin and at both ends of an inter-dental expansion site.

Next, section the alveolus from the internal aspect using the Piezosurgery® insert OT7S-3. (Fig. 9B) Cut obliquely at a 45º to 60º angle toward the facial, parallel to the adjacent tooth root through the facial cortex. This allows the bone flap to bend open at the release, and the bevel reduces the discontinuity defect after expansion. (Fig. 8 B-D) Take care to section through the buccal cortex so as to place the vertical defect away from the final implant site or adjacent tooth root. (Fig. 8E)

Mechanical Rotary Expansion

Use custom rotary expanders (Meissinger USA, Centenial, Colorado) (Fig. 9F) of progressively increasing diameter to mobilize the buccal segment. Complete initial alveolar purchase with a 1 mm to 2 mm twist drill at the desired implant site or sites. Use a narrower diameter with narrower ridge widths to preserve the maximum thickness of the buccal plate. In multi-tooth edentulous segments the bone mobilizes more readily. Additional screw purchase sites can be added to assist bone flap mobilization. Insert progressively increasing diameter expansion screws at the sites using a handpiece or rachet handle. Mobilize the bone flap facially to produce an increasing intra-cortical gap.

With the posterior expansion screw or screws in position, modify the anterior site with rotary instrumentation or Piezosurgery® inserts (IM2A, IM2P). Up-right the implant site buccally from its initial lingual angulation. (Fig. 10D) Next insert larger expanders in the anterior site to maintain expansion accesss to up-right the posterior implant site. The bone mobilization is progressive, with increasing diameter expanders, and there is often significant elastic rebound. (Fig. 8B-D) Adequate apical preparation is required, depending on the degree of implant taper and amount of bone flap mobilization.

Complete implant insertion, first at the anterior site, and then, after final site preparation, in the additional sites. Attention to three-dimensional implant position, location of the inferior alveolar nerve and any lingual undercut are important during site development. If there is loss of continuity of the buccal bone segment or a true ridge split, it can be secured as an autograft with fixation screws and managed with GBR principles and primary closure. (Fig. 10C-J)

Wound Closure

If the segment is intact and buccal bone flap thickness is adequate, healing caps can be placed when graft material is placed at the vertical component of the buccal cortical defect. The flap design allows apical repositioning, often with a periosteal releas-

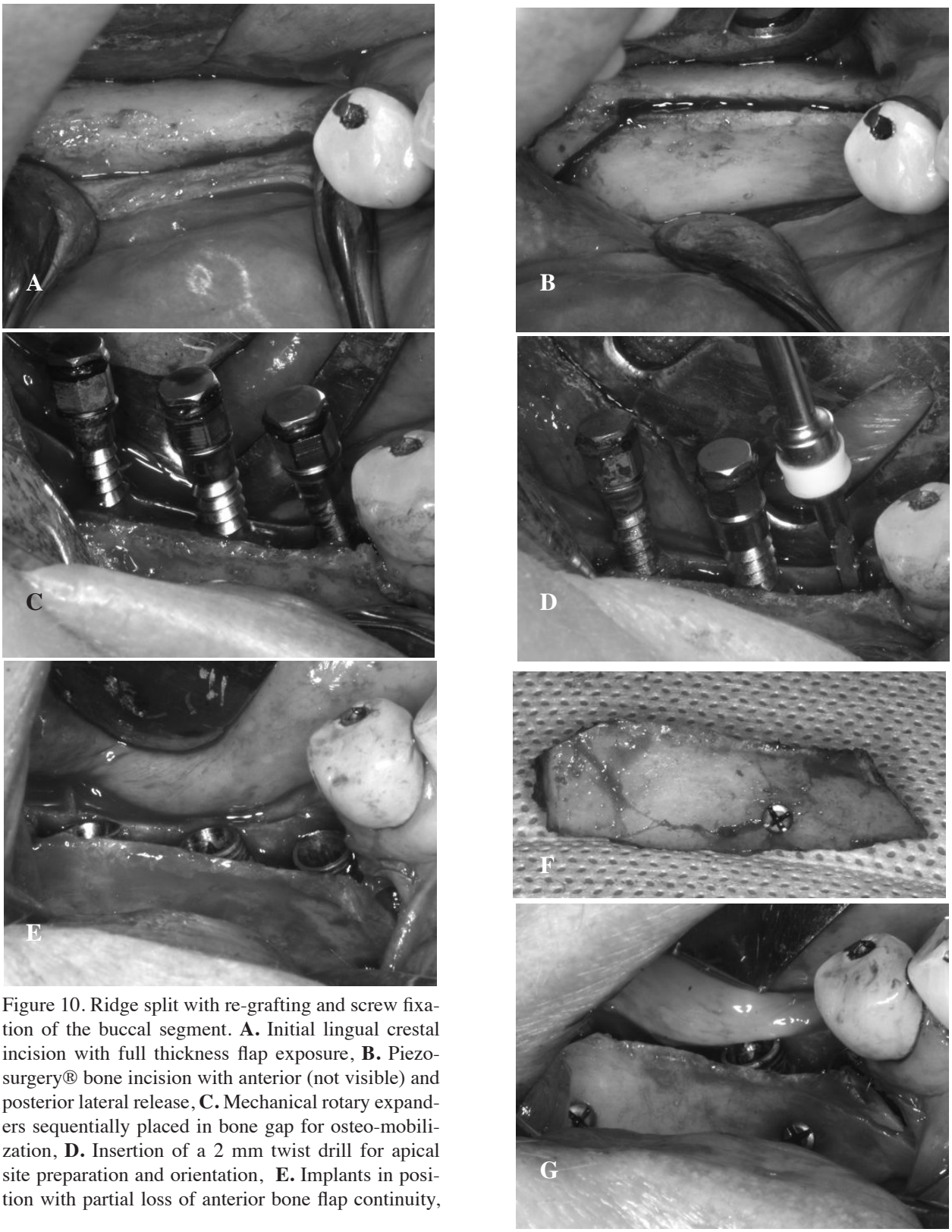
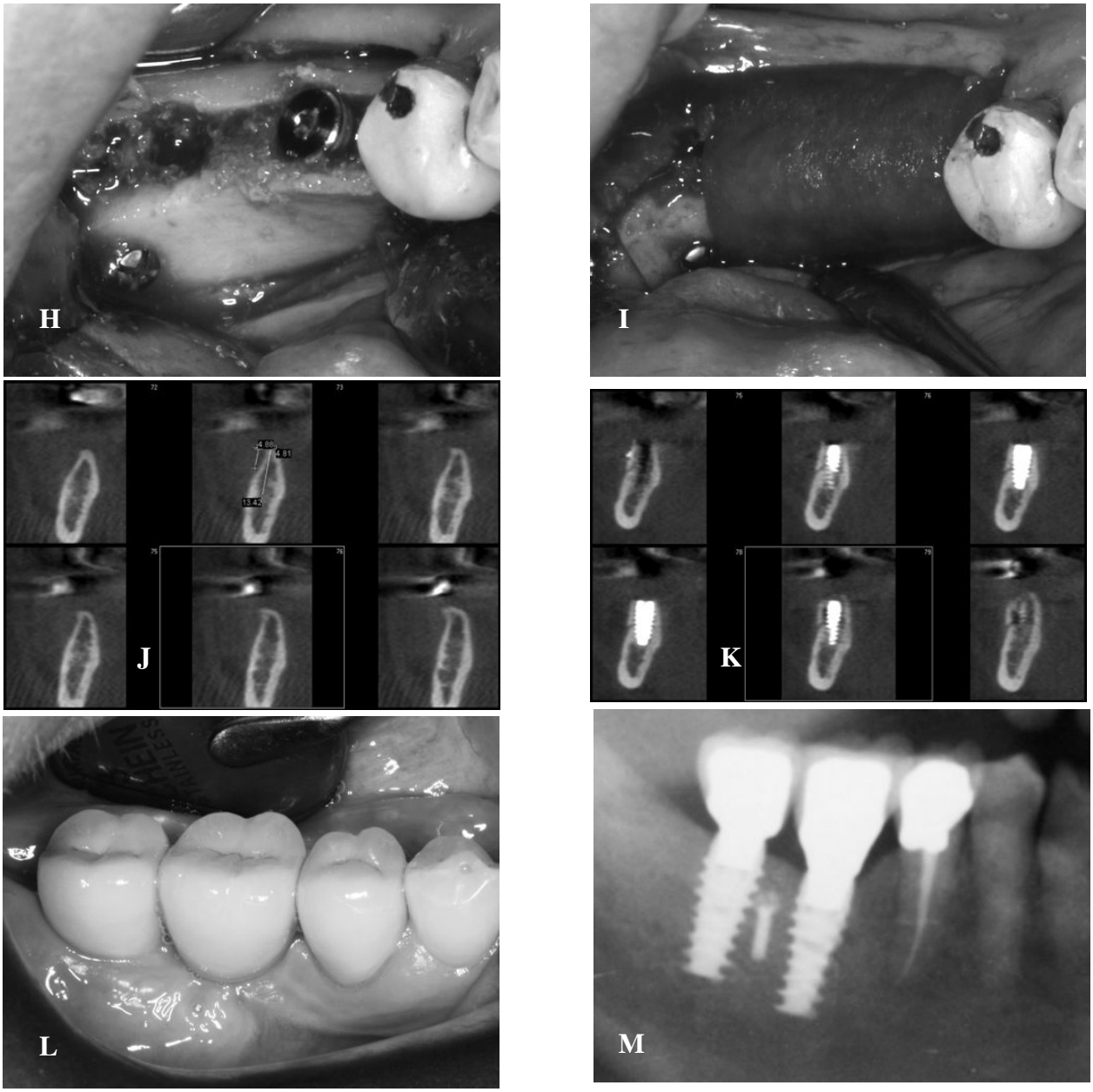


Figure 10. Ridge split with re-grafting and screw fixation of the buccal segment. **A.** Initial lingual crestal incision with full thickness flap exposure, **B.** Piezosurgery® bone incision with anterior (not visible) and posterior lateral release, **C.** Mechanical rotary expanders sequentially placed in bone gap for osteo-mobilization, **D.** Insertion of a 2 mm twist drill for apical site preparation and orientation, **E.** Implants in position with partial loss of anterior bone flap continuity,



F. Isolated "split" free auto-graft, **G.** Ridge split with re-graft and screw fixation of the buccal segment, **H.** Particulate grafting of the intra-bony gap, **I.** Collagen barrier ®, Osteogenics, Lubbock, TX) placed following the GBR protocol for primary closure, **J.** Pre-operative CBCT scan demonstrating ridge dimensions in the #29-30 region, **K.** Post-operative CBCT demonstrating screw fixation of the buccal segment, **L.** Post-restoration clinical image after uncovering with connective tissue grafting, **M.** Post-operative panoramic image, demonstrating good implant position and bone levels.

ing incision at the anterior margin for mobilization. Place inter-implant sutures for flap repositioning after insertion of collagen in the ridge expansion defect. Obtain primary closure around the healing caps with finger flaps incised from the flap if there is adequate attached tissue width, or obtain near-primary closure with apical flap repositioning to the implant margin and inter-proximal sutures minimizing the exposed wound. (Fig. 8F) Protect the wound with Barricaid® light-cured periodontal dressing. (See Case Study 2, p.28)

Osteo-mobilization for Horizontal Deficiency in the Maxilla with Flap Designs for Periosteal Retention (Split-thickness, Mini-flap or Flapless).

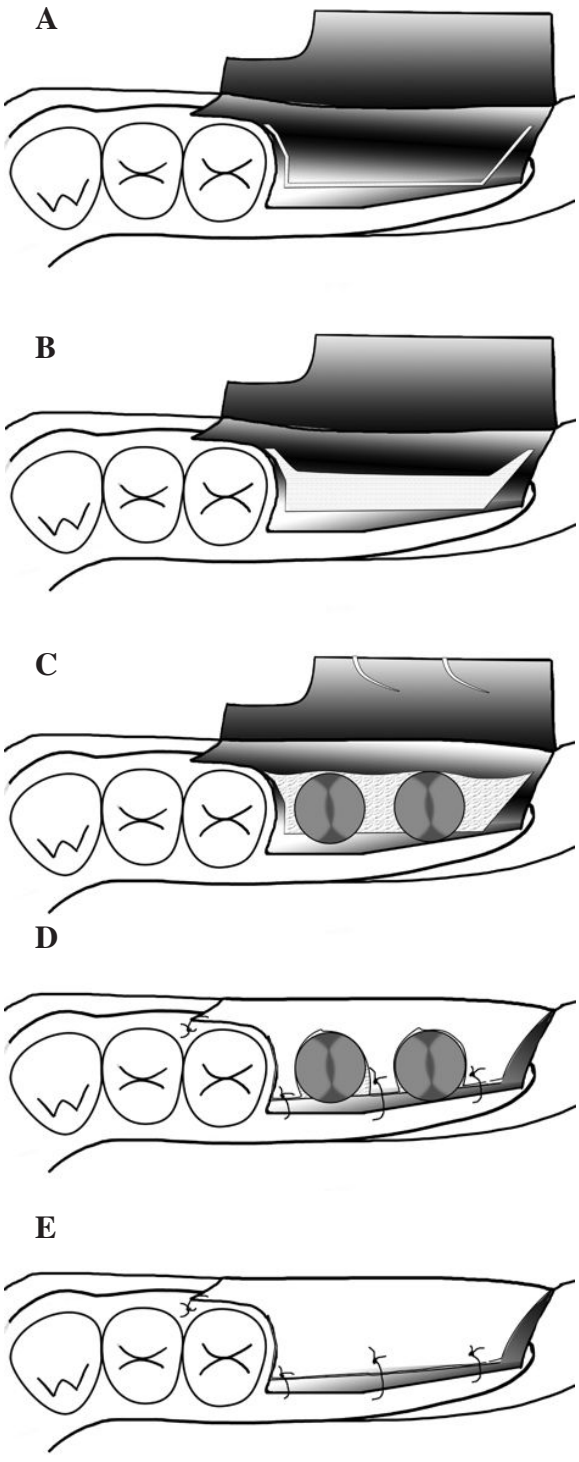
Ridge expansion (also referred to as "bone spreading") mobilizes the buccal cortical plate from the stable palatal cortex, maintaining the continuity of the expanded buccal segment as a viable "bone flap" or "bone-periosteal flap."[18,20,23,43,44,65] The maxilla is best approached using a partial thickness flap or with limited crestal access with a "flapless" approach.[65] Expansion techniques include the use of chisels and osteotomes with several modified designs.[18,20,23,42,54,61,66] (Fig. 11)

Split-thickness Flap

Develop a buccally-based palatal incision just above the level of the periosteum using a #64 "mini" beaver blade. (Fig. 11B,C) Extend the split thickness flap anteriorly or posteriorly the distance of one to two teeth, with a marginal release at the muco-gingival junction. (Fig. 11C) This flap can be further extended with a beveled vertical release to gain access, visibility or soft tissue mobilization for repositioning. Beveling the vertical incision 45º away from the periosteal base significantly reduces or eliminates vertical scar formation. With edentulous spans that extend posterior to the esthetic zone or in patients with esthetic display to the molar region, the flap should extend a one- to two-tooth distance distal to the site or to the tuberosity with lateral/vertical release. Releasing the periosteum at the distal and superior margin with a "cut-back" incision greatly enhances mobility of the soft tissue flap. Flap repositioning improves soft tissue vestibular depth and quantity of attached tissue, with the residual soft tissue defect remote from the expansion and implant site. (Fig. 11)

Avoid perforation during dissection of the flap, in particular, at the muco-gingival junction. Insuring a sharp blade and increasing the blade angle more vertically reduces the risk of perforation as the muco-gingival junction is approached.[23] Expose the palatal aspect of the ridge with split thickness dissection and bone sounding to determine the clinical anatomic dimensions of the ridge and the inclination of the palatal vault.[20,42] With experience, the procedure can often be completed with minimal flap development.[66]

Larger expansion sites require greater soft tissue mobilization to allow movement of the bone flap. A larger flap may also be required for anterior and apical soft tissue repositioning.[23] (See Case Study 3, p.31) Alternatively, a limited crestal flapless exposure can be completed in the anterior regions or for single tooth sites. (Fig. 7A-C) (Case Study 4, p. 33)



Bone Incision

Using Piezosurgery® instrumentation with insert OT7S-4 reduces the time needed for alveolar sectioning. Alternatively, a #64 "mini" beaver blade can be used to section the residual alveolar ridge with a gentle malleting action. (Fig. 7B) The #64 "mini" beaver blade should be progressively advanced and mobilized in an anterior-posterior direction when removing the blade from the site (buccal-palatal manipulation risks blade fracture). Simply advancing to final depth directly can make blade removal extremely difficult. Therefore, proceed cautiously, using progressive advancement and removal to achieve the final depth.

The residual ridge should have at least 4.0 mm of thickness to leave the expanded bone flaps with adequate thickness for regeneration. Complete initial osteo-mobilization

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Figure 11. Graphic representation of the posterior maxilla showing a split thickness flap for ridge expansion with intrabony osteotomy, internal lateral beveled bone incisions, trans-gingival tapered implant placement with apical repositioned flap. **A**. Palatal incision for a buccal-based, split thickness flap with completion of Piezosurgery® intra-bony incisions, **B.** The buccal bone-periosteal flap is progressively mobilized facially with chisels and D-shaped expanders. Care is taken to maintain flap continuity and preserve the overlying periosteum, **C.** Implants placed, with expansion gap filled with heme-saturated collagen and particulate grafting of the anterior and posterior vertical buccal defects. **D.** An abundance of attached tissue allows development of anterior-based "finger" flaps and the flap is anteriorly and apically repositioned, Or **E.** Near primary closure with periosteal margins exposed for secondary intention healing.

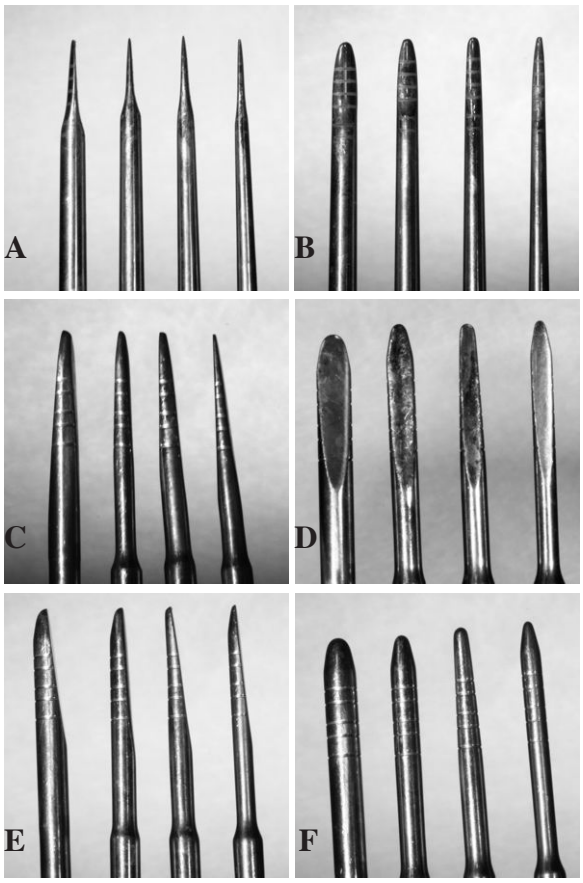

Figure 12. Examples of various modified oseotomes for ridge expansion (H & H Co., Ontario, CA). **A**. Edge and **B.** Face views of spade osteotomes, **C.** Edge and **D.** Face views of bi-bevel osteotomes, **E.** Edge and **F.** Face views of D-shaped osteotomes.

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with spade expanders (Fig. 12A,B) or a small chisel. (Fig. 7C) This is necessary to move the bone buccally, creating an expansion gap for adequate access of an internal beveled lateral bone release incision. (Fig. 7D)

Section the alveolus from the internal aspect using the Piezosurgery® insert OT7S3 or a #64 "mini" or "micro-mini" beaver blade. Cut obliquely at a 45°to 60° angle toward the facial, parallel to the adjacent tooth root but not through the facial cortex. This is usually necessary at one or both ends of the expansion site to allow the bone flap to bend open at the release while preserving both bone and periosteal continuity after expansion. (Fig. 7G) Sometimes it is necessary to section through the buccal cortex for adequate mobilization.

Modified Osteotome Ridge Expansion

Osteo-mobilization of the bone flap at a single-tooth edentulous site is progressive and utilizes specially designed instruments (i.e., spade expanders, bi-beveled expanders, D-shaped expanders and tapered osteotomes (H & H Co., Ontario, CA). (Fig. 12) Complete progressive buccal bone mobilization by increasing instrument thickness. (Fig. 7B,F,G) Use a gentle malleting action to strike the expanders and osteotomes to mobilize the bone flap. Use narrower tips for lateral incisors and mid-size and widest tips for central incisors, canines and premolars (based on the mesial-distal dimension of the edentulous site). Use a lateral, buccal bending movement to manipulate the bone and begin the expansion process. Open the bone gap to allow enough access for completion of a beveled intra-bony incisions at the mesial and distal aspects of the site. (Fig. 7C) Complete these at a 45° angle away from the site and parallel to the adjacent tooth roots (Fig. 7D) to release stress and allow a point for bending at the cortex while preserving continuity of the bucal cortex. The entire process is like opening a book, with the buccal cortex as the binding.[57]

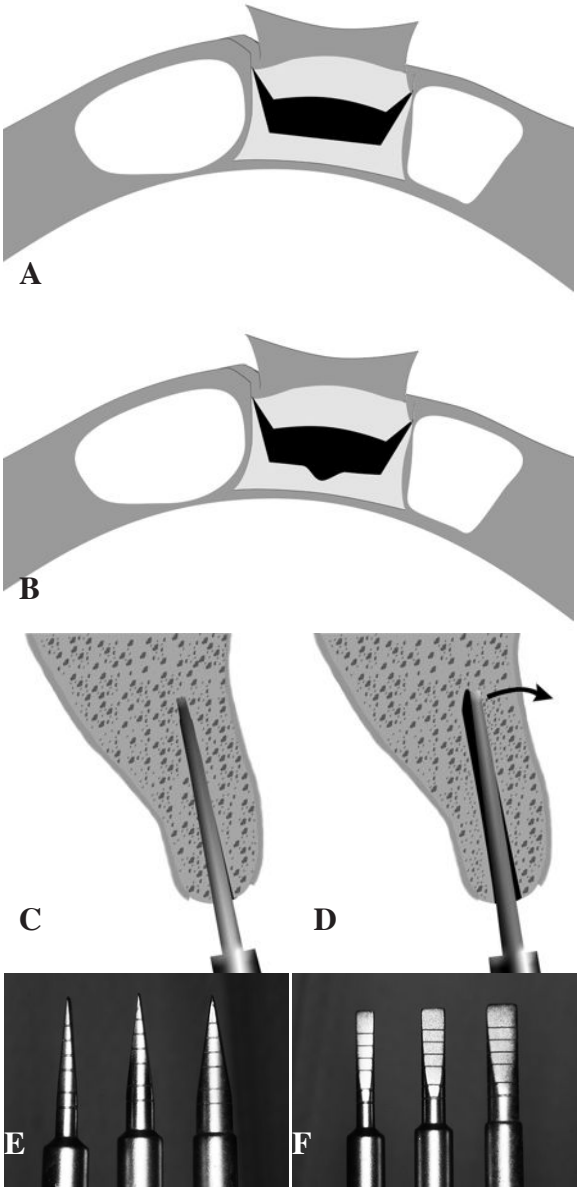


Figure 13. Crestal and apical implant site modification to correct or reduce labial inclination. **A.** & **B.** Graphic representation of palatal purchase for palatal relocation of implant margin, **C.** & **D.** Graphic representation of apical lateral buccal cortical manipulation with chisels to reduce facial angulation or risk of apical perforation, **E.** Edge and **F.** Facial views of chisels (H & H Co Ontario, CA).

Next use the bi-bevelled expander, with its increasing tip thickness and bi-bevelled taper. (Fig. 12D,E) Tip selection is based on the width of the site, and two or three sequentially larger instruments are often used. A malleting action mobilizes the bone flap buccally, with some minor buccal bending using hand motions. Simultaneous palpation with the non-dominant index finger gives the surgeon a feel for the amount of bone mobilization. The buccal bone flap can also be observed via a split thickness dissection to ensure even mobilization and opening at the intra-bony incisions.

The apical one-third must be managed carefully if there is moderate labial undercut. The crestal bone mobilizes relatively easily, but the undercut region has strong resistance due to its geometric curvature. At this point it may be necessary to use a standard tapered chisel to mobilize the broadest apical portion of the undercut, (Fig. 13C-F) with gentle progressive lifting of the instrument tip at the apex of the site. Additionally, turning the instrument (like tightening and loosening a screwdriver) will mobilize the apical buccal cortex. Advancing the expansion without opening of the apical corners risks buccal perforation, either with the larger diameter osteotomes or on implant insertion.

Site development continues with the D-shaped expanders. The smaller two are used for narrow teeth and the larger two for wider teeth. (Fig. 12E-F) First, place the flat surface of the “D” against the palatal bone and advance it to the desired depth, shaping the buccal plate. Then turn the instrument 180° so its flat surface is toward the buccal. Reinsert the instrument to depth and manipulate

the apical corners of the buccal bone toward the facial. Place the next larger instrument, repeating the same procedure to mobilize and manipulate the bone. The three-dimensional positioning must be managed carefully because the instruments follow the path of least resistance and can be displaced or deflected by internal variations in bone density. Therefore, adjustment of the positioning must be active with each step, with Piezosurgery® or rotary instruments.

It is often useful to insert a 2 mm twist drill and take periapical radiographs after crestal opening to control facial angulation and positioning relative to adjacent tooth roots. (Case Study 4J, p. 34) (See *Selected Readings in Oral and Maxillofacial Surgery*, Vol. 18, #4 for more details.) In cases with wider ridges (6 mm to 7 mm) that require minimal expansion, it is often necessary to complete additional palatal purchase for proper positioning. (Fig. 13A,B)

Tapered osteotomes (Fig. 3A) are progressively used to achieve the final site diameter. (Fig. 7F-G) Continue palpation during instrumentation. If the buccal plate feels as though apical thinning or angulation could result in perforation, additional apical preparation of the osteotomy or additional mobilization of the apical bone will be necessary, as described above. (Fig 13C,D) The buccal plate often displays significant rebound of 20% to 30% after instrument removal. Implant insertion usually encounters moderate to significant torque resistance when there is excellent primary stability.[23] (Fig. 7H) Take care not to damage the periosteum attached to the bone flap or the overlying soft tissue flap. If mobilization is inadequate, ensure that both the vertical and releasing bone incisions are complete. A curved thin chisel can also be used to undermine the base of the buccal bone flap. Indexing on the palatal aspect of the implant site, along with repetitive manipulation of the bone flap or implant may be necessary to achieve the desired three-dimensional position. A tapered implant is necessary to conform to the expansion defect and to prevent buccal or apical fracture during final implant seating. (Fig. 6C,D) (See Case Study 4, p. 33)

Micro-flap access and closed sub-epithelial connective tissue grafting have also been described with ridge expansion to address additional soft tissue demands in the esthetic zone.[83,84] After expansion with an intact bone and soft tissue flap, a closed supra-periosteal pocket can be developed with a #64 "mini"-beaver blade for insertion of a connective tissue graft. Sub-epithelial connective tissue can be harvested from the palate or tuberosity. Trim the graft to fit the desired dimensions and guide it into the closed pocket with a 6-0 horizontal mattress suture.[83,84] (See Case Study 4I-K, p. 34)

Osteo-mobilization Combined With TASE In The Posterior Maxilla For Horizontal and Vertical Deficiency With Partial Thickness Flap Exposure

After the surgeon has become experienced with ridge expansion and TASE procedures, combining them has great potential as a minimally invasive procedure. Preoperative CBCT imaging is essential for anatomic evaluation and planning. The posterior maxilla can be managed with a combination procedure [such as ridge expansion

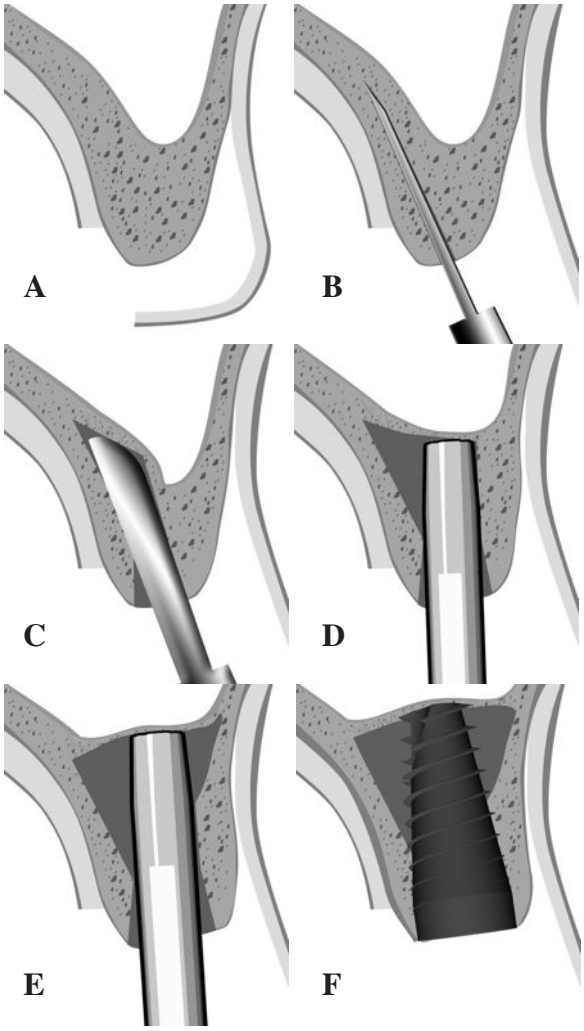
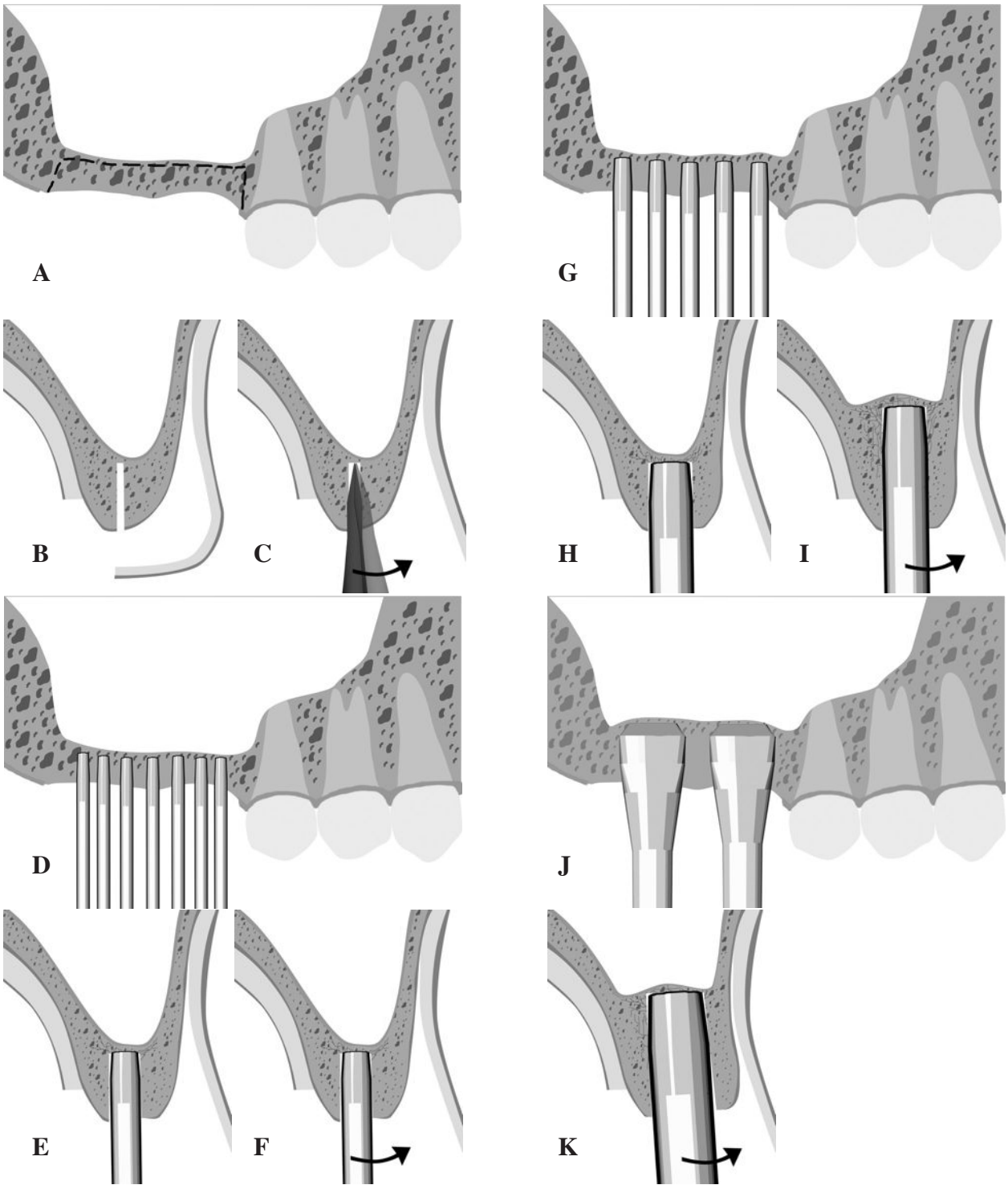


Figure 14. Graphic representation of split-thickness flap for ridge expansion combined with localized management of the sinus floor, LMSF. **A.** Palatal incision for a buccal-based, split thickness flap. **B.** Palatal bone-wall incision with a malleted #64 "Beaver" blade, **C.** Medial bony in-fracture of the sinus floor with a D-shaped expander, **D.** Using a concave-tipped osteotome for intrusion and elevation of the apical region and medialization of the sinus floor, **E.** Additional osteotome elevation and expansion completed to the desired implant dimension, **F.** Implant insertion with ridge expansion and LMSF.

with localized management of the sinus floor (LMSF) and contiguous sinus floor elevation (CSFE)] if there is 4 mm to 5 mm of ridge width and height. (See *Selected Readings in Oral and Maxillofacial Surgery*, Vol. 18, #4 for more details on these techniques.) After the split thickness dissection with periosteal retention, the type of bone incision selected is made based on the companion technique. (Fig. 11A, Fig. 14A, Fig. 15A,B)

For LMSF, make a palatally inclined incision with a # 64 beaver blade malleted into the palatal aspect of the bone of the sinus floor. (Fig. 14B) Then mallet a D-shaped instrument into the osteotomy to produce medial and superior displacement of the sinus floor. (Fig. 14C) Repeat with a larger instrument for further bone manipulation in the medial and superior directions. Add collagen (CollaTape®, Carlsbad, CA) to cushion and displace the forces. Use patient and repetitive manipulation to mobilize the bony sinus floor. Continue elevation vertically with traditional osteotomes for elevations of 4 mm or more. (Fig. 14D,E) Insert the implant with attention to three-dimensional positioning and primary stability. (Fig. 14F) Closure and flap management are as described above for ridge expansion alone. (Fig. 11D,E)

For CSFE, use a piezosurgery® OT7S4 insert to section the residual alveolus from anterior to posterior, with a lateral release at the tuberosity. Then complete an anterior beveled intra-bony release as described above for ridge expansion alone. (Fig. 11A and Fig. 15A,B) Complete the bone incisions to 1 mm to 2 mm below the sinus floor, following the floor contour. Take trial-length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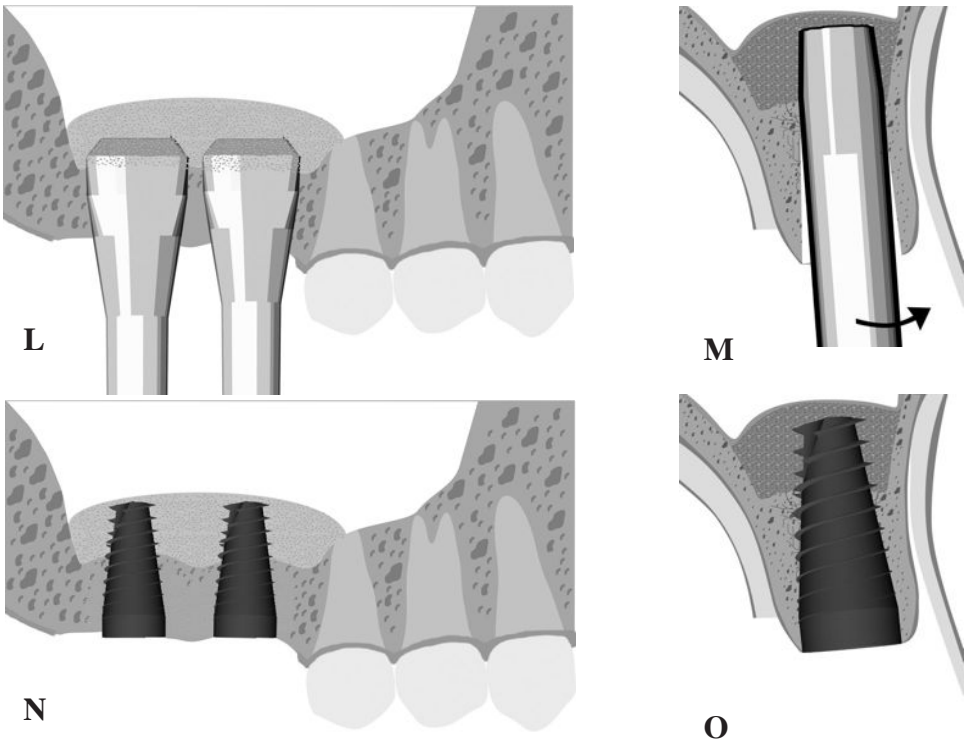


Figure 15. Graphic representation of split-thickness flap for ridge expansion combined with contiguous sinus floor elevation, CSFE. **A.** Lateral view and **B.** Lateral view of palatal incision for a buccal-based, split thickness flap. Moderate sinus pneumatization with Piezosurgery® bone incisions 1 mm below sinus floor, **C.** Osteo-mobilization with chisels for horizontal expansion, **D.** Lateral view and **E.** Frontal view of sequential floor fracture with 2 mm concave tipped osteotomes across the sinus floor (fractured but not elevated), **F.** Ridge expansion with 2 mm CSFE instrument or chisels, **G.** Lateral view and **H.** Frontal view of floor fracture with 3 mm concave tipped osteotomes across the sinus floor (fracture +/- elevation), **I.** Ridge expansion continued with 3 mm CSFE instrument with elevation and expansion. Steps G-I are repeated with 4 mm instruments with initial 0.5 mm sinus floor elevation. **J.** Lateral view and **K.** Frontal view of Contiguous Sinus Floor elevators mobilizing and elevating the floor 1 mm to 3 mm with continued buccal osteo-mobilization of the bone-periosteal flap, **L.** Contiguous Sinus Floor elevators are used to mobilize and elevate the floor 3 mm to 5 mm with the addition of particulate graft and continued buccal osteo-mobilization of the bone-periosteal flap, **M.** Final site osteotome for implant diameter (5-6 mm) used to complete final expansion, confirm primary stability and intact vertical elevation prior to implant placement, **N.** Lateral view and **O.** Frontal view of implant in position with ridge expansion and CSFE.

radiographs. (See *Selected Readings in Oral and Maxillofacial Surgery*, Vol. 18, #4.) Gently mallet bone chisels (H & H Company, Ontario CA) (Fig. 13E,F) just short of the sinus floor to begin initial osteo-mobilization for expansion of 2 mm to 3 mm at the site. (Fig. 15C) Then fracture the sinus floor with a standard 2 mm concave-tipped osteotome from the anterior to the posterior extent of the sinus floor. (Fig. 15D,E) As the sinus floor bone bends and mobilizes, depending on the degree of bone compliance, keep the sinus floor intact without any attempt to elevate. Continue the ridge expansion with

larger bone chisels or a 2 mm CSF elevator (CSF elevators, H & H Company, Ontario CA). (Fig. 15F) (See Case Study 5, E-F, p. 36) Fracture the floor the expanded width with a 3 mm concave-tipped osteotome. (Fig. 15G,H) CSF elevators can be used to start vertical elevation and for horizontal manipulation. (Fig. 15I) These instruments are designed to elevate the sinus floor by spreading the force and elevating over a large area. CSF elevators can also be used for additional ridge expansion by applying lateral bending forces. (Fig. 15J-M)

A surgical guide can be placed to determine implant positions after palatal purchase has been completed with Piezosurgery® or rotary instruments. (Fig. 13A,B) Complete localized expansion of the bone-periosteal flap and vertical elevation using CSF elevators or traditional tapered osteotomes. (Fig. 15M) Typically, tapered implant insertion produces good rotational stability with an intact bone-periosteal flap. (Fig. 15N,O) If compressive forces are inadequate with the osteotome a trial implant insertion can be completed, but if there is inadequate primary stability the implant should be removed. The intrabony defect of the implant site can also be grafted and implant placement delayed.

AVOIDING COMPLICATIONS

If the buccal plate at the expansion site is thin or if small vertical fracture lines develop at the height of contour, a full thickness flap approach allows the implant site to be augmented with a GBR overgraft. (See Case Study 1, p. 26) With a partial thickness flap the implant should be removed and the expansion gap grafted for delayed implant placement. Larger split defects, with loss of continuity, can be managed by combining screw fixation of the fracture segment with a barrier membrane, if adeqluate stability can be obtained. (Fig.10)

Facial manipulation of the bone flap can result in excessive buccal inclination of the implant. After the bone expansion gap is opened, the apical portion of the implant osteotomy can be modified with Piezosurgery® insets or rotary expanders, under copious irrigation. This can reduce excess facial inclination unless apical perforation or fracture of the labial plate would result.

The apical portion can also be progressively mobilized with sequential use of spade osteotomes or chisels, with an elevating force and twisting of the instrument like a screw driver. (Fig. 13C,D) Alternatively, increased crestal purchase of the palatal bone margin can improve implant position. (Fig. 13A,B) Rarely, the position or the angle of the osteotomy cannot be optimized, requiring interpositional grafting and delayed implant placement.

A number of factors are important to consider to avoid apical perforation or buccal fracture: the amount of labial undercut; ridge width, bone quality and compliance; bone incision design with partial or complete intra-bony release; and anatomic location in the arch (e.g., it is difficult to expand a multi-tooth defect with osteo-mobilization around the corner of the arch at the canine site). The use of a tapered implant that conforms to the shape of the expansion defect and a less ag-

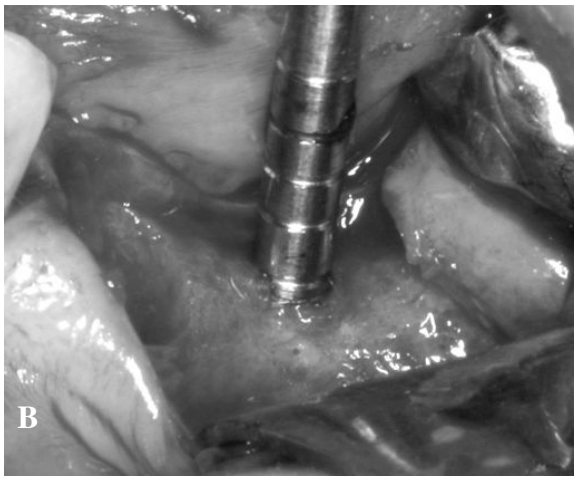
gressive thread pattern in the implant can also reduce the risk of fracture of the bone-periosteal flap. (Fig. 5C,D). Grafting of the expansion gap can be completed if there is fracture or vascular compromise. Grafting of vertical bone release incisions is recommended to prevent a contour deficiency. Sinus complications including small tears or breach of the sinus were discussed in detail in Part 1, *Selected Readings in Oral and Maxillofacial Surgery*, Vol. 18, #4.

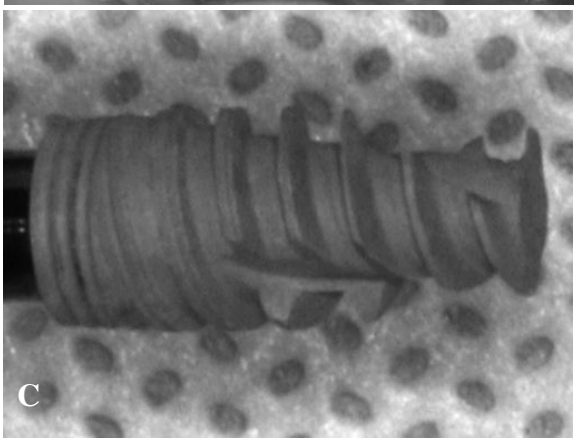
SUMMARY

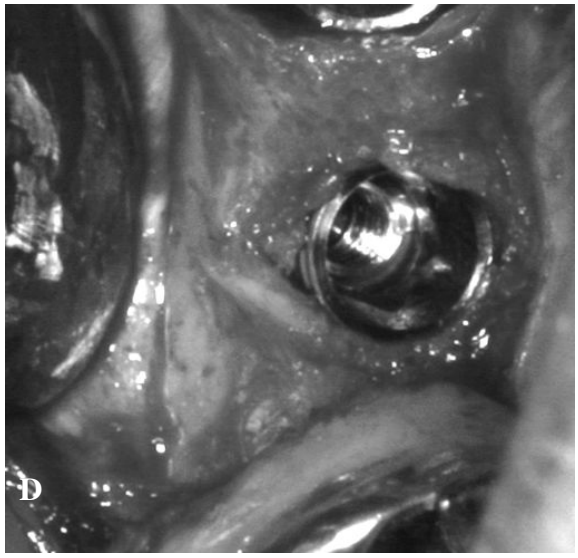
Bone manipulation for ridge expansion offer patients a less invasive option that preserves native bone on the implant surface. The design of the soft tissue incision determines the bone manipulation approach. Full thickness flap exposure can be used in conjunction with osteotome techniques or mechanical screw expanders and particulate over-grafting for a single or two-stage protocol. Partial thickness flaps improve the attached tissue margin and vestibular depth. The preservation of a vascular supply to the bone flap limits bone resorbtion of the expanded segment and is a source of pleuri-potent meschymal cells for regeneration. With partial thickness flaps or a flapless approach, osteotome techniques can expand and manipulate the alveolus for a single-stage protocol. The need for grafting materials is significantly reduced and a shorter healing interval is generally required. Buccal expansion restores lost alveolar dimensions and returns the implant to a restorative-driven position. Experience with osteotome site development for routine maxillary implant placement and TASE, prepares the surgeon for implementation of osteo-mobilization for reconstruction of horizontal deficiencies, and combined osteo-mobilization and TASE techniques for simultaneous reconstruction of horizontal and vertical defects prior to implant placement.

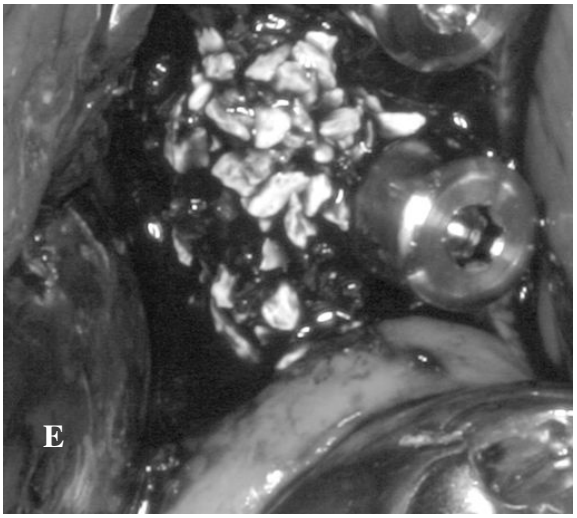
Dr. Dan Cullum completed his DDS with distinction at the University of Alberta, Canada and residency training at Westchester Medical Center, New York. He is a Diplomat of the American Board of Oral and Maxillofacial Surgery. Dr. Cullum speaks internationally and has contributed publications and textbook chapters on implant reconstruction. He has served in leadership roles with the American Association of Oral and Maxillofacial Surgeons (Dental Implant Sub-Committee), Academy of Osseointegration (Newsletter Committee), Kootenai Medical Center (Chairman, Department of Surgery) and at state and local societies. Dr. Cullum founded Implants Northwest LIVE, a learning center focused on live training for surgeon-restorative teams and surgical specialists. At Implants Northwest (Coeur d'Alene, ID), he practices oral and maxillofacial surgery with emphasis on minimally invasive techniques in esthetic implant reconstruction including bone manipulation and immediate and comprehensive management.

CASE STUDY 1: Osteo-condensation with mechanical rotary expansion and over-graft. **A.** Buccal based, lingual crestal incision for full thickness flap, and 2 mm drill preparation; **B.** Mechanical rotary expansion completed through 4 mm diameter; **C.** Self-tapping, aggressive thread pattern, expanding, tapered implant; **D.** Implant in position with expanded and partially fractured buccal cortex at the mid-implant height of contour; **E.** Particulate xenograft for lateral augmentation; **F.** A collagen barrier (Cytoplast RTM® Osteogenics, Lubbock, TX) with trans-gingival healing caps in position; **G.** Closure with an apically repositioned flap with trans-gingival healing. **H.** Pre-operative and **I.** 1-year post-restoration views demonstrating contour enhancement and stable soft tissue.





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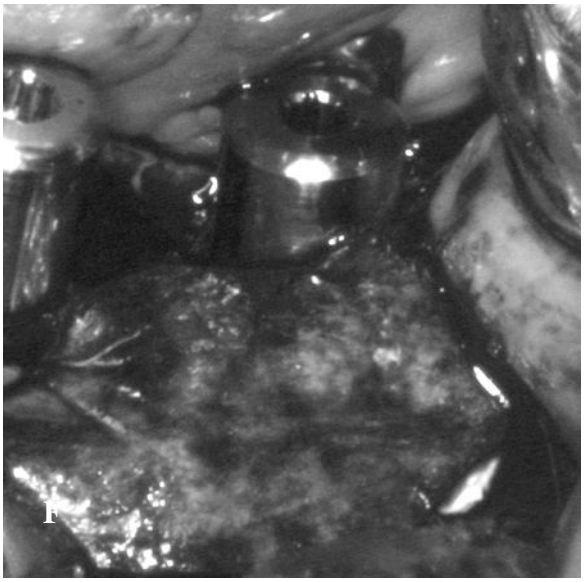
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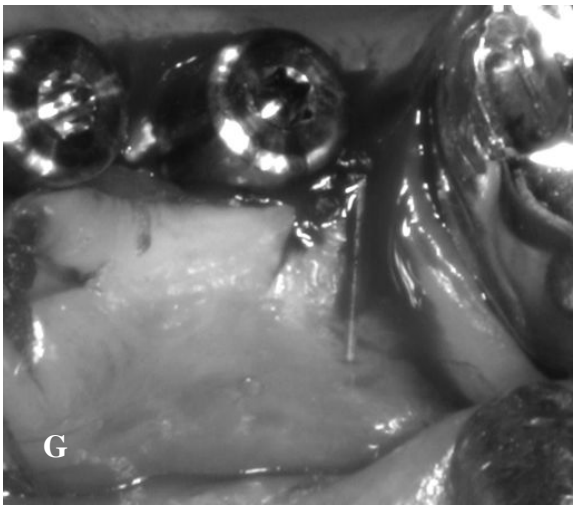
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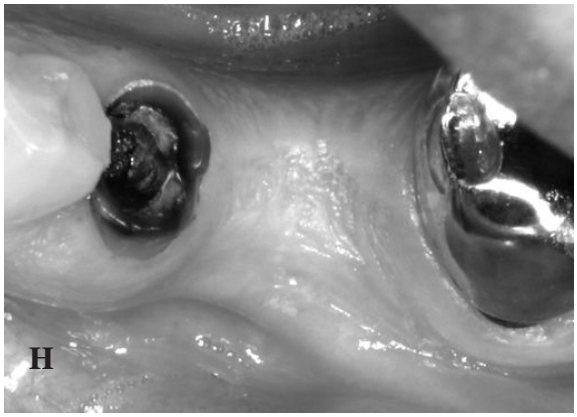
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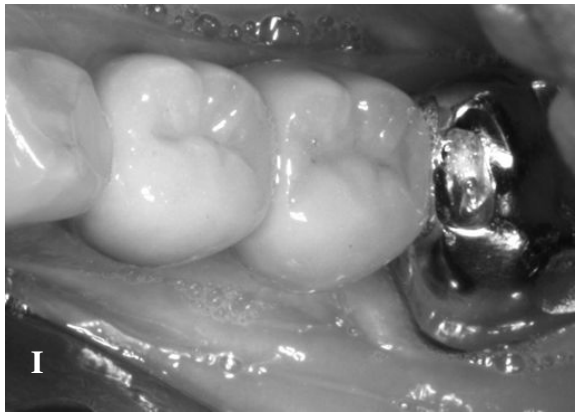
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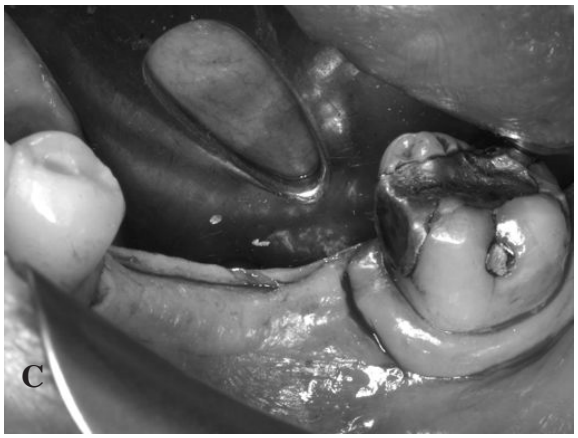
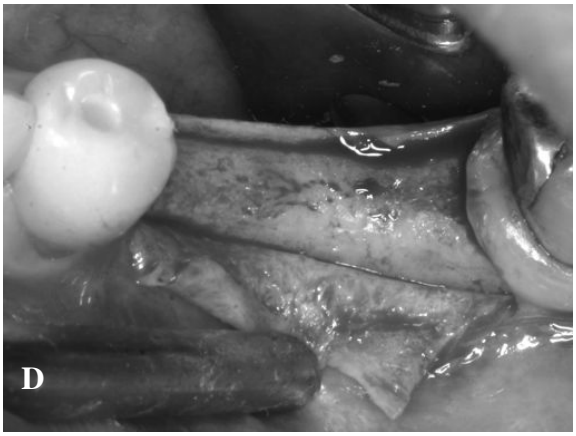
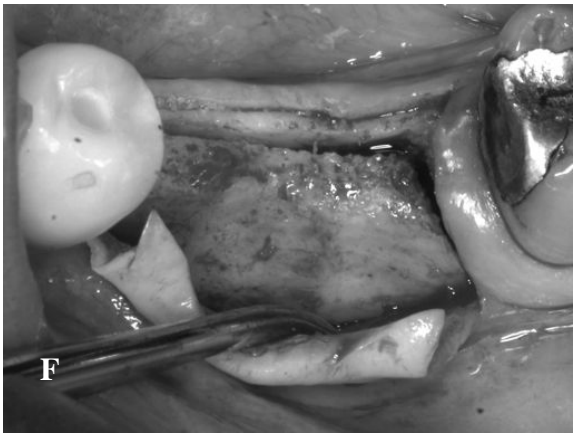
CASE STUDY 2: Osteo-mobilization with mechanical ridge expansion for a single stage procedure. **A.** Lateral and **B.** occlusal pre-operative clinical images showing horizontal dimensional loss; **C.** Buccal-based, lingual crestal incision for apical repositioning; **D.** Full thickness flap elevation; **E.** & **F.** Piezosurgery® bone osteotomy with beveled lateral cortical releasing incisions; **G**. Insertion of initial mechanical rotary expanders; **H.** Insertion of larger rotary expanders with osteo-mobilization producing an intrabony gap; **I.** Implant Insertion; **J.** Collagen inserted in the intrabony expansion gap and placement of 5 mm healing caps; **K.** Transgingival healing protocol with apical flap repositioning for increasing the attached tissue margin; **L.** Occlusal and **M.** Lateral views of 1-year post-restoration; **N.** 1-year post-restoration radiograph.



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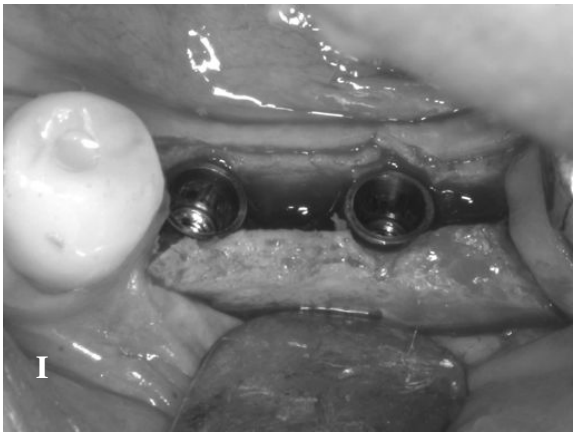
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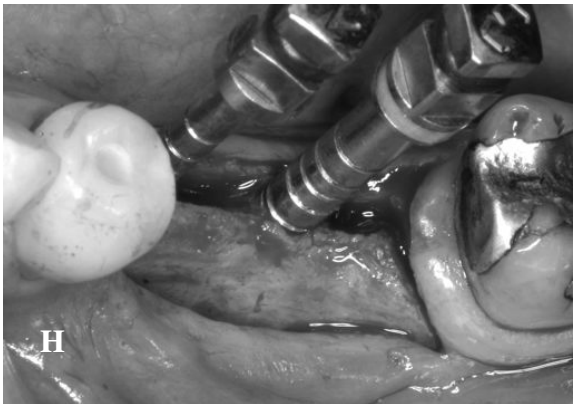
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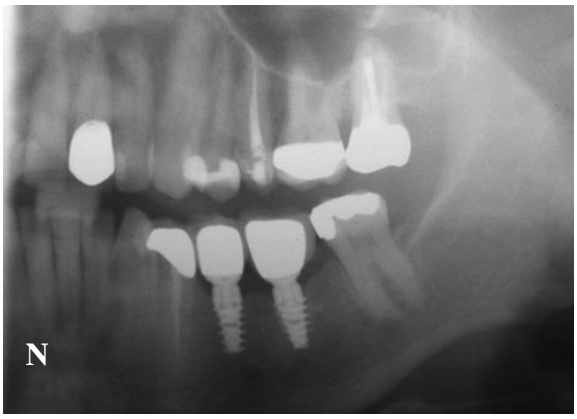
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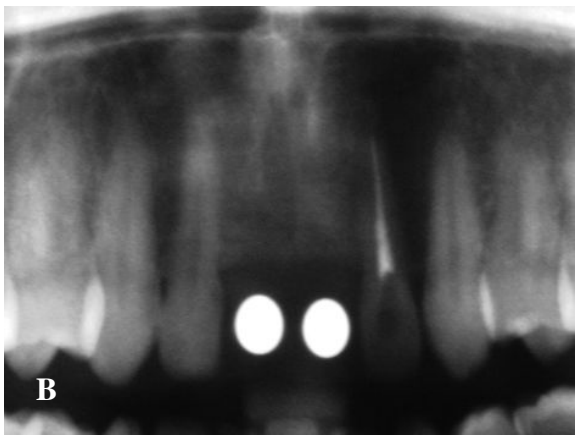
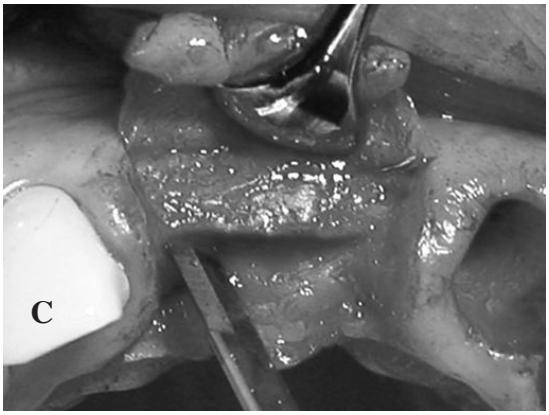
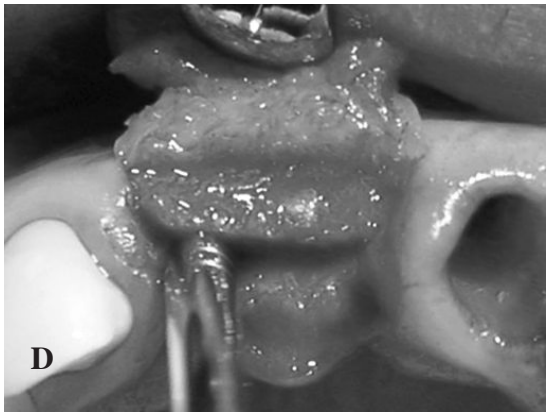
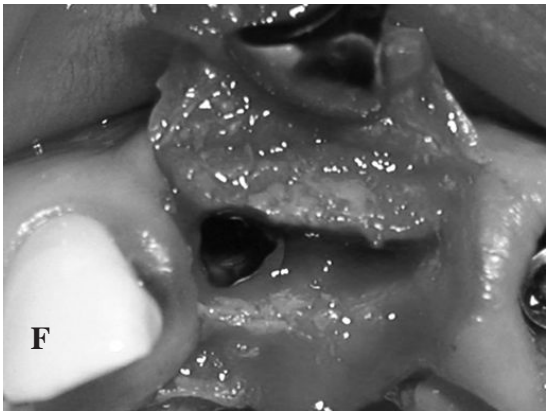
CASE STUDY 3: Split thickness flap for esthetic-zone ridge expansion. **A.** Occlusal view of pre-op horizontal ridge defect; **B.** Radiograph of pre-op horizontal ridge defect; **C.** After horizontal ridge bone incision and initial osteo-mobilization with spade expanders. The beveled intra-bony incision is completed with a #64 "mini" beaver blade; **D.** Horizontal osteo-mobilization with D-shaped osteotome, developing an expansion gap; **E.** & **F.** Progressive expansion with tapered osteotomes to 4.3 mm diameter with implant insertion and expansion gap;

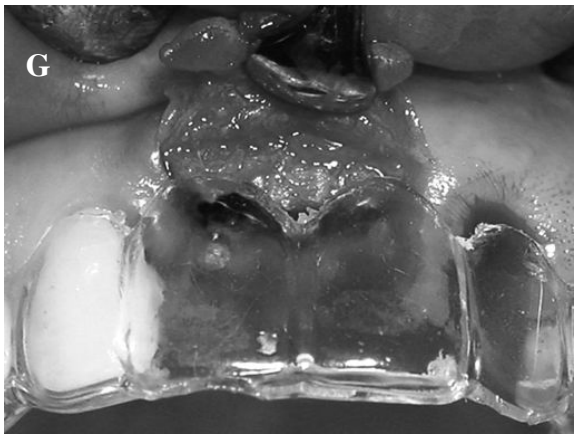


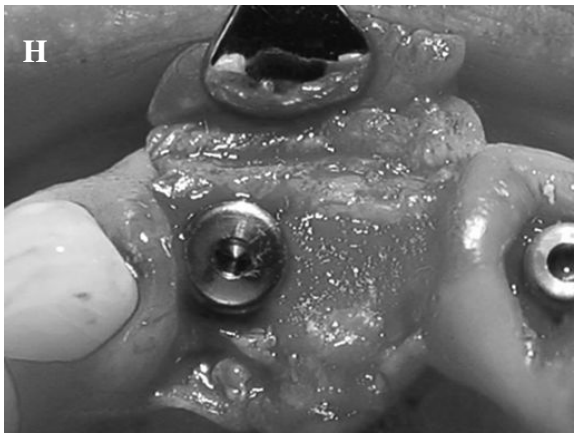


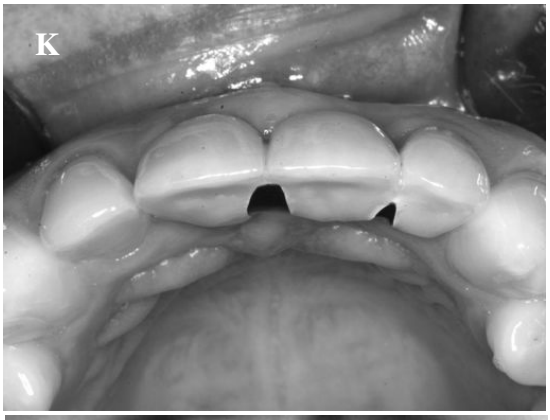


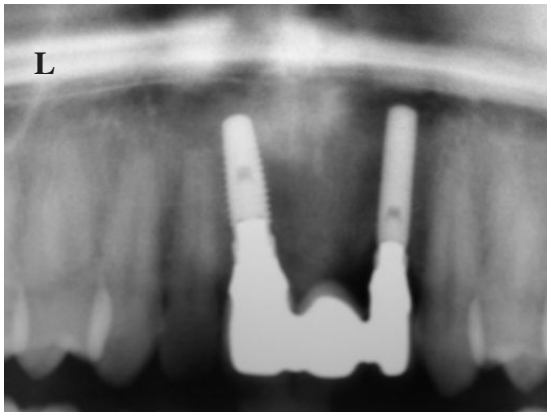


G. Stent evaluation showing that the implant position requires vertical height reduction of the labial plate; **H.** Implants with healing caps in position and collagen placed in the intra-bony gap; **I.** Passive flap positioning with closure; **J.** Frontal view and **K.** Occlusal view of 43-month post-op result; **L.** 43-month post-op radiograph demonstrating good bone maintenance.

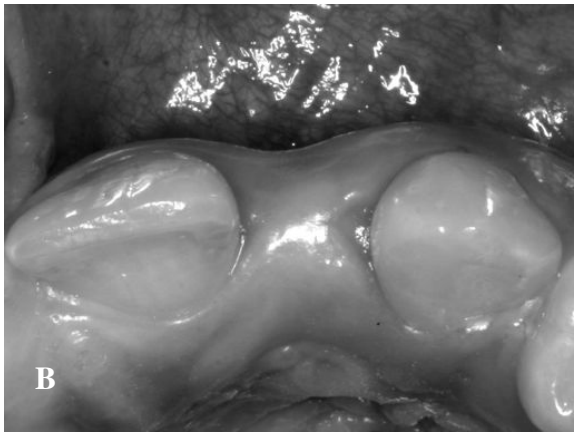


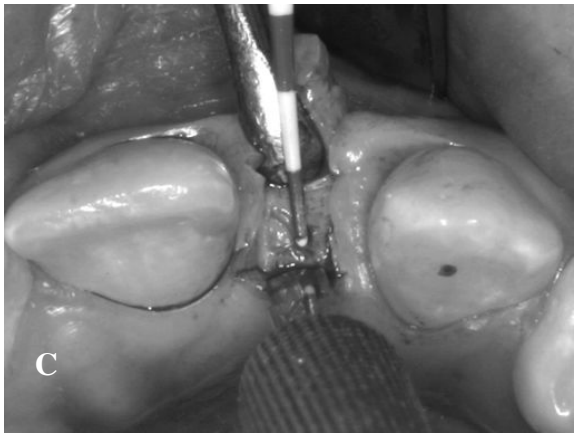


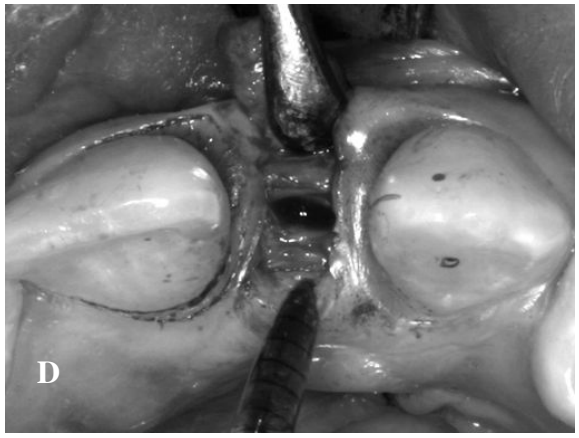




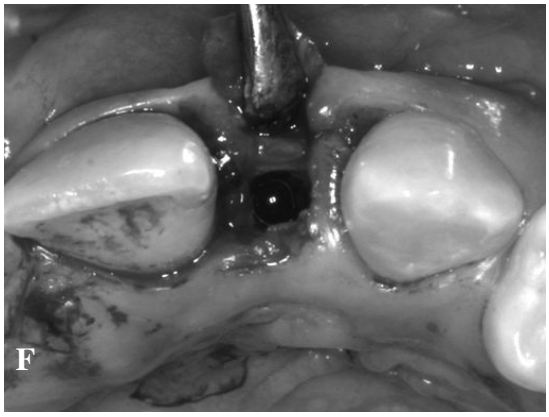
CASE STUDY 4: Esthetic mini-flap ridge expansion with a sub-epithelial CT eminence graft. **A.** Frontal view and **B.** Occlusal view of pre-op edentulous # 10, with mild clinical alveolar dimensional loss; **C.** Mini-flap exposure; **D.** After Piezosurgery® bone incision and osteo-mobilization with spade expanders; **E.** After osteo-mobilization with bibevel expanders and; **F.** D-shaped expanders for progressive ridge expansion; **G.** A 2 mm drill is placed (after opening of ridge crest for bone preservation) for site assessment. Additional apical osteo-moboilzation was completed with a chisel for apical site development to prevent perforation of the

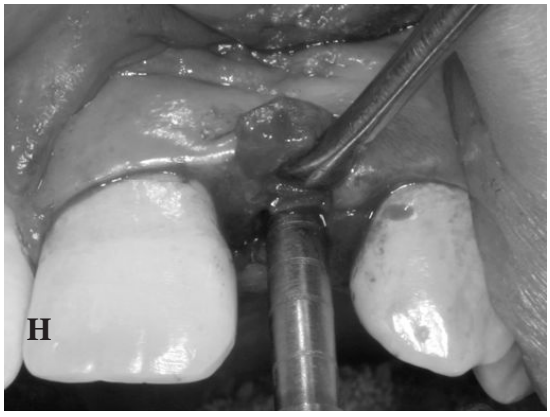


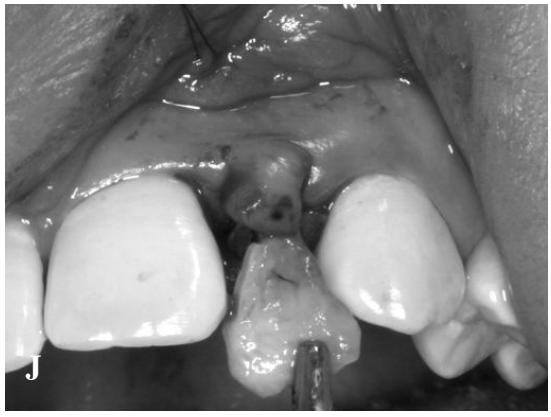




undercut; **H.** Final osteotome site development and **I.** Implant placement with healing caps. Closed supra-periosteal pocket was developed with **J.** Connective tissue graft and horizontal matress suture prior to pulling the graft into the pocket; **K.** After CT graft insertion and fixation with a 6-0 Nylon horizontal mattress suture; **L.** Parasagittal and **M.** Horizontal pre-op edentulous # 10 images with severe undercut and mild to moderate dimensional loss; **N.** Immediate post-op CBCT image, demonstrating osteo-mobilization of the facial bone plate; **O.** Frontal view and **P.** Occlusal view 42-months post-restoration clinical images with excellent tissue contours and health; **Q.** Radiographic image 42-months post-restoration with stable bone levels.





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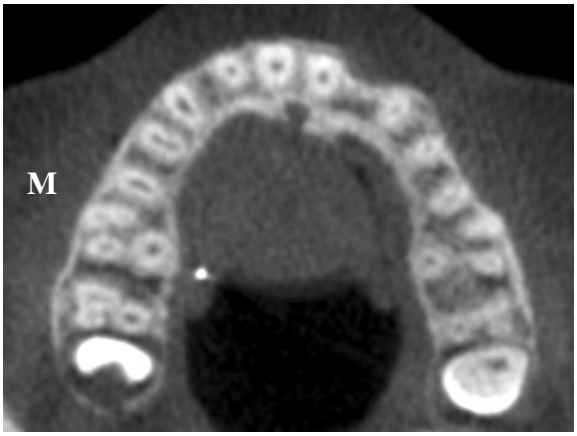
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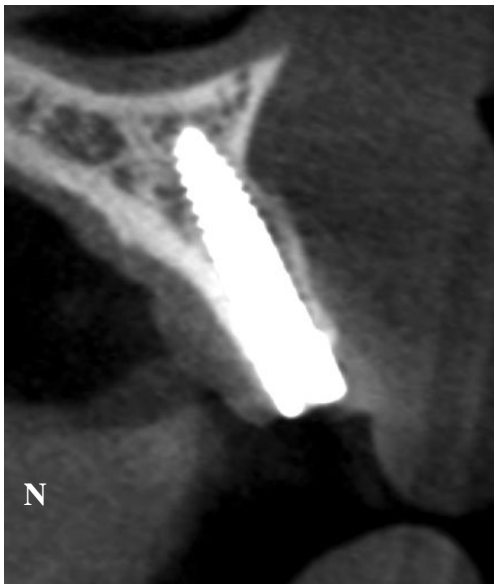
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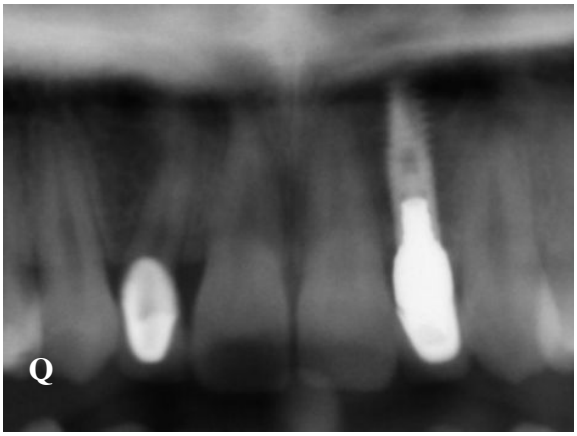
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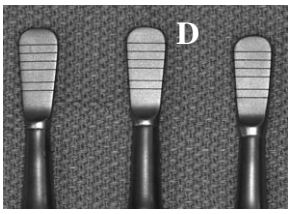
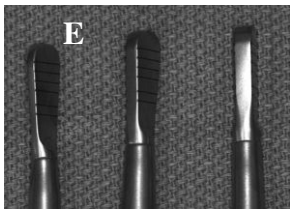
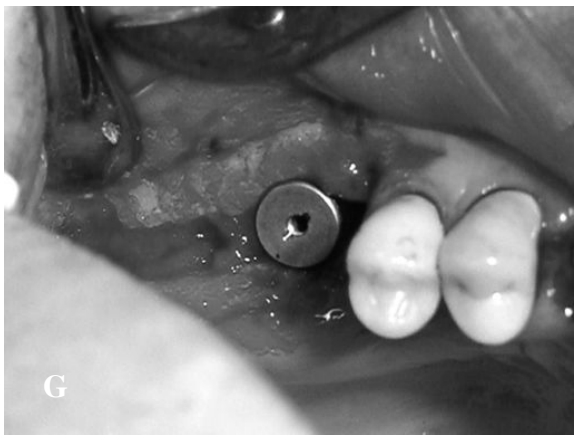
CASE STUDY 5: Osteo-mobilization and TASE with ridge expansion and CSFE. **A.** A buccal-based palatal incision is developed just above the level of the periosteum using the #64 "mini" beaver blade; **B.** The spit thickness flap can be extended anteriorly or posteriorly the width of one to two teeth, with a marginal release at the mucogingival junction. The flap can be further extended with a beveled vertical release for access. The bone incision is completed, extending posterior to the tuberosity; **C.** After horizontal buccal osteo-mobilization and sequential floor fracturing with concave tipped osteotomes; **D.** Face view and **E.** Edge view of CSF elevators, left to right 2 mm, 3 mm and 4 mm x 10 mm (H & H co. Ontario, CA) that are used to fracture the sinus floor and for horizontal bending for continued osteo-mobilization and sinus floor elevation; **F.** 6.5

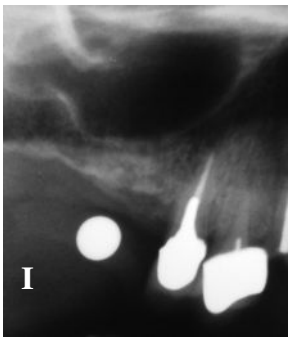


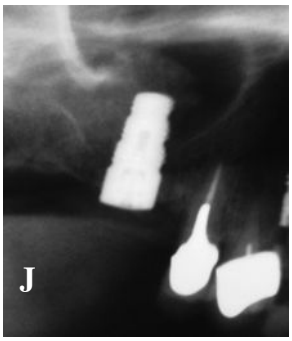


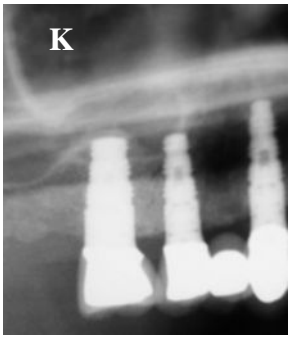


mm diameter implant inserted with an intact bone-periostal flap and good primary stability; **G.** Cover screw placed with collagen in the intra-bony expansion gap and particulate graft at the anterior vertical bone incision; **H.** Passive flap closure; **I.** Preop radiograph with 4 mm to 5 mm of bone to the sinus floor; **J.** Immediate post-op radiograph, with insertion of a 6.5 mm x 13 mm implant, containment of sinus elevation, and an intra-sinus graft; **K.** Radiograph at 28-month post-restoration, demonstrating stable crestal and intra-sinus bone levels; **L.** Occlusal view and **M.** Lateral view of clinical presentation at 48-months with restored soft tissue contours; **N.** CBCT image at 48-months post-op, demonstrating excellent maintenance of the bony reconstruction.

Note - Case Study 5 images A, B, C, F, G, I, K, N © Quintessence 2006 – used with permission.







REFERENCES

1. Atwood D: Reduction of residual ridges: A major oral disease entity. J Prosthet Dent 26: 266, 1971.

2. Atwood D: Bone loss of the edentulous alveolar ridges. J Prosthet Dent 50:266, 1979.

3. Tallgren A: Alveolar bone loss in denture wearers as related to facial morphology. Acta Odontol Scand 28: 251, 1970.

4. Branemark P-I, Hanson BO, Adell R, et al. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. Scand J Plastic Reconstr Surg;16(Suppl.):1, 1977.

5. Albreksson T, Zarb G, Worthington P, et al: The long-term efficacy of currently used dental implants: a review and proposed criteria of success. Int J Oral Maxillofac Implants 1:1, 1986.

6. Adell R, Leckholm U, Rockler B, et al: A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 10:387, 1981.

7. Leckholm U and Zarb G: Patient selection and preparation. IN: Branemark PI, Zarb G, Albrektsson T (eds.) ***Tissue Integrated Prosthesis: Osseointegration in Clinical Dentistry.*** Chicago: Quitessence 1985, pp. 199-210.

8. Bryant SR: The effects of age, jaw site and bone condition on oral implant outcomes. Int J Prosthodont 11:470, 1998.

9. Truhlar RS, Orenstein IH, Morris HF, et al: Distribution of bone quality in patients receiving endosseous dental implants. J Oral Maxillofac Surg 11:408, 1997.

10. Hammerle CH, Jung RF and Feloutzis A: A systematic review of the survival of implants in bone sites augmented with barrier membranes (guided bone regeneration) in partially edentulous patients. J Clin Periodontol 29: 226, 2002.

11. Lang NP, Bragger U, Hammerle CH, et al: Immediate trans-mucosal implants using the principle of guided tissue regeneration. I. Rational, clinical procedures and 30-month results. Clin Oral Implants Res 5: 154, 1994.

12. Bartee BK: The use of high-density polytetrafluorethylene membranes to treat osseous defect: Clinical reports. Implant Dent 4:21, 1995.

13. Misch CM: Comparison of intra-oral donor sites for onlay grafting prior to implant placement. Int J Oral Maxillofac Implants 12:767, 1997.

14. Keller EE, van Rockel NB, Desjardins RP, et al: Prosthetic-surgical reconstruction of the severely resorbed maxilla with iliac bone grafting and tissue integrated prosthesis. Int J Oral Maxillofac Implants 2:155, 1987.

15. Boyne PJ, Cole MD, Strolinger D, et al: A technique for osseous reconstruction of deficient edentulous maxillary ridges. J Oral Maxillofac Surg 43:87, 1985.

16. Boyne PJ and James RA: Grafting of the maxillary sinus floor with bone and marrow. J Oral Surg 38:613, 1980.

17. Khoury F: Augmentation osseuse et chirugie implantare. Implant 5:221, 1999.

18. Tatum OH Jr: Maxillary and sinus implant reconstructions. Dent Clin North Am 30:207, 1986.

19. Khoury F: Die modifizierte Alveolar-Extensionsplastik. Zeitschrift Zanarztl Implantologie 3:174, 1987.

20. Scipioni A, Brushi G and Calesini G: The edentulous ridge expansion technique: a five-year study on 123 implants with 1 - 5 year follow-up. Int J Periodontics Rest Dent 14:451, 1994.

21. Vercellotti T: Piezoelectric bone surgery in implantology: A case report—A new piezoelectric ridge expansion technique. Int J Periodontics Restorative Dent 20:358, 2000;

22. Simion M, Baldoni M and Zaffe D: Jawbone enlargement using immediate implant placement associated with a split-crest technique and guided bone regeneration. Int J Periodontics Restorative Dent 12:462, 1992.

23. Cullum DR and Jensen OT: Trans-alveolar sinus elevation combined with ridge expansion. IN: Jensen OT (ed). ***The Sinus Bone Graft***, 2nd ed. Chicago: Quintessence 2006, pp. 251-262.

24. Chiapasco M, Ferrini F, Casentini P, et al: Dental implants placed in expanded narrow edentulous ridges with the Extensio-Crest® device: a 1 to 3-year multicenter study. Clin Oral Implants Res 17:265, 2006.

25. Cortes AR and Cortes DN: Non-traumatic bone expansion for immediate implant placement: An analysis of 21 cases. Implant Dent 19:92, 2010.

26. Chin M and Toth BA: Distraction osteogenesis in maxillofacial surgery using internal devices. J Oral Maxillofac Surg 54:45, 1996.

27. Jensen OT, Cockrell R, Kuhlke L, et al: Anterior maxillary alveolar distraction osteogenesis: a prospective 5-year clinical study. Int J Oral Maxillofac Implants 17:52, 2002.

28. Roummanas ED, Markowitz BL, Lorant JA, et al: Reconstructed mandibular defects: fibula free flaps and osseointegrated implants. Plas Reconstr Surg 99:356, 1997.

29. Nevins M, Kirker-Head C, Nevins M, et al: Bone formation in the goat maxillary sinus induced by absorbable collagen sponge impregnated with rhBMP-2. Int J Periodont Restor Dent 16:8, 1996.

30. Howell TH, Fiorellini JP, Jones A, et al: A feasibility study evaluating rhBMP-2/absorbable collagen sponge for alveolar ridge preservation or augmentation. Int J Periodntics Restorative Dent. 17:124, 1997.

31. Boyan BD, Weesner TC, Lohmann CH, et al: Porcine fetal enamel matrix derivative enhances bone formation induced by demineralized freeze-dried bone allograft in vitro. J Periodontal 71:1278, 2000.

32. Simion M, Rocchietta I and Dellavia C: Three-dimensional ridge augmentation with xenograft and recombinant human derived growth factor-BB in humans: Report of two cases. Int J Periodontics Restorative Dent. 27:109, 2007.

33. Marx RE, Carlson ER,Schimmele SR, et al: Platelet-rich plasma: Growth factor enhancement for bone grafts. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 85:638, 1998.

34. Simion M, Rocchietta I, Monforte M, Maschera E. Three-dimensional alveolar bone reconstruction with a combination of recombinant human platelet-derived growth factor BB and guided bone regeneration: A case report. Int. J Periodont Restorative Dent 28:239, 2008.

35. Buser D, Mericske-Stern R, Bernard JP, et al: Long-term evaluation of non-submerged ITI implants. Part I: 8-year life table analysis of a prospective multicenter study with 2359 implants. Clin Oral Implants Res 8:161, 1997.

36. Garber DA and Belser U: Restorative driven implant placement with restoration-generated site development. Compend Contin Educ Dent 16:796, 1995.

37. Whorle P: Single tooth replacement in the esthetic zone with immediate provisionalization: fourteen consecutive case reports. Pract Periodontics Aesthet Dent 9:1107, 1998.

38. Saadoun A, LeGall M, Touati B. Selection and ideal tri-dimensional implant position for soft tissue aesthetics. Prac Periodontics and Aesthetic Dent 11:1063, 1999.

39. Covani U, Crespi R, Cornelini R, et al: Immediate implants supporting single crown restorations: A 4-year prospective study. J Periodontol 75:982, 2004.

40. Kan JU, Rungcharassaeng K, Morimoto T, et al: Facial gingival tissue stability after connective tissue graft with single immediate tooth replacement in the esthetic zone: consecutive case report. J Oral Maxillofac Surg 67:40, 2009.

41. Chiapasco M and Casentini P: Implant supported dental restorations in compromised sites: optimization of results with a multidisciplinary integrated approach. IN: Khoury F, Antoun H, Missika P (ed). ***Bone Augmentation in Oral Implantology.*** Chicago: Quintessence, 2007, p.36

42. Bruschi G, Scipioni A and Calesini G: Localized management of the sinus floor with simultaneous implant placement. Int J Oral Maxillofac Implants 13:219, 1998.

43. Bravi F, Bruschi GB and Ferrini F: A 10-year multi-center retrospective clinical study of 1715 implants placed with the edentulous ridge expansion technique. Int J Periodontics Restorative Dent 27:557, 2007.

44. Scipioni A: Bone regeneration in the edentulous ridge expansion technique: histologic and ultrastructural study of 20 clinical cases. Int J Periodont Rest Dent 19:269, 1999.

45. Coatoam GW and Kreiger JT: A four year study examining the results of indirect sinus augmentation procedures. J Oral Implantol 23:117, 1997.

46. Rosen PS, Summers R, Mellado JR, et al: The bone added osteotome sinus floor elevation technique: Multi-center retrospective report of consecutively treated patients. Int J Oral Maxillofac Implants 14:853, 1999.

47. Fugazotto PA and Vlassis J: Long-term success of sinus augmentation using various srugical approaches and grafting materials. Int J Oral Maxillofac Implants 13:52, 1998..

48. Deporter DA, Caudry S, Kermalli J, et al: Further data on the predictability of the indirect sinus elevation procedure used with short, porous-surfaced dental implants. Int J Perio Rest Dent 25:585, 2005.

49. Toffler M: Treating the atrophic maxilla by combining short implants with minimally invasive osteotome procedures. Pract Proced Aesthet Dent 18:301, 2006.

50. Ferringo N, Lauureti M and Fanali S: Dental implant placement in conjunction with osteotome sinus floor elevation: A 12-year life-table analysis from a prospective study on 588 ITI implants. Clin Oral Implants Res 17:194, 2006.

51. Pjetursson BE, Ignjatovic D, Matuliene G, et al: Transalveolar maxillary floor elevation using osteotomes with or without grafting material. Part I: Implant survival and patients' perception. Clin Oral Implant Res 20:667, 2009.

52. Pjetursson BE, Ignjatovic D,Matuliene G, et al: Transalveolar maxillary floor elevation using osteotomes with or without grafting material. Part II: Radiographic tissue remodeling. Clin Oral Implant Res 20:677, 2009.

53. Nadir R, Biscof M, Vasquez L, et al: Osteotome sinus floor elevation technique without grafting material: 3-year results of a prospective pilot study. Clin Oral Implant Res 20:701, 2009.

54. Summers RB: The osteotome technique: Part 2-The ridge expansion osteotomy (REO) procedure. Compendium 15:422, 1994.

55. Winter AA, Pollack AS and Odrich RB: Placement of implants in the severely atrophic posterior maxilla using localized management of the sinus floor: a preliminary study. Int J Oral Maxillofac Implants 17:687, 2002.

56. Summers RB: A new concept in maxillary implant surgery: the osteotome technique. Compendium 15:152, 1994.

57. Summers RB: The osteotome technique: Part 3 – Less invasive methods of elevating the sinus floor. Compendium 15:698, 1994.

58. Summers RB: The osteotome technique: Part 4 – Future site development. Compendium 16:1080, 1995.

59. Saadoun AP and Le Gall MG: Implant site preparation with osteotomes: Principles and clinical application. Pract Proced Aesthet Dent 8:453, 1996.

60. Horowitz RA: Clinical uses of osteotomes for sinus augmentation at the time of implant placenment. Compend Cont Educ Dent 18:441, 1997.

61. Davarpanah M, Martinez H, Tecucianu J, et al: The modified osteotome technique. Int J Periodont Restorative Dent 21:599, 2001.

62. Alberti PW: Applied surgical anatomy of the maxillary sinus. Otolaryngol Clin North Am 9:3, 1976.

63. Blus C and Szmukler-Montcler S: Split-crest and immediate implant placement with ultra-sonic bone surgery: a 3-year life-table analysis with 230 treated sites. Clin Oral Implants Res 17:700, 2006.

64. Danza, Guidi R and Carinci F: Comparison between implants inserted into piezo split and unsplit alveolar crests. J Oral Maxillofac Surg 67:2460, 2009.

65. Jensen OT, Cullum DR and Baer D: Marginal bone stability using 3 different flap approaches for alveolar split expansion for dental implants – a 1-year clinical study. J Oral Maxillofac Surg 67:1921, 2009.

66. Horrocks GB: The controlled assisted ridge expansion technique for implant placement in the anterior maxilla: a technical note. Int J Periodont Restorative Dent 30:3, 2010.

67. Jensen OT: The book bone flap: The island flap IN: Jensen OT (ed). ***The Osteoperiosteal Flap,*** Chicago: Quintessence 2010, pp 101-114.

68. Coatoam GW and Marrotti A: The segmental ridge-split procedure. J Periodontology 74:757, 2003.

69. Malchodi L, Scarano A, Quaranta M, et al: Rigid fixation by means of titanium mesh in edentulous ridge expansion for horizontal ridge exansion in the maxilla. Int J Oral Maxillofac Implants 43:87, 1998.

70. Jensen OT: The book bone flap: Sequential alveolar crest expansion IN: Jensen OT (ed). ***The Osteoperiosteal Flap***, Chicago: Quintessence 2010, pp. 96-99.

71. Chiche G and Pinault A: Artistic and scientific principles applied to esthetic dentistry. IN: Chiche G and Pinault A. ***Esthetics of Anterior Fixed Prosthodontics***, Chicago: Quintescence 1994, pp. 13-32.

72. Sclar AT: Systematic evaluation of the esthetic implant patient. IN: Sclar AT. ***Soft Tissue and Esthetic Considerations in Implant Therapy***, Chicago: Quintessence 2003, pp. 13-41.

73. Kois J and Kan J: Predictable peri-implant gingival aesthetics: Surgical and prosthodontic rationales. Pract Proced Aesthet Dent 2001:13;691-698

74. Kois J. Predictable single-tooth peri-implant esthetics: five diagnostic keys. Compendium 25:895, 2004.

75. Tarnow DP, Magner AW and Fletcher PW: The effect of the distance from the contact point to the crest of bone on the presence or absence of the inter-proximal dental papilla. J Periodointol 63:995, 1992.

76. Salama H, Salama M, Garber D, et al: Developing optimal peri-implant papillae within the esthetic zone: guided soft tissue augmentation. J Esthet Dent 7:125,1995.

77. Tarnow DP, Cho SC and Walace SS: The effect of inter-implant distance on the height of inter-implant bone crest. J Periodontol 71:546, 2000.

78. Goodacre JC, Bernal G, Rerengcharassaeng K, et al: Clinical complications with implants and implant prostheses. J Prosthet Dent 90:121, 2003.

79. Khoury F and Tunkel J: Bone augmentation and soft tissue management. IN: Khoury F, Antoun H and Missika P (ed). ***Bone Augmentation in Oral Implantology.*** Chicago: Quintessence, 2007, pp. 75-114.

80. Palaci, P: Peri-implant soft tissue management: Papilla regeneration technique. IN: Palaci P, Ericsson I, Engstrand P, Rangert B: ***Optimal implant positioning & soft tissue management for the Brånemark system.*** Chicago: Quintessence 1995, pp. 59-70.

81. Sclar AT, Surgical techniques for management of peri-implant soft tissues. IN: Sclar AT. ***Soft Tissue and Esthetic Considerations in Implant Therapy***, Chicago: Quintessence 2003, pp 52-56.

82. Silverstein LH, Kurtzman GM, Moskowitz E, et al. Aesthetic enhancement of anterior dental implants with the use of tapered osteotomes and soft tissue manipulation. J Oral Implantology 1999;15:18-22

83. Cullum DR: Esthetic reconstruction of lateral incisiors using micro-flap ridge expansion. Clinical Innovation Abstract, AO Annual meeting CI-10, p58, 2003.

84. Cullum DR: Micro-flap ridge expansion for single-stage reconstruction of congenitally missing lateral incisiors. Clinical Innovations Abstract, AO Annual meeting CI-05, p70, 2006

85. Ulm CM, Solar P, Gsellmann, et al: The edentulous maxillary alveolar process in the region of the maxillary sinus-A study of physical dimension. Int J Oral Maxillofac Surg 24:279, 1995.

86. Gray H. ***Anatomy of the Human Body*** (28th ed). Philidelphia, PA; Lea & Febiger, 1966.

87. Uchida Y, Goto M, Katsuki T, Soejima Y. Measurement of Maxillary Sinus Volume using Computerized Tomomgraphic Images. Int J Oral Maxillofac Impl 13: 811, 1998.

88. Worthington P, Rubenstein J, Hatcher DC. The role of cone-beam computed tomography in the planning and placement of implants. J Am Dent Assoc. Oct;141 Suppl 3:19S-24S, 2010

89. Agaloo TL, Moy PK. Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement? Int J Oral Maxillofac Impl 22(suppl):49-70, 2007.

90. Misch CE: Bone character: Second vital implant criterion. Dent Today 7:39, 1988.

91. Reiser G, Rabinovitz Z, Bruno J, et al: The evaluation of maxillary sinus membrane response following elevation with the crestal osteotome technique in human cadavers. Int J Oral Maxillofac Implants 16:833, 2001.

92. Barengo M, Sivolella Z, Majzoub G, et al: Endoscopic evaluation of the bone added osteotome sinus floor elevation procedure. Int J Oral Maxillofac Surg 35:185, 2004.

93. Kang T: Sinus elevation using a staged osteotome technique for site development prior to implant placement in site with less than 5mm of native bone. Int J Periodont Restorative Dent 28:73, 2008.

94. Pennarocha M, Perez H, Garcia A, et al: Benign paroxysmal positional vertigo as a complication of osteotome expansion of the maxillary alveolar ridge. J Oral Maxillofac Surg 59:106, 2001.

95. Saker M and Ogle O: Benign paroxysmal vertigo subsequent to sinus lift via closed technique. J Oral Maxillofac Surg 63:1385, 2005.

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