Morphogenic Bone Splitting: Description of an Original Technique and Its Application in Esthetically Significant Areas

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Purpose: This article presents a regenerative technique, morphogenic bone splitting (MBS), which overcomes the limitations associated with expansion techniques described to date. ***Materials and Methods:*** The authors propose a method whereby the bone-mucosa-gingival complex (BMGC) is displaced in its entirety, establishing a new focus for a secondary hinge located in the coronal reaches of the osteotomy. Depending on clinical needs, this approach modifies or eliminates the facially inclined hinge displacement characteristic of ridge expansion techniques. By exploiting the inherent capacity for second intention healing, the regenerative MBS technique avoids the use of graft material, membranes, or mechanical devices. It effectively harnesses the intrinsic regenerative capabilities of the treated site. ***Results and Conclusions:*** The MBS technique is performed in a single operation. By permitting the insertion of implants of an appropriate size in the optimum position for esthetic and functional requirements, it achieves the desired 3-dimensional reshaping of the BMGC and thereby restores the anatomy of the implant site. This reshaping includes: root prominences, keratinized gingiva, papillae, fornix, and the mucogingival junction. In addition to these esthetically significant issues, it permits implants to be placed at a functionally favorable axial inclination. *Int J Prosthodont 2008;21:389–397.*

One criterion for success that emerged from the Toronto Conference was described by Zarb and Albrektsson[1] as follows: "The result of implant support does not preclude the placement of a planned functional and esthetic prosthesis that is satisfactory to both the patient and dentist."

This underscores the notion that implant placement must be "prosthetically driven,"[2] especially given the ever-increasing expectations expressed by both restorative dentists and patients. This need has driven the development of techniques that enable placement of implants in their most functional and esthetically desirable positions by modifying the anatomy of recipient sites that have been altered by events associated with edentulism.[3–5]

A significant factor when evaluating the final outcome in areas of esthetic importance is the degree to which the implant-prosthesis successfully blends in with the normal anatomy of the adjacent areas. Such an evaluation must include the bone-mucosa-gingival complex (BMGC) along with the prosthetic restoration. The degree of success relates not only to the functional integration of the implant, but also to the overall anatomic appearance resulting from reconstruction efforts to correct both the anatomic deformities from preexisting disease and the implant surgery itself. Ideal results would include the following characteristics:

1. Bone volume that permits an implant of appropriate size to be placed in the most favorable position.
2. Alveolar mucosa and keratinized gingiva of appropriate size, volume, and color in correct anatomic relationship with the prosthesis and adjacent tissues.
3. Interproximal papillae of the proper shape at the correct level.
4. Mucogingival junction confluent with the adjacent sites.
5. Presence of root prominences of proper dimensions.
6. Prosthetic restoration(s) appropriate in form, emergence profile, and color.
7. Long-term maintenance of the results.

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If one or more of these characteristics is lacking or defective, the final result will be compromised.

Various surgical techniques have been described that correct horizontal anatomic defects in order to facilitate placement of implants appropriate in size, location, and inclination. A recent review of the literature found that the techniques that offer the most success in terms of implant survival and amount of new tissue gained and maintained over time are those involving bone-splitting procedures.[6]

This article describes an original technique that avoids the biologic and clinical complications associated with previous applications of ridge expansion procedures. This new technique is named morphogenic bone splitting (MBS) since it produces a morphologic restoration of the peri-implant BMGC, treating hard and soft tissues in a single surgical step and using the process of inserting the implant as part of the anatomic reshaping.

The MBS regeneration technique does not view the implant body simply as a means for prosthetic anchorage; rather, it employs it as a device through which to plan, achieve, and stabilize the planned anatomic modifications.

The Morphogenic Bone Splitting Technique

Goals

The goals of the MBS technique are as follows:

- To increase the local volume of the BMGC at the implant site
- To restore the morphology of the implant site appropriate for the patient's phenotype, including root prominences, papillae, the mucogingival junction, attached gingiva, gingival festooning, and vestibular form
- To create a biologically and biomechanically reliable supporting polygon structure with regard to the number, position, and diameter of the implant bodies

With the MBS technique, these goals are usually achieved in a single surgical session.

Indications

The technique is indicated in the first 4 classes described by Cawood and Howell[7] (Table 1), where there is the presence of a bony ridge of at least 10 mm in height and 3 to 4 mm in thickness.

Description of the Technique

For descriptive purposes, the MBS technique may be divided into 5 phases:

1. Access to the bone via a partial-thickness mucogingival flap.
2. Bone preparation: primary and secondary incisions.
3. Mobilizing the BMGC.
4. Final preparation of the recipient site and implant placement.
5. Protecting the site.

Access to the bone. Access to the bone is achieved through a partial-thickness flap, preferably a pocket flap that conserves the connective tissue and the periosteum to maintain adequate bone vascularization. This approach is borrowed from periodontology, and implicates a learning curve that is not dissimilar to that of other techniques. The partial-thickness flap is commonly considered more complex to perform. This prejudice may be due to the fact that although the partial-thickness surgical approach is taught in universities, it is not in widespread use in clinical practice and has received little attention in scientific literature. The incision is paramarginal and thus avoids injuring the adjacent tooth-gingival unit, reducing the risk of attachment loss or recession. The coronoapical extension of the incision is correlated both buccally and lingually to the form of the bone ridge; if the buccal plate is concave, the apical extension is increased. Once the flap has been raised, the shape, dimensions, and orientation of the ridge are evaluated, and the clinical situation is compared with the diagnostic images. This will help to avoid damaging the bone with perforations, fenestrations, and fractures during the subsequent phases of preparing and mobilizing the BMGC.

Preparation of the bone. The object of bone preparation is to create a bony wall of sufficient flexibility to allow its displacement. Since elasticity is proportional to height, an overall height of no less than 10 mm is required. To avoid fractures, the primary bone incision must produce a buccal bony wall as uniformly thick as possible. The primary (guide) bone incision can be practiced with the thinnest bone chisel (Fig 1), or through piezosurgery, using subsonic instruments, oscillating saws, etc. However, bone chisels, prescribed by the technique, produce a cleaner surgical wound and develop less heat, thus laying the foundations for quicker healing with fewer complications. The characteristics of the bone must also be taken into account when selecting the instrument, particularly its hardness, as well as the individual preferences of the surgeon. The preparation of the bony wall to be mobilized must be modified according to the planned emer-

Table 1 Changes in the Alveolar Process According to Cawood and Howell[7]

Class	Description
I	Dentate
II	Immediately postextraction
III	Well-rounded ridge form, adequate in height and width
IV	Knife-edge ridge form, adequate in height and inadequate in width
V	Flat ridge form, inadequate in height and width
VI	Depressed ridge form, with some basilar loss

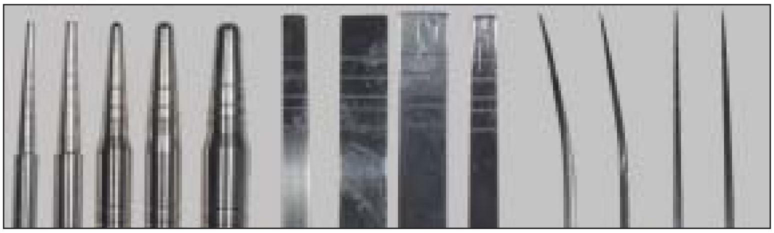


Fig 1 Bone chisels.

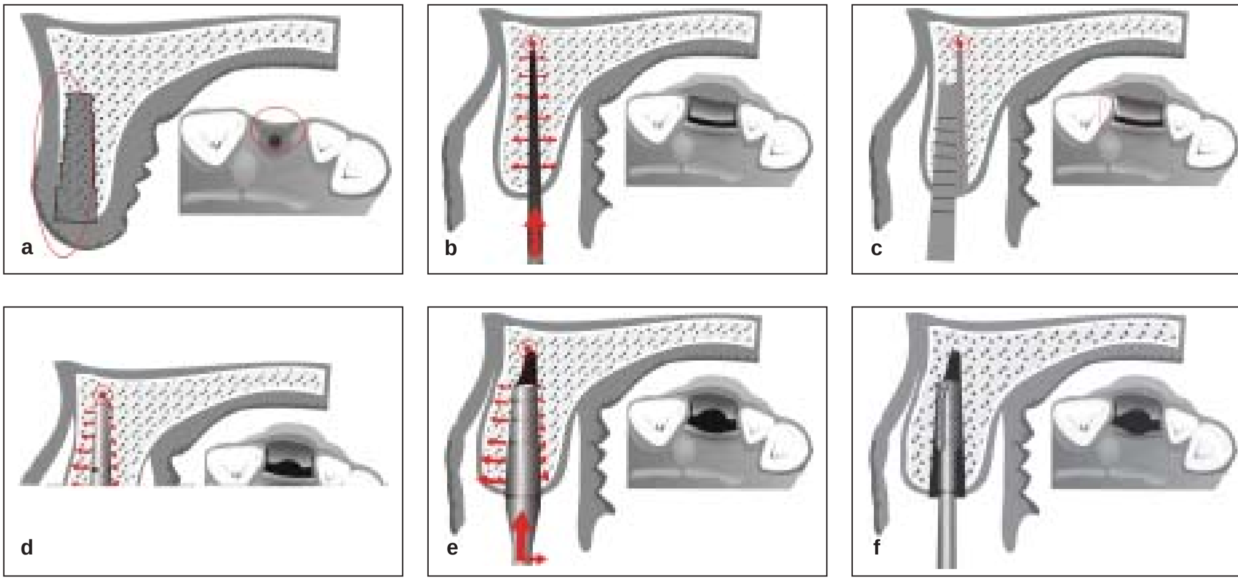
gence of the implant, the thickness and inclination of the ridge, and the presence of vestibular or palatal concavities.

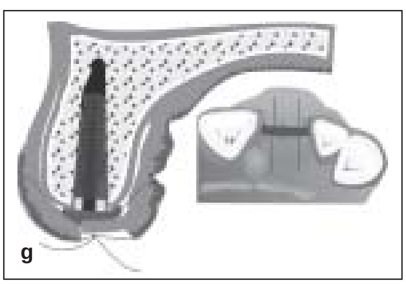
For explanatory purposes, the MBS technique will be described schematically in 2 cases representing the 2 ends of the range of its applications. All other applicable cases fall between these 2 examples:

1. Ridge with no concavities with slight buccal inclination.
2. Ridge with accentuated inclination in the buccal direction and/or vestibular concavities.

In the first instance, bone incision and mobilization are 2 separate and consecutive phases. In the second instance, it is necessary to alternate several times between incision and mobilization to achieve the desired anatomic correction.

Treatment of a ridge with no concavities with slight buccal inclination is shown in Figs 2a to 2g. The primary incision must result in a 3-mm-thick buccal wall and not less than 1 mm of palatal bone thickness (see Fig 2b). The incision should be deeper than the length of the selected implant and as deep as possible in keeping with sensitive anatomic structures. This will confer optimal flexibility to the BMGC, reducing the risk of bone fracture and improving its adaptation to the implant body. The extension of the incision along the crest of the ridge in the mesiodistal direction should be the maximum possible, maintaining a minimum distance of 2 mm from the neighboring teeth. The direction of the incision is parallel to the vestibular wall. To mobilize the bone, 2 vertical releasing incisions are made (see Fig 2c), which must be beveled buccally to increase the mesiodistal width of the bone wall to be mobilized. This increases its elasticity and aids in its adaptation to the implant surface while avoiding, where possible, cutting the retained connective tissue covering the bone. The coronoapical extension of these incisions must reach approximately one third of the length of the implant to enable the bone plate to be mobilized, avoiding condensation and/or fracture of the most critical part of the surgical alveolus, ie, the coronal portion. Maintenance of the buccolingual thickness of the 2 bone sections that are neither condensed nor fractured means that a greater increase in the osteomucogingival volumes of the treated area can be achieved than is possible with traditional techniques, above all in the cervical area. During the dislocation maneuvers, care must be taken to avoid horizontal fractures between the dislocated part and the basal bone to ensure that the elastic memory of the dislocated bone portion will remain, contributing to the primary stability of the coronal portion of the implant. The releasing incisions are made with the same instruments used for the primary bone incision, as described earlier.





Figs 2a to 2g Treatment of a ridge with no concavities with slight buccal inclination. **(a)** Proper implant placement can only be achieved by modifying the anatomy of the critical area. **(b)** The bone incision, parallel to the bone surface to be displaced, extends as deeply as the anatomic structures permit. **(c)** Releasing bone incisions, beveled buccally, will extend coronoapically to the maximum concavity of the recess. **(d)** The BMGC is displaced using chisels with both wedge and lever movements. The thinner bone expanders, working at a depth greater than the length of the planned implant, increase the elasticity of the surface to be displaced, reducing the concentration of stress where the bone is thinnest and thus decreasing the risk of fracture. **(e)** The surgical alveolus is reoriented and its position controlled with bone expanders. Displacement of the BMGC is completed, adjusting the extent of the hinge movement through the serial application of bone expanders, until the desired diameter and depth are achieved. **(f)** If it is not necessary to modify the basal bone, the osteotomy can be carried out using calibrated burs with smooth axial surfaces and by cutting edges only in the apical portion to avoid damaging the coronal portion of the newly formed socket. **(g)** The anatomic modifications, created by displacing the BMGC and stabilized by the implant, prevent flap closure. Healing of the resultant gap by second intention will regenerate new gingival tissue.

Treatment of a ridge with accentuated buccal angulation and/or vestibular concavity is shown in Figs 3a to 3g. In order to orient the implant, of adequate diameter and length, according to an ideal axis, it will be necessary to remove coronal bone restrictions, dictated by the shape and size of the ridge, as well as apical restrictions caused by the buccal recess and by the width of the basal bone (see Fig 3a). These interferences can be removed by alternating the phases of incision and mobilization of the bone walls.

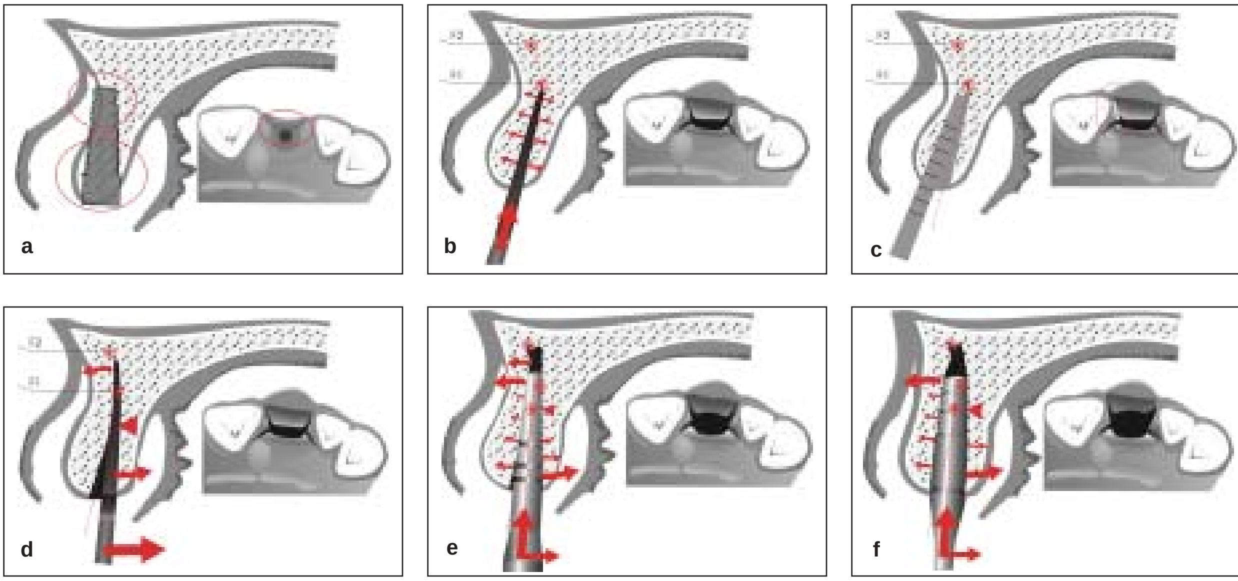
The primary incisions and vertical releasing incisions are similar to those described for the previous case (see Figs 3a to 3c), up to the point where the ridge changes orientation. To get past the area of recess and complete the incision in the apical direction, it is necessary to change the angle of the blade (see Fig 3d). The space needed for this maneuver, which is directly proportional to the size of the recess, is created by dislocating the portion of bone prepared up to that point.

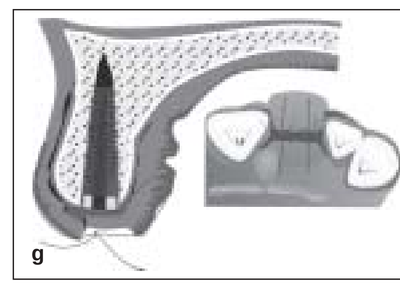
Once access has been obtained, the angle of the blade is modified to rectify the direction of the secondary incision, which can now be made parallel to the buccal bone surface.

Dislocation is achieved by using bone chisels with lever and wedge action, alternately (see Fig 3e).

Mobilizing the BMGC. Mobilization starts by inserting the thinnest chisel into the pilot incisions and widening the apical portion of the dissection to the desired dimension (see Figs 2d and 2e and 3e and 3f). Once the secondary incisions have reached the target depth, bone chisels of increasing thickness are used, alternating lever and wedge movements, to begin to mobilize the BMGC. The width of the chisels selected is proportionate to the mesiodistal extension of the edentulous site.

Once this initial phase has been completed, considerable information will have been obtained that is useful to guide the subsequent operative phases: *(1)* consistency and elasticity of the bone, and *(2)* evaluation of





Figs 3a to 3g Treatment of a ridge with accentuated buccal angulation and/or vestibular concavity. **(a)** Proper placement can only be achieved by modifying the anatomy of the critical areas: bone volumes of coronal and basal portions. **(b)** The coronoapical extension of the incision is correlated to the shape of the bone ridge; if the buccal plane is concave, the apical extension will be increased to make direct evaluation possible. The bone incision is extended to the maximum concavity of the recess (F1). **(c)** Releasing bone incisions, beveled buccally, will extend coronoapically to the maximum concavity of the recess. **(d)** Subsequently, the BMGC portion coronal to the concavity is displaced using bone chisels with alternating wedge and lever movements; this creates access for the secondary incision, which, in angling past the depth of the concavity, can be extended apically (F2). **(e)** The entire BMGC is mobilized after the secondary bone incision. Applying forces in a lingual-buccal direction results in the elimination of the labial concavity and the lingual displacement of the palatal wall crest. Inserting the thinnest bone expanders to the depth of the secondary bone incision augments the elasticity of the bone wall in the area of the concavity and prevents undue stress concentration. This reduces the risk of fracture while producing a reorientation of the surgical alveolus. **(f)** Sequential application of the bone expanders until the predetermined diameter and depth are reached completes site preparation. **(g)** The anatomic modifications, produced by displacing the BMGC and stabilized by the implant, prevent complete flap closure. Healing of the gap by second intention will regenerate new bone and gingival tissues.

the primary incision, as correlated to the ideal inclination of the axis body, will indicate which wall or walls are to be displaced, including the extent of this displacement.

Mobilization of the selected wall or walls is achieved by applying cautious but progressive force on the handle of the instrument used in a buccal or lingual direction. The instruments used for this procedure are chisels, extraction elevators of the Heldbrig type, and bone expanders (manual instruments with the shape of the working portion similar to the implant to be inserted). The area of the newly formed alveolus to be used as a fulcrum to achieve mobilization will depend on the clinical situation. The physical action to achieve mobilization will be the application of action and reaction forces (wedging) and force moments (levering). The new hinge of movement is now located in the coronal portion of the osteotomy, effectively changing the angulation of the insertion path of the implant body.

During this phase, microfractures may occur in the slimmer and more apical portions of the basal bony wall, usually in correspondence with the more concave zone of the buccal recess. Initially, this may produce a bizarre topography, but since the structures involved are protected by the periosteum and overlying connective tissue, bone healing is rapid, as is the functional remodeling of the entire BMGC.

Final preparation of the recipient site. To assure proper primary stability, final preparation of the site is accomplished by establishing a solid purchase in basal bone (see Figs 2f and 2g and 3f and 3g). The choice of instruments for this preparation depends on the following parameters: *(1)* the volume of bone in the basal portion, *(2)* the quality and elasticity of the bone, and *(3)* the degree of mobilization of the bony wall.

Fig 4 *(left)* Preoperative clinical situation.

Fig 5 *(right)* Preoperative radiograph.

According to Lekholm and Zarb,[8] standard burs are used in bone types I and II if there is ample bone volume with nonmobilized basal bone. In bone types III and IV with mobilized basal bone, bone expanders are indicated no matter the volume. The final phase of the preparation utilizes the implant itself to stabilize the changes to the BMGC achieved at that point and to shape the future anatomy of the site. The elastic return of the coronal portion of the mobilized walls, influenced by the quality/quantity of bone, the extent of mobilization, and the height of the dislocated bone wall, will contribute to the primary stability of the coronal portion of the implant, integrating the stability provided by the apical portion engaged in the basal bone.

Protecting the site. One of the fundamental characteristics of the MBS technique is that it exploits the healing processes by second intention to achieve regeneration of soft and hard tissues at the treated site. The coagulum stabilized between the bone walls of the artificial newly formed alveolus can only evolve during healing into bone tissue and the related covering tissues. Not only does the presence of the implant within the gap not interfere with the healing process, it facilitates it, thanks to the osteoconductivity of the implant surface and the fact that by occupying part of the alveolus, it reduces the volume of tissue to be regenerated. It should also be noted that the phenomena of competition between connective and epithelial tissue, typical of wound healing in periodontology, do not concern the implant surface; therefore, achievement of osseointegration will not be hampered.[9,10] Since the partial-thickness surgical approach does not expose the bone, eliminating the need to protect the treated site by covering it with membranes and/or with the flap, the covering or healing screw may be left exposed. If the gap is very large and/or deep, one or more layers of equine lyophilized and resorbable collagen (Gingistat, Vebas) are placed within the coronal portion of the newly created alveolus. Sutures are kept to a minimum and are left loose to encourage optimum blood supply to the flap. The advantage of this surgical approach lies in restoring proper placement and continuity to the mucogingival junction, increasing the quantity of keratinized tissue, and deepening the fornix. If a further increase in these features is necessary, the flap can be repositioned apically. These results may be achieved in a single surgical step thanks to partial-thickness dissection. A full-thickness approach would require closure of the surgical wound by first intention, thus altering the anatomy of the soft tissues in the area involved. This often makes a second corrective mucogingival operation necessary. Synthetic braided sutures (4-0 or 5-0) are used and removed 5 days after surgery.

Pharmacologic Protocol

For antibiotic therapy, 2 g of amoxicillin and clavulanic acid are administered 1 hour before surgery, to be continued at a dose of 1 g every 12 hours for 5 days. For anti-inflammatory therapy, 550 mg sodium naproxene is administered 1 hour before surgery, to be continued as needed. Chlorhexidine digluconate 0.20% mouthwash was prescribed twice a day for 1 week.

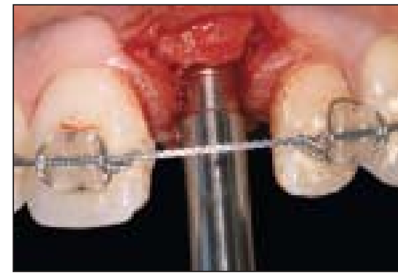


Fig 6 *(left)* Access to the bone crest is achieved through a partial-thickness flap.

Fig 7 *(right)* The final phase of the displacement of the BMGC is finished with bone expanders.

Fig 8 *(left)* Occlusal view showing the complete relocation of the cortical buccal wall.

Fig 9 *(right)* The flap is stabilized with a few sutures, loosely drawn, to permit blood supply and neoangiogenesis.

An Illustrative Clinical Example

A particularly complex clinical case has been selected to demonstrate the clinical results that can be achieved through the MBS regeneration technique. The complexity of this case was determined by a Class 4 tissue deficit, thin and festooned tissue biotype, high smile line, and young patient with high esthetic expectations.

The pre-operative clinical image (Fig 4) shows the severity of the labial concave defect left by the traumatic loss of the maxillary left central incisor and the cortical buccal bone wall due to a car accident. The provisional restoration, an improperly made resin-bonded prosthesis fitted by the previous dentist, had caused the labial migration of the 6 anterior teeth, thus creating an open bite. This required orthodontic correction before determining the final position of the implant. Figure 5 shows the preoperative radiograph.

Access to the bone crest is achieved through a partial thickness flap. The incision is parasulcular to avoid damage to the adjacent soft tissues. Figure 6 clearly shows that the periosteum, overlying connective tissue, and related vascular network were maintained, protecting the bone crest. The area of labial concavity is also visible.

After making the primary bone incisions and partially displacing the coronal third of the BMGC, the secondary bone incisions are made. The final phase of the displacement of the BMGC, which was started by using scalpels and is finished with bone expanders, is shown in Fig 7.

Figure 8 shows the complete relocation of the cortical buccal wall—well protected by periosteum and overlying connective tissue and maintained by the appropriately sized implant—which is accurately centered and oriented. The ideal implant axis is verified using the mounting device emerging from the area corresponding to the palatal cingulum.

Rotation of the cortical buccal wall produces realignment of the mucogingival junction, (neo)formation of the radicular prominence, and an increase in peri-implant and interproximal keratinized gingival (Fig 9). A wide base to the gingival pyramid is the prerequisite for a vertical development of the interproximal papillae. The flap is stabilized with a few sutures, loosely drawn, to permit blood supply and neo-angiogenesis. The dislocated bone wall is covered with the flap and, if necessary, repositioned apically. The uncovered bone wall is protected by the periosteum and the overlying connective tissue thanks to the partial-thickness flap. This type of flap can be displaced apically, if necessary, because the bone not covered by the flap remains protected by the periosteum and overlying connective tissue.

Figure 10 shows the labio-occlusal view of the area 1 month after implant insertion. The apical microfractures have permitted remodeling of the concavity caused by relocation of the labial surface of the defect. The anatomy of the site will be remodeled within a few weeks by functional forces: muscular activity, impact of the food bolus, speech, oral hygiene, etc.

Fig 10 Labial-occlusal view of the area 1 month after implant placement.

Fig 11 Five months after implant placement, striking morphologic changes are evident.

Fig 12 *(right)* Radiograph of the implant 5 months after placement. Note the proper dimensions of the implant.

Figs 13 to 15 Final results 2 months after placement of the definitive restoration.

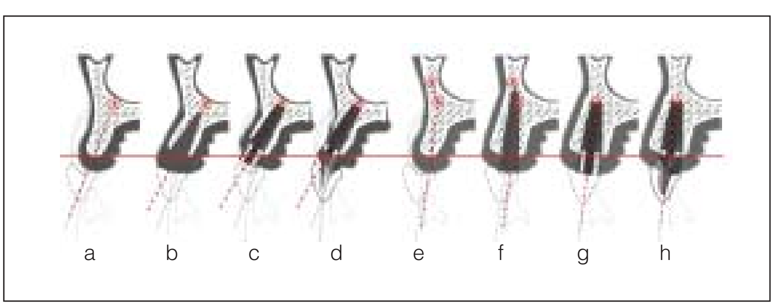


Fig 16 Comparative diagram showing the short- and long-term differences between the conventional split crest procedure (a to d) and the MBS technique (e to h).

Five months after insertion of the implant, striking morphofunctional changes in the defect area and the reestablished osteomucogingival framework in relation to the adjacent anatomic areas are evident (Fig 11). It can be inferred that the MBS procedure, if properly applied, leads to correct positioning of the implant. Despite the length (15 mm) and diameter (4.7 mm) of the implant used, the entry hole for the closing screw is in the palatal portion of the prosthetic abutment, the custom milling of which has left the buccal surface undamaged. The postoperative radiographs (Fig 12) show that the dimensions of the implant influence the attainment and maintenance of the anatomic modifications, rather than serving as a mere retention device.

The final results are shown in Figs 13 to 15.

Discussion

Traditional bone splitting techniques present problems associated with the fact that the axis of rotation is situated at the apical end of the osteotomy. In most cases, this produces an excessive vestibular inclination of the implant body (Fig 16). Various short- and long-term problems derive from this situation, specifically:

- *Esthetic:* The festooning is more apically located than that of the adjacent teeth. The BMGC buccal to the implant may be of significantly reduced thickness, resulting in tissue instability that can lead to recession, dehiscence, and exposure of the implant body.
- *Biologic:* Thin and poorly vascularized peri-implant tissue may be more susceptible to mechanical and bacterial attack. Exposure of the implant body, especially if it has treated surfaces, increases the risk of peri-implantitis.
- *Operative:* The emergence profile of the implant-prosthesis is displaced vestibularly and apically. Due to the presence of the screw connecting the implant and abutment, the head of which lies several millimeters coronal to the implant, the reorientation of prosthetic components in the cervical portion may be difficult or impossible. This is particularly critical in regions of esthetic importance.
- *Biomechanical:* The increased stress along an unfavorable axis creates biomechanical risks affecting mechanical components (implants, connecting screws, abutments, and restorations) and biologic components (crestal bone and peri-implant tissues), particularly on the buccal aspect of the implant site.

The MBS technique avoids these problems. The targeted modification of the edentulous alveolar process and of the related soft tissues enables the implant to be placed along the ideal axis. This ensures an emergence profile that optimizes the thickness of the bone-mucosa-gingival tissues. The procedure also eliminates or minimizes any adjustments associated with reorienting the abutment with respect to the implant and the prosthetic axis.

The possible complications of the technique presented do not differ from those that can occur with the standard techniques for placing implants in native bone (weeping, hemorrhage, edema, hematoma, infections, postoperative pain, etc), and the same treatment protocols also apply.

Conclusions

If implants are inserted in a non-ideal position, it is impossible to meet the criteria for success as defined by the Toronto conference. Non-ideal placement establishes the basis for an unsatisfactory functional and/or esthetic result. A critical analysis of traditional bone splitting techniques reveals a series of clinical limitations and potential prognostic risks. It is especially important when restoring anatomic deficiencies in areas of esthetic importance to reestablish an appropriate bone-mucosa-gingival complex. The prosthetic restoration and tissues that receive it must harmonize with the adjacent sites and stabilize over the long term.

The minimally invasive regenerative technique presented here avoids the use of graft materials and mechanical expansion devices. It treats the hard and soft tissues together in a single surgical step, properly positions an implant that is appropriate in size and location, and blends in with the adjacent dentate sites. The healing period is no more than 2 to 3 months.

Despite the limitations inherent in a clinical study, the results obtained to date (114 implants over a period of 30 months, with a mean follow-up of 14 months) show that the MBS technique achieves results that meet the criteria established by the Toronto conference. The technique attains the desired bone and soft tissue volume augmentation predictably, quickly, and with reduced biologic and economic costs, creating the ideal environment to receive the prosthetic restoration and conceal its presence.

Acknowledgments

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