Abstract: Dental implants are the treatment of choice for the replacement of missing teeth nowadays. But placement of implants in the alveolar bone remains a challenge for most of the clinicians because of the resorption of the residual ridge resulting in insufficient bone volume in one or more dimensions. Various surgical techniques to augment the thin ridges not only increases the morbidity but also results in increase of the expenditure involved as well as time taken. All these factors act as deterrents for the acceptance of the treatment plan by the patient. Need of the hour is to review the various bone manipulation techniques developed over the years and use a suitable conservative technique.

Keywords: Bone expansion, ridge splitting, bone manipulation, expansion screws, osteotomes.

“Set the teeth where they grew”, so said Dr S Howard Payne almost 50 years back. Carrying this basic concept forward, more awareness has been developed toward the principle of prosthetically driven implant in recent years. The position of the implant should not be directed by the amount or location of available bone, but by the ideal position of the final prosthetic restoration1 to fulfill esthetic, functional and phonetic needs of the patient. The mesial, distal, facial and palatal aspect of the dental implant must be spatially correct in relation to the final prosthesis to avoid biomechanical, esthetic and functional problems.

It would be easy to meet these goals if implants were shaped like missing roots they replace and the alveolar bone did not resorb after tooth loss. If only the available bone was sufficient to place the implants with proper height, width and angulation and circumferential bone coverage to facilitate a functional and esthetic restoration. But unfortunately the vast majority of the patients who request restorations for missing teeth do exhibit some degree of bony deficiency by the time they present for their treatment. Alveolar ridge deficiencies may be seen in the vertical or horizontal axes, or commonly in both.

PATTERN OF BONE LOSS

The alveolar bone loss is known to occur at a rapid rate during the first year after tooth extraction and may continue for years. Within the first year of the tooth loss there’s a 25% decrease in the width of the crestal bone and a 40% decrease in the bone width occurs within the first 1-3 year after tooth extraction, resulting in a labial plate of bone that is located lingual of its original location.11 bone volume changes after tooth loss were evaluated in the mandible by Atwood. The posterior mandible resorbs at a rate approximately 4 times faster than the anterior mandible. Resultant narrow ridge is often inadequate for many 4 mm wide root form implants. Preservation or recontouring of the labial appearance of the alveolar process is one of the keys to optimal implant esthetics and a long-term result. To re-establish ridge architecture to sufficient height and width seems only natural before implant placement in the available edentulous ridge area, if the goal is to create biologically sound replicas of natural teeth meeting the demands of their original form and function.2

AVAILABLE BONE

A multidimensional assessment of the available bone in the edentulous region is the most important factor necessary for a sound treatment planning ensuring longevity and functionality of implant supported prosthesis. Determinants of available bone are:
1. height
2. width
3. length
4. angle
5. crown/implant ratio.

The minimum implant length (i.e. bone height) in an ideal bone density situation for predictable success is 10 mm. Allowing a margin of 2 mm from the vital landmarks like inferior alveolar canal is recommended. Available width is defined as the distance between the buccal and lingual plates, measured at the crest. Each 1 mm increase in diameter increases the surface area by about 20 to 30% therefore increasing diameter effectively decreases crestal stress. Thus implant diameter is much more critical than its length. Implant length, on the other hand, only improves initial stability.3

INADEQUATE RIDGE WIDTH

Ridge width affects many of the parameters of the final restorations, which can easily be overlooked without careful preoperative planning. Edentulous alveolar ridges less than
Bone Manipulation Techniques

5 mm. wide require horizontal augmentation or horizontal expansion of the available bone for the placement of endosseous implants in order to produce the necessary quantity of bone of at least 1 mm around the implants and to guarantee long-term osseointegration. If the ridge width is not adequate following problems can occur:

- Leaving a thin labial bone plate at the time of implant placement can lead to exposure of the implant after the slightest of resorption.
- A labial dehiscence of bone may contribute to future implantitis or an unesthetic metal showing through the gingiva.
- Undercuts found on the labial alveolar bone give rise to off-axis loads and a less than perfect emergence profile.

To overcome all these problems the deficient sites are either grafted or enhanced by different means. Numerous procedures have been devised to compensate for a deficient ridge width:

Various treatment options devised over the years for inadequate ridge width are:
1. Increase width by osteoplasty
2. Utilize narrower diameter implants.
3. Increase width by augmentation.\(^{19}\)
4. Bone expansion
5. Ridge splitting\(^{12}\)
6. Horizontal distraction osteogenesis\(^{16}\)

Disadvantages of a few above mentioned but routinely used techniques are following:

If we increase width by osteoplasty assuming that there is sufficient bone length available, very valuable cortical crestal part of the bone is still lost and the implant lies in underlying trabecular bone which is less dense and offers less bone to implant contact, thus less primary stability and an increased prosthetic space.

Narrower diameter implants suffer from increased incidence of fatigue fracture of abutment or post and poor emergence profile with more difficult maintenance due to poor contours.

Most bone augmentation procedures include long waiting periods of 6-12 months, increased morbidity, an additional surgical site with increased cost to the patient and less than 100% predictable results.

Distraction osteogenesis procedures are cumbersome causing limitations to patients and producing considerable discomfort.

This leaves us with two techniques of bone manipulation, i.e. Bone Expansion and Ridge splitting, which may appear technique sensitive but their advantages are far too many not to use these techniques on regular basis.

**RATIONALE FOR BONE MANIPULATION TECHNIQUES\(^{23}\)**

Ridge splitting and expansion makes use of viscoelastic properties of bone. Bone is a biologically privileged tissue in that it has the capacity to undergo regeneration as a part of the repair process. When the clinician is patient and allows ample time for the manipulation of the bone, it can eventually be modeled towards the desired location. Careful manual manipulation is more important than merely tapping with the surgical mallet.\(^{13}\) Displacement of the osseous segment results in positioning of a healthy portion of bone into a previously deficient site. Because the soft tissue is left attached to the transported segment, the movement of the bone also results in expansion of the soft tissue adjacent to the bone segment, improving both the hard and soft tissue contour. At the original location of the segment is left a regeneration chamber which has a natural capacity to heal by filling with bone, instead of fibrous tissue.\(^{14}\) This is a function of the surrounding, healthy cancellous bone walls and location within the skeletal functional matrix. As a result, the alveolar housing, including the osseous and soft tissue components are enlarged in a single, simultaneous process. This technique will permit placement of regular sized implants through the expanded ridge crest. This bone segment is not regenerated or grafted tissue, it is native, mature bone which is an ideal situation to deal with.

The success of the bone manipulation procedures relies on maintaining the integrity of the labial wall, which occurs as long as the periosteum remains intact. Since 80% of the blood supply is from the periosteum, we feel the high degree of the success in expanding very thin ridges is due to our ability to manipulate the thin cortical bone without disrupting the periosteal attachment to this bone. So often during bone splitting or expansion, the periosteum is not raised and it remains encasing the bone to provide blood supply and physical support. Its elastic nature allows the bone to spread and expand and at the same time contains all the microfractures that may occur. In fact intact periosteum acts as a barrier membrane and makes the fractures heal very well because of the intact blood supply. Tatum draws an analogy to the car’s shattered windshield that is still kept intact in spite of the trauma.\(^{28}\)

**BONE EXPANSION**

*Definition:* Bone expansion can be defined as the manipulation of the bone to form a receptor site for an implant without the removal of any bone from the patient.\(^{10}\) Many people incorrectly believe that bone is hard and unbendable. However Living bone is much softer and can be stretched open, making the concept of bone expansion possible. Through the serial use of graduated chisel-like cylindrical or tapered instruments ridges can be slowly expanded to increase their width.

**OBJECTIVE OF RIDGE EXPANSION\(^ {20}\)**

The objective of this technique is to maintain the existing soft bone by pushing the buccal bony plates of the residual ridge laterally with minimal trauma while simultaneously developing an accurately shaped osteotomy. This technique takes
advantage of the softer bone quality found in type III and type IV maxillary bone by relocating the alveolar bone rather than losing the precious bone by drilling. The residual alveolar ridge in the maxilla has a much higher percentage of cancellous bone than in the mandible. Cancellous bone is pliable and can be slowly expanded. Mechanical expansion is obtained as a result of tissue elasticity, this being the characteristic of minimally mineralized bone of poor quality where the buccal cortical wall is normally extremely thin, and the medullar poorly mineralized.

**INDICATIONS**

The most common anatomic area in which ridge expansion is performed is in the narrow anterior maxilla, followed by posterior maxilla, and then the anterior and posterior mandible respectively. Width of the residual alveolar crest should not be less than 4 mm to be able to insert the round osteotomes.

- For reducing maxillary undercuts
- For changing the emergence angulation
- For expanding the buccal or labial bone for esthetic reasons.

The bone manipulation technique is recommended as per the available width of the bone assuming that sufficient height is present (Table 1).

### Table 1: Choice of Manipulation

<table>
<thead>
<tr>
<th>Bone width</th>
<th>Bone manipulation technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 3-4 mm</td>
<td>Bone expansion by means of osteotomes</td>
</tr>
<tr>
<td>&lt; 3-4 mm</td>
<td>Ridge splitting by means of sharp blade like chisels</td>
</tr>
</tbody>
</table>

**BONE EXPANSION BY MEANS OF OSTEOTOMES**

The word osteotomy is derived from the Latin words ‘osteo’, meaning bone and ‘tome’, meaning to incise or cut. In the field of implant dentistry Dr Hilt Tatum coined the word in the early 1970s to describe a special set of hand instruments developed to form or shape bone in preparation for the replacement of dental implants. This bone expansion technique addresses the natural resorptive pattern of the premaxilla. Resorption from the buccal aspect often results in inadequate ridge width for ideal implant placement. The ridge expansion technique can be performed predictably while using the osteotome technique in elderly women.

**ADVANTAGES OF OSTEOTOMES**

Osteotomes can offer several significant advantages over the traditional graded series of drills.

1. Drilling removes bone. When adequate quantities of dense bone are available, this is not a problem. But when the alveolar bone is compromised in quality or quantity, the need is to preserve the remaining bone and improve its quality. This technique retains the total bone mass.
2. It is an alternative to block grafting in select cases to increase the ridge width for implant placement.
3. Allows immediate placement of implants in narrow ridges at the time of expansion.
4. Osteotomes take advantage of the fact that bone is visco-elastic and can be compressed and manipulated. Compression creates a denser bony interface with increased bone to implant contact and therefore good initial stabilization of the dental implant.
5. Heat is a major detriment to osseointegration, but the osteotome technique is an essentially heatless and therefore should not destroy the viable bone-forming cells.
6. This technique also allows for greater tactile sensitivity.
7. It is minimally invasive and cost effective.
8. Faster prosthetic restoration is possible.

**DISADVANTAGES OF OSTEOTOMES**

1. All the osteotomes are based on a palm-held design that can be problematic to use in the posterior maxilla due to limited mouth opening.
2. Considerable care needs to be taken in their use due to the possibility of uncertain amount and direction of force being exerted towards the apex.
3. If the cortical plates of the bone is fused due to atrophy, the osteotome technique may not be effective.
4. Case reports of benign positional vertigo has been reported while using the osteotome technique in elderly women.

**METHOD**

The ridge expansion technique can be performed predictably by adhering to the following guidelines (Figs 1A to F):

1. This technique should be performed only when there is at least > 4 mm of buccal to palatal ridge width.
2. All site preparation is performed through the initial incision preferably without reflecting a flap or elevating the periosteum.
3. Subsequent to minimal reflection of the mucoperiosteal flap and insertion of a surgical stent, an initial hole into the implant or expansion site is made with a 1.5 mm drill through the cortical bone to the desired depth.
4. The crest of the ridge is explored with the blade, and the bone entry point is made 1 mm labial to the palatal wall. The dense palatal wall serves as a reference point for proper angulation and labial-lingual position. An error in placing the entry point too far labial will result in poor angulation, a long tooth, and unacceptable gingival architecture. The thin
A layer of cortical bone covering the ridge is easily penetrated by tapping the scalpel handle with a surgical mallet.

The initial bone incision splits the cortical plates and serves as a purchase point for subsequent instruments.

5. The tip of the smallest osteotome is then inserted 1-2 mm into the pilot hole, and the osteotome instrument is then pushed into the implant or ridge expansion osteotomy site while using a rotating motion. If the bone is dense, it may be necessary to use a mallet to tap the osteotome to the predetermined depth.

Note: It is important to leave the osteotome in place for approximately 1 minute to allow for flexure of the bone while

Figs 1A to F: Bone expansion and implant insertion by means of round osteotomes
comparing the buccal and palatal bony plates simultaneously. Tactile sensation is an essential part of this ridge expansion process, particularly during the insertion of the next larger sized osteotome.

Enlargement of the osteotomy is accomplished by sequentially inserting larger sized osteotomes. This will improve the maxillary ridge topography by widening the osseous ridge as the larger diameter osteotomes are sequentially inserted into the osteotomy site opening created by the previous instrument. Expansion of the bone would routinely occur labially, compensating for the original dimensional loss of bone. Thus, bone manipulation enables one to recontour the bone in the direction of its loss, place the implant in a position closer to that of the original tooth socket, and ultimately restore normal root morphology planned to support the restorative crown.

**Atraumatic Ridge Expansion Technique**

Despite the benefits of the Bone Expansion by means of osteotome technique pioneered by Summers, Tatum and Linkow, there are limitations because it is mainly designed for the maxilla. The technique mainly requires the use of a mallet and serial osteotomes to widen the receptor sites. The force which is used for malleting can be intimidating for both the clinician and the patients. There is also the risk of fracturing the osteotomy site if sudden uncontrolled force is applied. A full thickness reflection is also not recommended in cases where the periosteal support is indicated in extreme atrophy to keep the fragments of the osteotomed fragments together (Tatum).

In the past couple of years, the profession was introduced to the concept of bone expansion screws that did not require the use of mallets. When proper case selection is made this technique is a valuable adjunct to the repertoire of bone expansion armamentaria.

**Indications for Expansion with Bone Screws**

1. Atrophic ridges in the maxilla with a minimum of 2.5 mm body width (body width is the average of the bony width 1 mm from the crest of the alveolar bone to about 10 mm apically).
2. Atrophic ridges in the mandible with a minimum of 3 mm body width.
3. Type IV bone with adequate width where conventional drill osteotomies would compromise bone volume.
4. Type III bone with compromised width where additional bone compaction would improve bone quality.
5. Any history of reported positional vertigo where an osteotome technique may aggravate or precipitate the vertigo.
6. Apprehensive patients who may object to the osteotome technique.

**Contraindications**

1. Less than 2 mm of available bone.
2. Lack of marrow space between the cortical plates.
3. Atrophic type I bone.

**Advantages**

1. The bone screw expansion is a graftless solution to manage atrophy.
2. Almost any implant system can be utilized with this technique.
3. Atraumatic and controlled sequence of bone expansion.
4. Incidence of green stick fractures are minimized.
5. Can be utilized as an adjunct in dense bone protocol drilling.
6. No bone loss from osteotomy preparation.
7. No thermal injury to bone.
8. Multiple osteotomies can be serially prepared.

**Disadvantages**

1. Time consuming.
2. Dexterity involved in engaging the ratchet.
3. Resilience of bone sometimes requires revision of the osteotomies with final sizing drill before implant placement.

**Materials and Methods**

This technique utilizes the Meisinger split control bone management system (Neuss, Germany) to perform the osteotomies (Fig. 2). This technique was improvised by Drs. Streckbein and Hassenpflug and has since undergone several revisions. The author has provided some suggested modifications to this protocol and has been elaborated in the enclosed DVD. The sequence for bone expansion is as follows:

**For Single tooth osteotomies (for bone condensing)**

1. Evaluate the available bone for length, width and height – utilize a CT scan or alternatively perform bone sounding (Figs 3 to 6).
2. Prepare a pilot hole bisecting the crest of the ridge with a fine 1mm drill at low speeds (45 rpm at 50 Ncm torque). Prepare to the depth required for the implant.
3. Use the trispade drill at the same rpm to condense the walls of the osteotomy – At low speeds this drill does not harvest bone.
4. The bone spreading bur is then utilized at low speeds to further condense the bone and to help the osteotomy to receive the bone spreaders.
5. If there is insufficient width to utilize the bone spreading bur, then start with the first of the bone spreaders and gently ratchet the screw 1/4 turn at a time. The ratchet is designed to only be able to perform the 1/4 turn. The ratchet then has to be disengaged to allow for the bone to relive the stresses.
A continuous full turn in thin dense bone will lead to a green stick fracture and perhaps excessive osteocompression.

6. The bone spreaders are utilized to the desired depth and serially enlarged from A1 to E1 depending on the width of implant chosen.

7. Once the bone spreading has been completed, it may be necessary in type I bone to refine the osteotomy with the final sizing drill of the implant at extremely low speeds (30 rpm at 45 Ncm).

8. In type III and IV bone the implant can be safely tapped into the osteotomy using the handpiece or manually with a ratchet.

For Bone Spreading—Multiple implants:
1. A crestal split is initially made with the disk provided (Fig. 7).
2. The bone condensing drill is utilized to prepare the osteotomy for the bone spreaders (Fig. 8).
3. Serial enlargements are then made as in the osteotomy preparation for the single tooth implant (Fig. 9).
4. The defect that had been created between the two implants can be filled with bone grafting materials (Fig. 10).
5. Verify with radiograph (Fig. 11).
SUMMARY

The Meisinger split control method of osteotomy preparation has been elaborated by a step-by-step method. The authors use this technique whenever there is poor bone quality and a lack of width to prepare osteotomies through conventional drilling protocols. This technique further avoids the traumatic impact caused by osteotomes. The split control bone expansion/condensation method is a safe and predictable way to manipulate bone atraumatically.

RIDGE SPLITTING

Gaining access to a ridge that is less than 3 mm. wide requires splitting the buccal and palatal bone flaps with a scalpel first by separating the two cortices through its cancellous bone. This technique is employed in cases where there is insufficient width to utilize round osteotomes. The surgical defect created has ideal anatomical characteristics for regeneration. In fact, an autologous bone and/or biomaterial graft can be inserted in this environment that will be protected from external trauma, and will be characterized by double vascularization and double cellularity, with greater capacity for healing. This is the ideal condition to achieve bone regeneration and reduce the risk of repair with peri-implant connective tissue.

Often the need of multiple surgeries, longer treatment duration and a higher cost involved for bone grafting excludes some patients who would otherwise be amenable to implant reconstruction. The option of a minimally invasive technique appeals to a great number of potential implant patients. The ridge-split procedure provides a quicker method wherein an atrophic ridge can be predictably expanded and grafted with bone allografts, eliminating the need for a second donor site and a second stage surgery. Indications for bone splitting are restricted to those sites that do not require vertical ridge augmentation.

INDICATIONS OF RIDGE-SPLIT

Indications for bone splitting are restricted to those sites that do not require vertical ridge enlargement. Ideal sites demonstrate
a knife-edge ridge that widens further apically and that consists of adequate cortical thickness but with some degree of interpositional lamellar bone. The anterior region of the maxilla usually meets these demands while mandibular sites usually do not. When there’s adequate height of the residual ridge, 8-10 mm of bone between the crest of the ridge and opposing landmark but inadequate buccolingual width, ridge splitting is an option. The bone splitting technique enables problem free widening from 2 to 5 mm.

**REQUIREMENT FOR RIDGE SPLITTING**

Following requirements are absolutely necessary for the bone splitting technique:

- A minimum ridge width of 2-3 mm. If little bone is available, lateral augmentation with bone grafting material and titanium-reinforced membrane or only grafting is recommended. These dimensions are necessary in order to guarantee spongiose bone structures within the lamellar splitting region.
- A minimum bone height of 10 mm, since the splitting process should affect not more than 70 percent of the total bone height.

**SURGICAL TECHNIQUE (TABLE 2)**

Narrow edentulous alveolar ridges less than 4 mm wide can be expanded by following means:

- Single stage ridge split procedure
- Two stage ridge split procedure.

Sensitive action is necessary since the flexibility of the bone depends on the density and the thickness of the cortical layer. Method of choice will be dictated by the fact that implants to be placed can have primary stability in the expanded ridge or not.

**Table 2: Staging of splits**

<table>
<thead>
<tr>
<th>Primary stability</th>
<th>Ridge split technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can be assured</td>
<td>Single stage ridge split</td>
</tr>
<tr>
<td>Can not be assured</td>
<td>Two stage ridge split</td>
</tr>
</tbody>
</table>

**Single Stage Ridge Split Procedure**

In this procedure the entire edentulous bony segment is opened like an envelop to receive the implants (Figs 12A to E). During the course of these procedures, it is important to maintain the vitality of bone. The implants are only inserted during the same session if there is sufficient primary stability. In these cases the pilot drills are used after the desired ridge widths have been reached and the implants inserted. In order to prevent soft tissue from growing into the depths of the resultant cavities, it is advisable to fill the entire area generously with β-TCP, granule size 500–1,000 mm, mixed with blood. If there has been any difficulty in achieving complete flap closure, then the area is

**Figs 12A to E:** Ridge splitting shown by means of sharp chisel-shaped bone spreaders
covered with a barrier membrane. Healing will take approximately 5 to 7 months.

**Two Stage Ridge Split Procedure**

Staged ridge split procedures are indicative when enough primary stability is not achieved.

- In the first stage the buccal segment is lateralized and periostium is sutured back. The vertical relieving incisions in the bone are given in cases with a bone density of D2-D3 in order to gently and deliberately direct the bone lamella towards vestibule and avoid uncontrolled fracturing.\(^4\) In the second stage osteotomy for implant placement is done after 40 days.

This technique has following advantages:

- In the mandible, greenstick fracture during widening with osteotomes is not controllable because of cortical thickness of the bone. The risk of malfracture during single-stage was high. With this approach, the location of greenstick fracture is predetermined.

- Blood supply to the lateralized buccal segment (which remains as a pedicled graft after ridge splitting) remains intact. Although vascularization shifts from internal perfusion from spongy bone after the first intervention to external perfusion from the periosteum after the second intervention.

Mechanical expansion by ridge splitting is not generally performed in the mandible because the cortical bone is highly mineralized, especially in the region between the mental foramina. This situation presents physical resistance to the maneuver used in separation of the bone flaps, with consequent risk of ridge fracture and worsening of the defect.

Studies show that the problems and limitations of traditional expansion techniques are not due to the fact that it is more difficult to expand a bone ridge in the lower arch than in the upper in an absolute sense, but that it is difficult to expand a very mineralized ridge in any quadrant, due to the physical resistance that the mechanical cutting forces encounter in tissue of this type. In such a situation piezoelectric cutter or disks can be a very effective instruments. It is engineered to reduce heat and gives a precise and nontraumatic incision very efficiently in highly mineralized structures also thus reducing the risk of fractures.\(^15\)

**CONCLUSION**

Surgical techniques that reduce trauma, preserve and augment the alveolar ridge represent key areas in the goal to optimize implant results. We must understand bone as it pertains to its regenerative potential and its viscoelastic properties. When the clinician can be patient and make the best use of privileged status of bone tissue, the lesser used but novel techniques of ridge expansion and ridge splitting can take their rightful place in the much needed bone enhancement techniques to facilitate the placement of prosthetically driven implants.

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