REVIEW ARTICLE

Implant Site Development Part II

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ABSTRACT

The internal and external architecture of bone determines positioning of dental implants in partially and fully edentulous patients. A deficient jaw bone creates a new demand for bone reconstruction before or during implant therapy. The second part of the review discusses various surgical reconstructive modalities to improve bone support for placement of implant in prosthetically driven position to restore the natural position and to emulate the natural emergence of a tooth from soft tissues. Surgical procedures that have been developed to deal with problems of insufficient alveolar ridge width or height include extraction site bone grafting, ridge augmentation using principles of GBR with block grafts or particulate materials and protective barriers, grafting with bone harvested from both extraoral and intraoral donor sites, use of platelet rich plasma and growth factors etc. Bone augmentation allows clinicians to reconstruct alveolar bone deficiencies, preserve alveolar dimensions and replace missing teeth with dental implants in a prosthetically driven position with natural appearance and function.

Keywords: Bone augmentation, Block grafts, Particulate materials, Protective barriers, GBR (guided bone regeneration), PRP (platelet rich plasma), Growth factors, Intraoral and extraoral donor, Autogenous donor grafts.

BONE AUGMENTATION FOR IMPROVING THE IMPLANT SITE[1,2,4]

Bone Grafting for Implant Placement: Applications and Principles

Following an extraction, there is 25% decrease in width and 4 mm decrease in height of the alveolar bone during the first year. Bone loss following an extraction can have negative cosmetic, hygienic, prosthetic and structural consequences. Preservation of bone contour for dental implants, pontic design, denture stability, soft tissue esthetics, and maintaining periodontal status of adjacent teeth are important considerations following an extraction. To reduce or eliminate potential problems, extraction site grafting can be commonly employed by the general dental practice.

Extraction Site Bone Grafting (Figs 1 to 6)

The keys to bone grafting in extraction sites (Misch):

- Atraumatic tooth removal
- Asepsis and complete removal of granulomatous tissue
- An evaluation of the remaining walls of bone following the extraction and evaluation of the size of defect
- Ensuring adequate blood supply to the graft site
- Graft containment and soft tissue closure
- Choice of the appropriate graft material
- Insuring adequate time for healing.

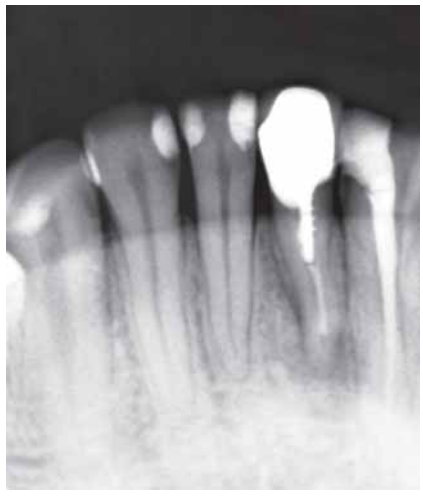


Fig. 1: Radiograph showing endodontic failure with 24

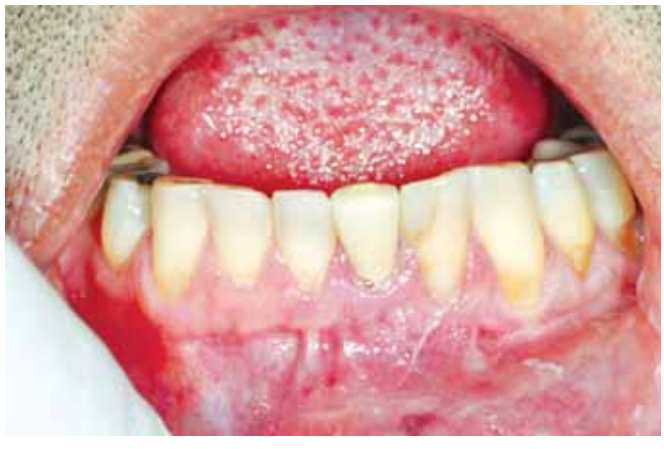


Fig. 2: Clinical picture showing failing 24

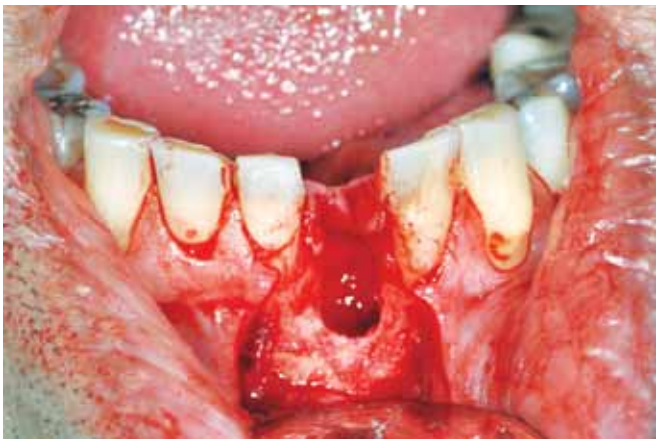


Fig. 3: Postextraction socket

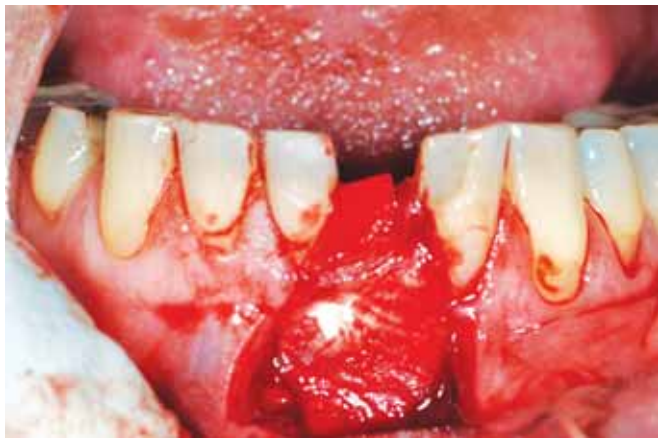


Fig. 5: Resorbable membrane placed over the grafted site

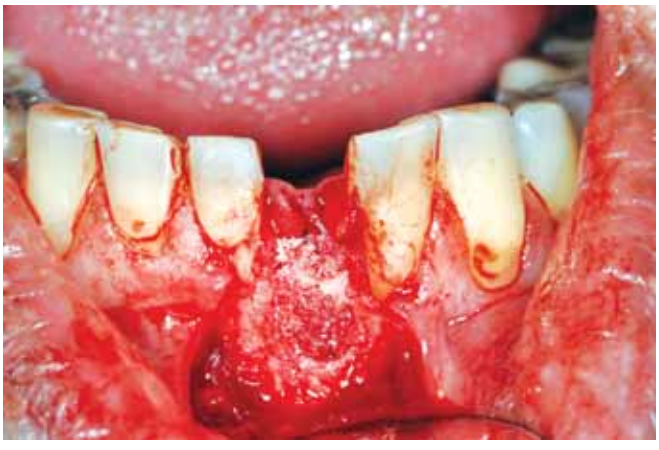


Fig. 4: Bone graft placed in the socket

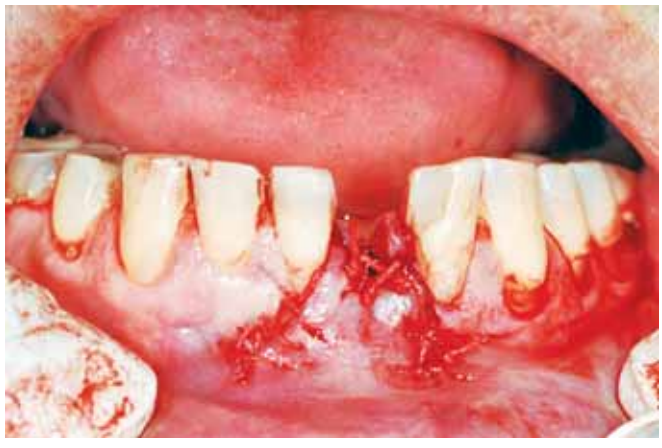


Fig. 6: Primary closer achieved by suturing

Atraumatic Tooth Removal

Atraumatic extraction of teeth can be achieved with the use of periotomes, tooth sectioning, orthodontic therapy and minimum forceps rotation. When all the walls of bone surrounding a tooth are left intact, the grafting material is better contained and immobilized and osteoprogenitor cells are more readily recruited. When walls of bone are missing (i.e. the loss of facial plate as a consequence of periodontal disease or the extraction process), the graft procedure is more complicated.

Asepsis and Removal of Granulomatous Tissue

Before an extraction site can receive a graft, any granulomatous tissue present must be removed. Ideally, bone remodels through cell-mediated resorption. If infection is present in an extraction site, the graft will undergo solution-mediated resorption due to the lower (acidic) pH, and bone will not form.

An Evaluation of the Size of the Defect

Once a tooth is removed, first the remaining walls of socket are evaluated. The greater the number of walls of bone remaining, the more predictable will be the ridge preservation procedure. The choice of grafting material, the need for a membrane, provisionalization of the graft area, and healing time are all affected. Once the tooth is removed, the walls of remaining bone can be used to classify the area as a 2, 3, 4 or 5 wall defect. A 5-wall defect contains all possible walls of bone, offering the greatest predictability. When a large facial wall of bone is missing, a barrier membrane should be used to contain the graft material. Use of the barrier can prevent fibrous tissue ingrowth.

Ensuring Adequate Blood Supply to the Graft Site

A bone graft requires blood supply to provide osteoprogenitor cells and associated growth factors. While blood supply from the soft tissue does supply blood to the graft site, osteoprogenitor cells will be supplied only from adjacent bone, or in a limited fashion from the periosteum. To ensure the presence of these critical cells, the bone adjacent to a graft site must be 'traumatized' in a non-pathological fashion. This has been called a regional acceleratory phenomenon *(RAP)* by Frost. A tooth extraction also provides a RAP, and the periodontal membrane complex provides an excellent blood supply to the

extraction site. If little or no bleeding exists, decortication of the bone beyond the apex with a round bur using sterile saline for cooling is suggested. This decortication also allows for an improved physical integration of the graft material.

Graft Containment and Soft Tissue Closure

When the extraction site is an optimal 5-wall defect, the surrounding walls of bone will contain and immobilize the graft. Grafting bone into a 5-wall defect usually requires only coverage of the graft site with a rapidly resorbing collagen membrane stabilized with sutures. If the extraction site has 4 walls or less, use of a barrier membrane to contain the graft material and to exclude fibrous cells. Also, primary soft tissue closure to minimize bacterial contamination of the membrane in larger defects is suggested (Fig 7).

Choice of Appropriate Graft Material

The choice of graft material is based on the number of remaining walls of bone and prosthetic treatment plan. As a general rule, more the missing walls of bone, more the autogenous bone should be part of extraction site grafting. The terms *osteogenic*, *osteoconductive* and *osteoinductive* are useful to explain the different types of grafts.

Osteogenesis is the growth of bone from cells transferred within a graft. An osteogenic material will promote growth of bone in ectopic tissue.

Osteoconduction is growth of bone from surrounding bone. Osteoconductive materials act as a biocompatible scaffold. Osteoconductive materials are biocompatible, but will not grow bone without the presence of cells that will form bone.

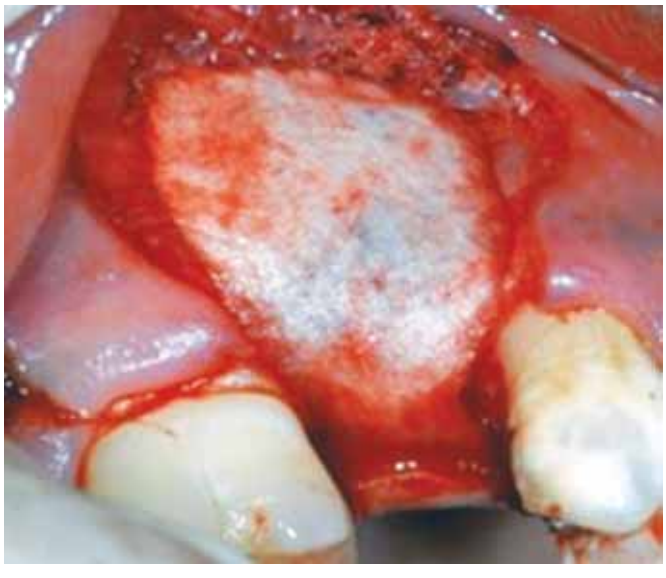


Fig. 7: Clinical picture showing barrier membrane for guided tissue regeneration and to contain the particulate bone graft in position

Osteoinduction induces bone growth from osteoprogenitor cells created by the influence of inducing agents from the host bone matrix.

There are four types of grafting materials available for use in the oral cavity:

- Autogenous bone is the only source of osteogenic bone.
- Allograft bone (demineralized)
- Xenograft bone
- Alloplastic

Autogenous bone is the gold standard for bone grafting, since it contains both osteoprogenitor cells and scaffolding. It can be obtained from an intraoral or extraoral source. Common intraoral sites for socket grafting include the mandibular symphysis, mandibular ramus, and maxillary tuberosity.

The advantages of autogenous bone include:

- Only osteogenic material available
- A source of the bone proteins
- Cost effective and predictable
- Fastest bone regeneration material.

And the disadvantages are:

- Need for a second surgical site
- Possibly postoperative discomfort
- Potential limitations on the amount of graft material that can be harvested.

As a general rule, however, the more walls of the socket that are missing, greater consideration should be given to the use of an autogenous graft.

Allograft bone is from the same species but a different genotype (individual). This is a donor bone obtained by FDA-regulated tissue banks, and is both tested for infection (donor) and processed. Allograft bone has been used extensively in dentistry for more than two decades.

Allograft bone is available as:

Particles in different sizes: Cortical fibers, putty forms have various proprietary carriers, such as glycerin and cellulose. The handling characteristics differ for the different preparations and the choices dependent on the clinical situation and the clinician. Cortical bone (versus medullary bone) as the source of allograft material offers advantages for extraction site grafting. These advantages include ease of handling, increased containment in the graft site, and an increase in the osteoinductive effect. There are two types of allograft material; mineralized and demineralized forms. When allograft bone is demineralized, it is processed with an acid solution. This process dissolves the mineral component (hydroxyapatite) and exposes collagen and organic constituents, believed to include bone morphogenic proteins (BMPs). Although allograft bone may contain these

growth factors, it is not considered osteogenic. Preparation techniques vary among manufacturers, resulting in proprietary differences in handling characteristics and relative amounts of growth factors (Figs 8 to 11).

Demineralized bone allograft is a composite of collageneous proteins and bone growth factors following the mineral extraction of bone by a chemical preparatory process.

Fig. 8: Allograft from bone bank

Fig. 9: Demineralized bone matrix and cancellous putty

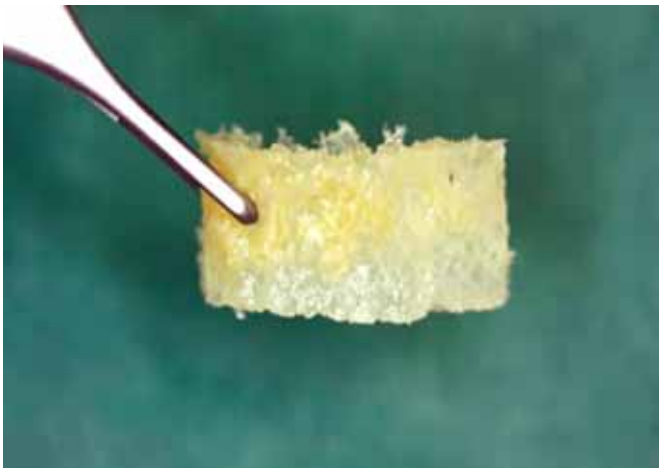


Fig. 10: Rocky mountain bone allograft

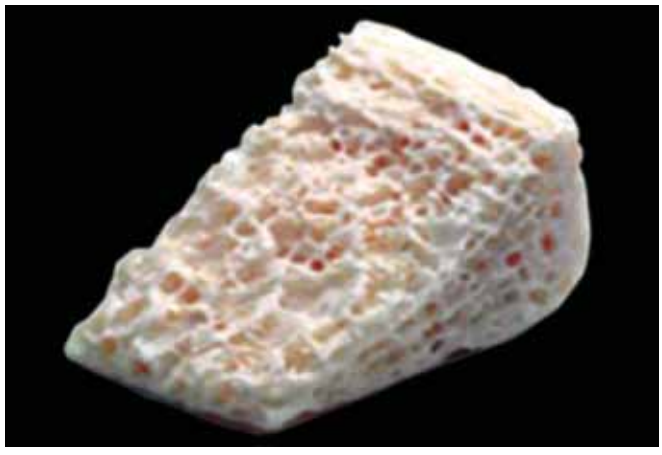


Fig. 11: Puros allograft

Xenograft bone is from a different species (e.g. bovine), contains the inorganic portion of bone (hydroxyapatite) and is available in various particulate sizes. These grafts are osteoconductive, without having any osteoinductive properties. These grafts create a biocompatible scaffold. The osteoprogenitor cells are provided by the recipient. Xenografts can be added to allografts to improve the mineralization potential (Fig 12).

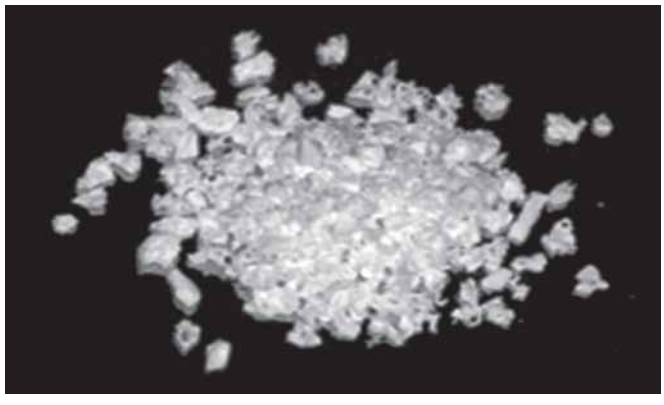
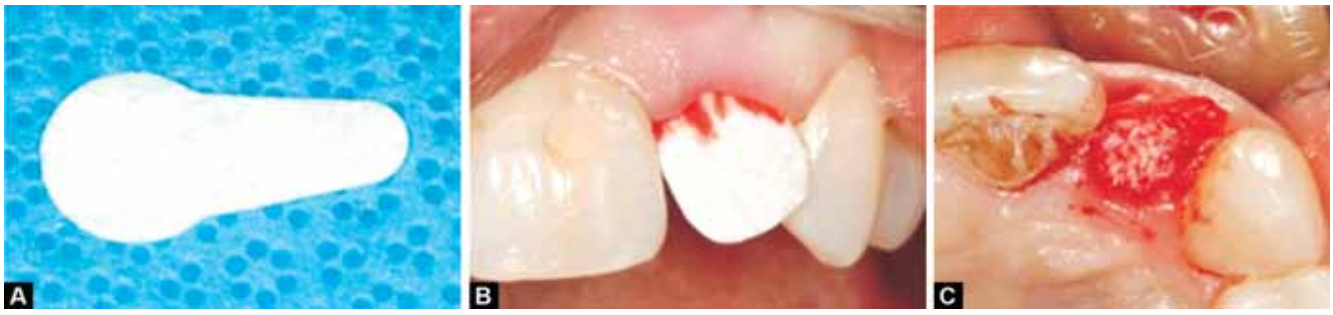


Fig. 12: Xenograft from bovine

Alloplastic materials are synthetic products, and include *ceramic and acrylic materials*. They can be resorbable or nonresorbable. Nonresorbable material should only be used when an implant will not be placed in the location of the graft. The nonresorable material cannot attach to the implant surface or grow into the thread or macro design of the implant.

Insuring Adequate Time for Healing

To allow a graft to mature into lamellar bone, adequate time for healing is needed. The time required is dependent on factors, such as the patient's age, the patient's healing capacity, residual infection in the graft site, and size of the defect. In general, the time for a graft to heal varies between 4 and 6 months when autogenous bone is a part of the graft.



Figs 13A to C: Socket repair membranes

Fig. 14: Recombinant growth factor

Biologic Requirements for Bone Regeneration[3]

Requirement	*Surgical procedure*
Blood supply	Cortical perforations
Stabilization	Fixation screws, membrane tacks
Osteoblasts	Autogenous bone (Graft or recipient site)
Confined space	Barrier membrane
Space maintenance	Tenting screws, bone graft materials
Wound coverage	Flap management, tension free suturing

Biologic Properties of Various Bone Graft Materials[3]

Source	*Osteoconductive*	*Osteoinductive*	*Osteogenic*
Alloplast	Yes	No	No
Xenograft	Yes	No	No
Allograft	Yes	Yes/No	No
Autograft	Yes	Yes	Yes

Guided Bone Regeneration (Figs 13A to 17)

Historically, augmentation or "regeneration" of alveolar bone lost as a result of tooth extraction, resorption or trauma was a challenge. Extraction sites healed with fibrous connective tissue or scar formation leaving an anatomic deficiency.

Guided tissue regeneration *(GTR)* principle employs exclusion of fast growing epithelium, and connective tissue from periodontal wound for six to eight weeks, allows slower tissues to occupy the space adjacent to the tooth. Osteoblasts, cementoblasts and periodontal ligament cells are then afforded the opportunity to regenerate a new periodontal attachment (new bone and new connective tissue fibers inserted in newly formed cementum).

Guided bone regeneration (GBR) employed the same principles of specific tissue exclusion and regenerated single tissue, namely bone by use of barrier membranes.

Ideal Properties of Barrier Membranes

- Biocompatibility
- Space maintenance
- Cell occlusiveness
- Good handling properties
- Resorbability

Nonresorbable Membranes

- Latex
- Teflon (Expanded poly tetrafluoroethylene ePTFE, Gore tex peridontal and bone regenerative membranes, Gore and associate, Flagstff, Ariz)
- Titanium reinforced membranes (TR)

Resorbable Barrier Membranes

- Copolymers of polylactide and polyglycolide (PLA/PGA)
- Collagen

Membranes for guided bone regeneration[3] act as a biological barrier to protect underlying bone graft. They also provide matrix for formation of new keratinized tissue.

Platelet Rich Plasma[5,7]

Clinical implications: PRP has proved to be effective at improving surgical results in the field of oral and maxillofacial surgery and periodontal regenerative therapy. Using platelet rich plasma (PRP), is a way to accelerate and enhance the body's natural wound-healing mechanisms. Platelets primarily are involved in wound healing through clot formation and release of growth factors that initiate and

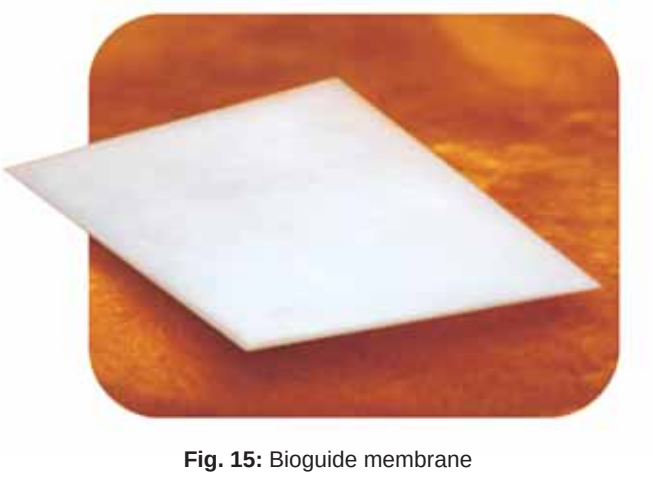


Fig. 15: Bioguide membrane

Fig. 16: Alloderm

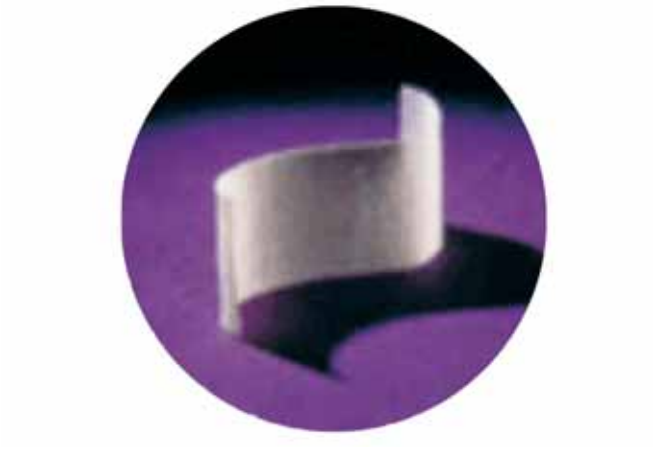


Fig. 17: Collatape

support wound healing. Using PRP involves taking a sample of a patient's blood preoperatively, concentrating autologous platelets and applying the resultant gel to the surgical site. Surgical sites enhanced with PRP have been shown to heal at rates two to three times that of normal surgical sites.[6]

Growth Factors[5,7]

It is now known that platelets also actively extrude several growth factors involved in initiating and sustaining wound repair. The two most important of these growth factors are platelet-derived growth factor (PDGF) (Fig. 14) and transforming growth factor-ß (TGF-ß). PDGF is chemotactic for polymorphonucleocytes, macrophages, fibroblasts and smooth muscle cells. PDGF also stimulates cell replication of important stem cells for fibroblasts and endothelial cells (increasing budding of new capillaries), stimulates production of fibronectin—a cell adhesion molecule. With hyaluronic acid, it helps bring about wound contraction and remodeling. TGF-ß stimulates fibroblast chemotaxis and the production of collagen and fibronectin by cells, while inhibiting collagen degradation by decreasing proteases and increasing protease inhibitors, all of which favor fibrogenesis. The topical application of these growth factors to healing sites can accelerate repair and wound maturation.

Future Directions: To date, the greatest commercial interest has been in rhBMP-2 and rhBMP-7. Many different carriers have been used to deliver BMPs, i.e. collagen sponge impregnated with BMP. Also demineralized bone matrix (DBM) has been incorporated in various carriers, such as collagen or selected polymers. DBM can be used as a bone expander.

INTRAORAL AUTOGENOUS DONOR GRAFTS FOR DENTAL IMPLANT

A primary diagnostic consideration for implant placement is the available bone in the edentulous span. If inadequate bone exists, the morphology of a bony defect is an important consideration in the selection of a method for ridge augmentation. Although allografts and guided tissue regeneration techniques have been used bone repair, these methods have limitations in treatment of larger bone defects.

The use of autologous bone grafts with osseointegrated implants was originally discussed by Branemark et al 1975 and continues to be a gold standard for jaw reconstruction. With exception of alveolar bone, the maxilla and body of mandible develop intramembraneously while condyles develop from endochonral bone formation. These grafts show less resorption and revascularize more rapidly than endochondral bone grafts. An intraoral donor site (Figs 18 to 32) offers several advantages:

- Convenient surgical access
- Only require one operational field, which decreases the surgical and anesthetic time
- Proximity of donor and recipient site
- No cutaneous scar associated with extraoral donor sites
- Minimal discomfort and reduced morbidity
- Offers favorable results.

Block grafts offering large amount of bone are harvested from: mandibular symphysis (Figs 20 to 30), body or ramus (Figs 31 and 32).

Particulate autografts are harvested from (a) maxillary tuberosity, (b) zygoma, extraosseus tori (Figs 18 and 19), (c) residual ridge osteoplasty, (d) implant osteotomy, (e) extraction sites and (f) bone collection devices.

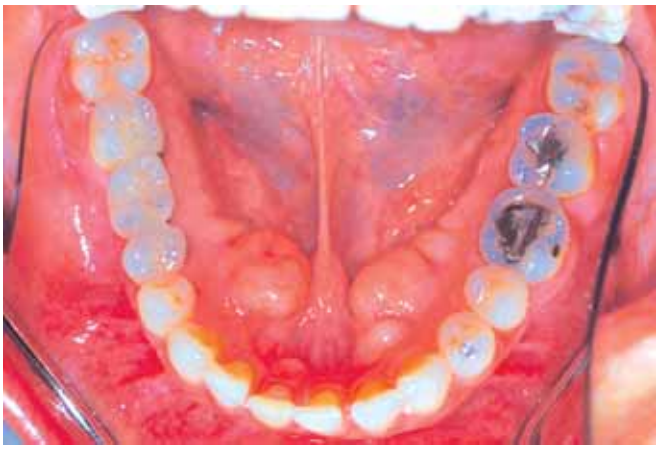


Fig. 18: Clinician view of mandibular tori

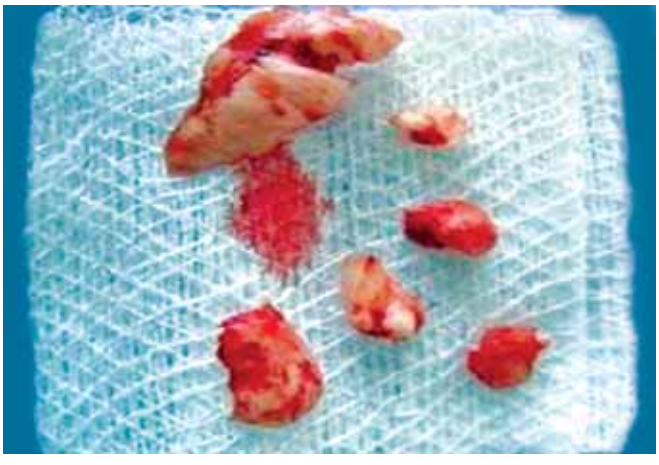


Fig. 19: Bone fragments retrieved from a tori

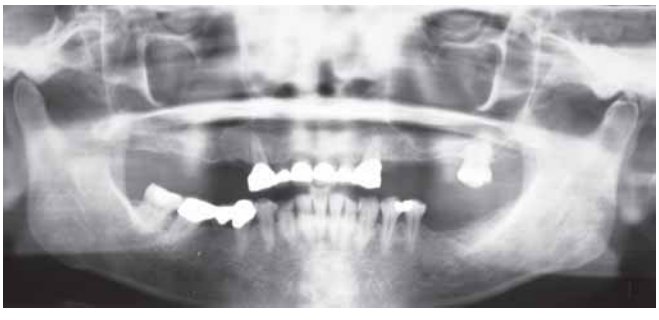


Fig. 20: X-rays are used to evaluate the existence of bone deterioration issues and clearly reveal to the patient what areas may require treatment

Comparison of Mandibular Donor Site[4]

	Symphysis	*Ramus*	*Tuberosity*
Surgical access	Good	Fair to good	Good to fair
Patient cosmetic Concerns	High	Low	Low
Graft shape	Thicker block	Thinner veneer	Porous block
Graft morphology	Cortiocancellous	Cortical	Cancellous
Graft size (cm^3)	> 1 cm^3	< 1 cm^3	< 1 cm^3
Graft resorption	Minimal	Minimal	Moderate
Healed bone quality	D1, D2	D1, D2	D3

MANDIBULAR SYMPHYSEAL GRAFT

Procedure (Figs 20 to 32)

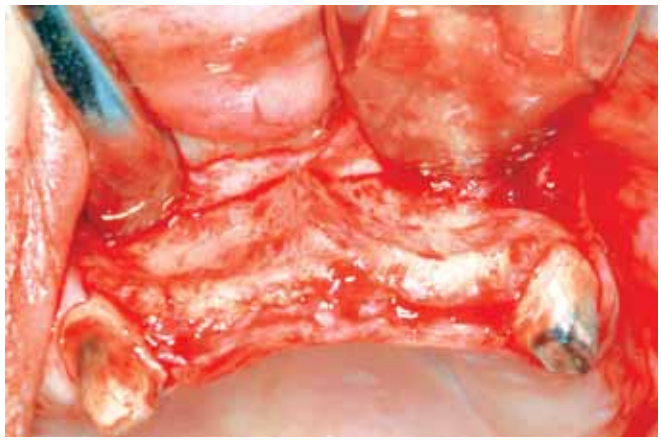


Fig. 21: Deficient areas are exposed, assessed and decorticated

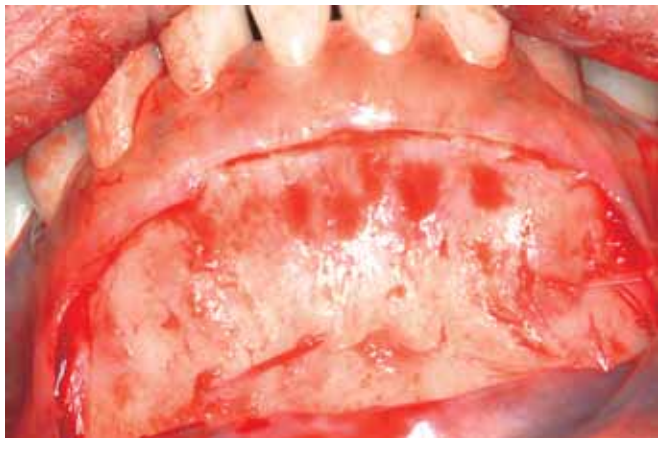


Fig. 22: Mandibular symphyseal region exposed

Donor Site Complications

Postoperative pain/edema	*Moderate*	*Minimal to moderate*	*Minimal*
Neurosensory-teeth	Common (temporary)	Uncommon	None
Neurosensory-tissue	Common (temporary)	Uncommon	Uncommon
Incision dehiscence	Occasional (vestibular)	Uncommon	Uncommon
Sinus perforation	None	None	Occasional

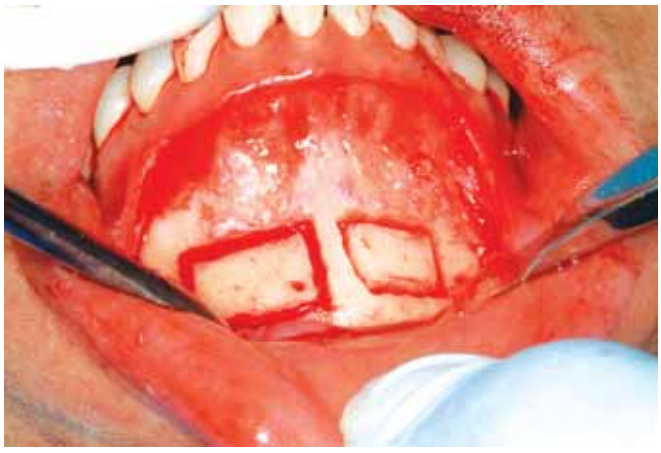


Fig. 23: Once these anatomical sites are identified, small perforations are made to outline the graft margins. Then perforations are connected, the appropriate sized area of needed bone is removed. Pieso surgery is also being used nowadays

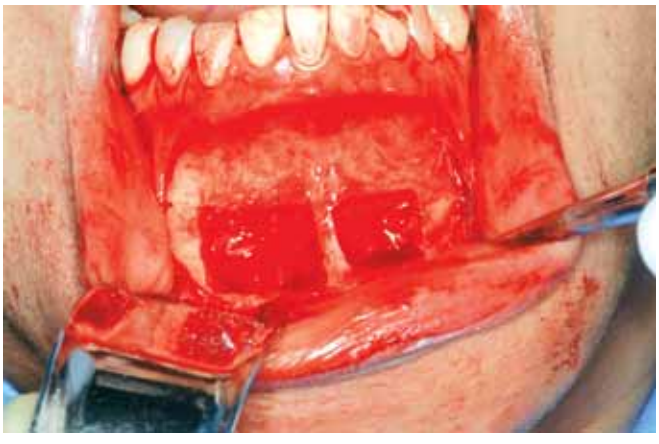


Fig. 24: Bone is harvested from the mandibular symphyseal region

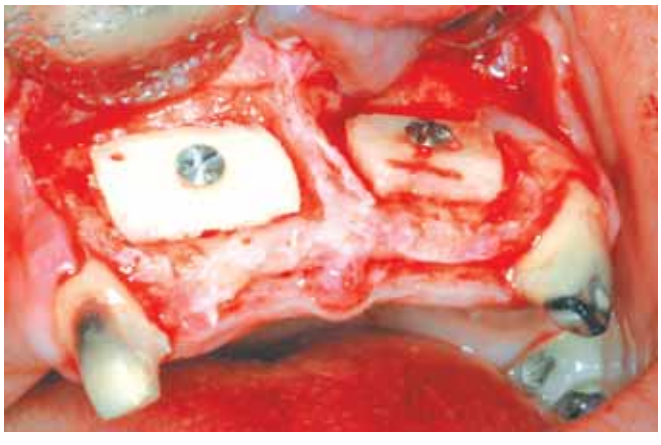


Fig. 25: Small holes are drilled in the bone for a titanium screw that affixes the bone to the desired surgical site. Titanium screws are small and will be removed at the next stage of surgery during implant placement

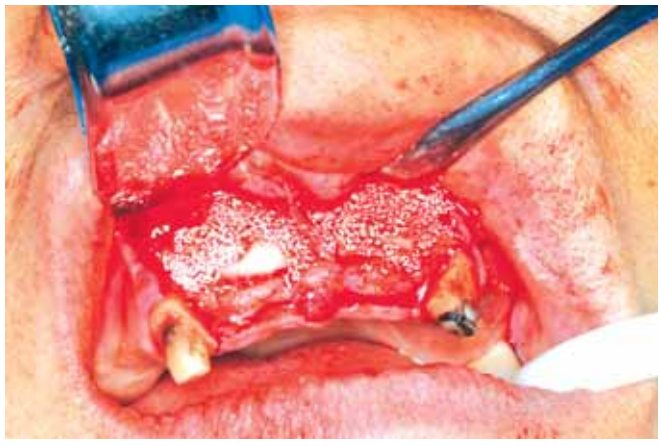


Fig. 26: Demineralized freeze-dried bone and bovine bone can also be used. This is a painless procedure with bone filling in the area through self-regeneration in a few short months

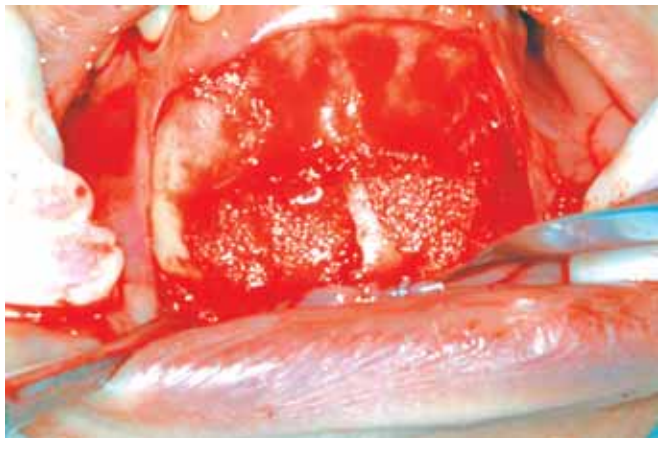


Fig. 27: Particulate graft may also be used to fill the donor site

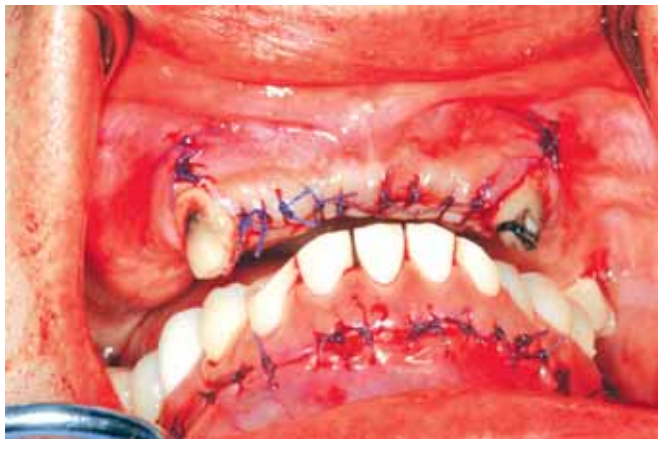


Fig. 28: A primary closure is achieved

EXTRAORAL AUTOGENOUS DONOR BONE GRAFTS FOR IMPLANTS

General Considerations

An extraoral origin for autogenous graft is necessary for large atrophic regions of the jaws. Extraoral donor sites are—iliac crest, tibia, cranium, rib and fibula. An advantage of corticocancellous solid block graft is to permit contouring and adaptation to the recipient bed anatomy, maintains greater volume and allows rigid fixation. The cortical bone on outside of the graft acts like a barrier similar to membranes used in GTR.

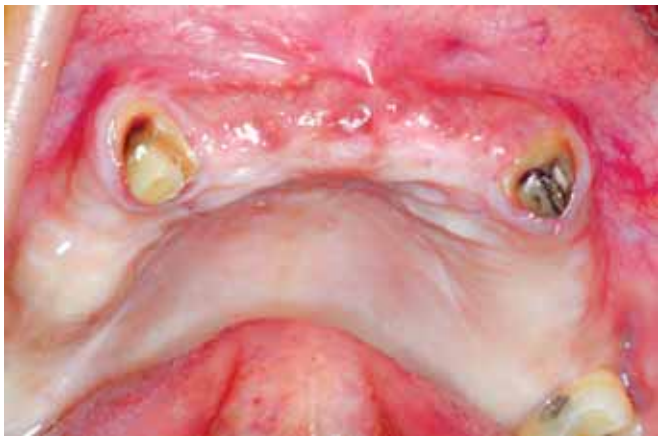


Fig. 29: Healed ridge, 3 months postoperatively

Fig. 30: Bone crusher is used to create a compound of prepared bone material (patient's own) that is used to fill in the spaces

Mandibular Ramus Bone Graft

Fig. 31: Posterior mandibular region is exposed and, similar to graft taken from the symphysis region, an island of bone is removed

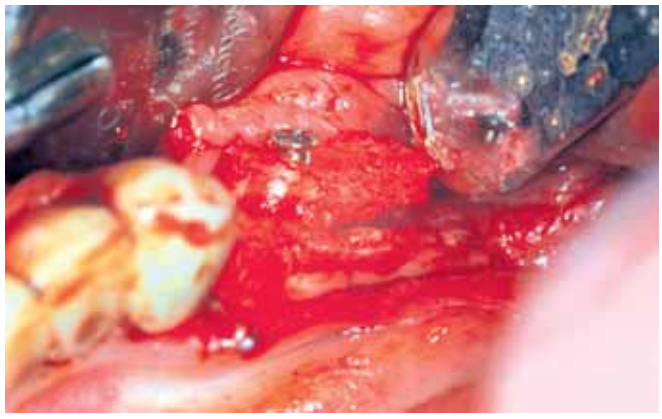
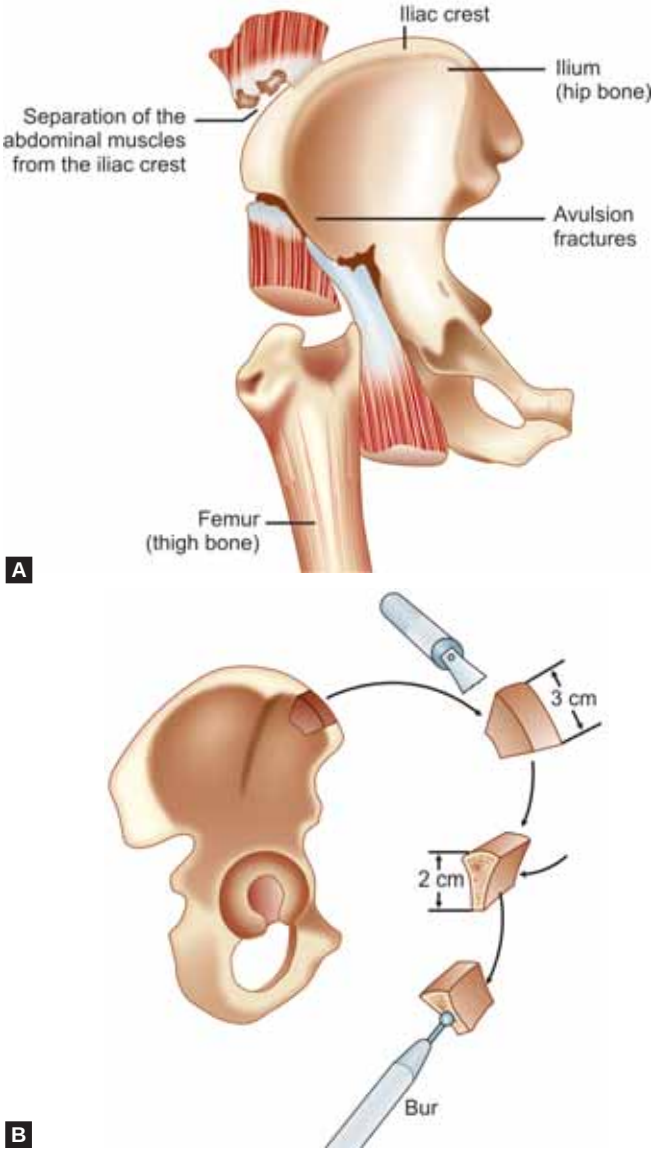


Fig. 32: This block is shaped and screwed onto the desired recepient site with best possible adaptation



Figs 33A and B: (A) Anatomical position and relations of iliac crest bone graft donor site, (B) steps to harvest and contour the block graft

Extraoral Donor Sites (Figs 33A and B)

Originally reported by Kratochil and Boyne in 1972, this area provides large volume of graft, permits shaping of 2/3rd of mandible or maxilla or filling larger bony voids. Outer portion is cortical with abundant cancellous bone underneath in the extraoral autogenous graft bone. Easy access and harvesting, safe well-accepted procedure makes it popular.

Rapid resorption of 30 to 50% of the grafts is reported when conventional dentures are placed, but placement of the implants in the grafted bone has modified, resorption rates similar to host bone.

Vascularized Bone Grafts

Ilium microvascular grafts are more often indicated when blood supply is severely compromized or when recipient bed is scarred, i.e. cancer patient who has undergone radiation therapy, post-trauma, postsurgery. This graft consists of a portion of iliacus and gluteus medius muscles, anterior and medial aspect of the iliac crest and the deep circumflex iliac artery and variable veins.

Distraction Osteogenesis

It is the formation of new bone between vascular bone surfaces created by an osteotomy and separated by gradual distraction.

Maxillary Sinus Lifts and Sinus Graft Surgery[8]

The maxillary sinus may be elevated and subantral bone regenerated to improve implant height. There are two main approaches for implant site development using sinus lift:

1. Indirect sinus lift done using various techniques like osteotome technique, balloon technique[9] etc.
2. Direct sinus lift; tantum lateral wall approach. Sinus membrane elevation and subantral augmentation with a mixture of autogenous bone and/or allograft material is placed into the area previously occupied by the sinus cavity. This helps gain height for immediate or subsequent implant placement.

CONCLUSION

The advent of biomaterials and advances in reconstructive techniques have contributed to increased application of dental implants in the restoration of partial and completely edentulous patients. Often, in these patients, soft and hard tissue defects create an anatomically less favorable foundation for ideal implant placement. For prosthetic-driven dental implant therapy, reconstruction of the alveolar bone through a variety of regenerative surgical procedures has become predictable; it may be necessary prior to implant placement or simultaneously at the time of implant surgery to provide a restoration with a good long-term prognosis.

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