Review Article

Bone grafts, substitutes, and various ridge augmentation procedures

Sri Vasavi Kadiyala[1], Dhanraj Ganapathy[2]*, R. M. Visalakshi[3]

ABSTRACT

Bone resorption is a natural phenomenon and can occur due to old age, loss of teeth, prolonged denture wear, and as a result of systemic conditions. For the replacement of teeth by fabrication of prosthesis or the use of implants, a minimum amount of bone density is required. Bone grafting is a method by which bone-deficient areas are built up, with the use of different materials, such as autografts, allografts, alloplasts, and xenografts. Over recent times, the use of frozen bone matrix formulations and synthetic ceramics has been used in greater frequency. This article discusses the use of human bone material (allografts), synthetic materials (alloplasts), and blood components as successful grafting materials. Their use has shown an effective amount of bone formation and proliferation in the defective sites and proves to be a beneficial choice in bringing back lost bone.

KEY WORDS: Allograft, Autograft, Bone reconstruction, Bone repair, Calcium sulfate, Ceramic, Hydroxyapatite, Implants, Osteoconduction, Osteoinduction

INTRODUCTION

Ridge defects develop as a result of surgery, trauma, infection, or congenital malformations. The goals of osseous replacement are the maintenance of contour and elimination of dead space, reduce post-operative infection, and thus enhance bony and soft tissue healing. The insufficient quantity of bone is due to tooth loss which results in rapid resorption of alveolar bone due to lack of intraosseous stimulation by periodontal ligament (PDL) fibers; for example, pneumatization of the maxillary sinus is common following tooth loss in the upper posteriors.

Bone grafting is a surgical procedure which entails replacement of missing bone with material from either patient's own body, an artificial or natural substitute. The rationale behind grafting is that bone grafting is possible because bone tissue can regenerate completely into the space which it has to develop. As natural bone grows, it generally replaces the graft material completely, resulting in a completely integrated region of the new bone.[1] It is indicated in prosthodontic cases where the requirement of minimal amount of bone is a prerequisite, such as implant placement and denture fabrication.

Defects in the alveolar ridge develop as a consequence of surgery, trauma, infection, or congenital malformations. The lack of intraosseous stimulation by PDL fibers after tooth loss results in rapid resorption of alveolar bone as happens in pneumatization of maxillary sinus following tooth loss.[1] Nevertheless, due to increased frequency of localized or generalized bone defects of the alveolar ridge, as a result of atrophy, dental trauma, extractions, or periodontal disease, reconstructive surgery is obligatory to regenerate such defects to have successful rehabilitation.[2,3] The goals of osseous replacement are the maintenance of contour, elimination of dead space, and reduction of postoperative infection, thereby enhancing bone and soft tissue healing. Bone grafts are a therapeutic option to correct abnormal intermaxillary relations and to attain appropriate bone volume and morphology.[4] They are used as a scaffold to allow the formation of bone and promote wound healing and act as a mineral reservoir which helps in new bone formation.

Access this article online

Website: jprsolutions.info | ISSN: 0975-7619

[1]Department of Prosthodontics, Saveetha Dental College, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India, [2]Department of Prosthodontics, Saveetha Dental College, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India, [3]Department of Prosthodontics, Saveetha Dental College, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India

***Corresponding author:** Dr. Dhanraj Ganapathy, Department of Prosthodontics, Saveetha Dental College, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai - 600 077, Tamil Nadu, India. Tel.: +91-7299031194. E-mail: dhanrajmganapathy@yahoo.co.in

Received on: 09-12-2018; Revised on: 13-01-2019; Accepted on: 17-02-2019

The biologic mechanisms that provide a rationale for bone grafting are osteoconduction, osteoinduction, osteopromotion, and osteogenesis.

OSTEOCONDUCTION

Osteoconduction occurs when bone graft material serves as a scaffold for new bone growth, which is perpetuated by the native bone. Osteoblasts from the margin of defect that is grafted utilize the bone graft material as a framework on which to spread and generate new bone. In the very least, a bone graft material should be osteoconductive.[2,3]

OSTEOINDUCTION

Osteoinduction involves stimulation of osteoprogenitor cells to differentiate into osteoblasts and then begins the formation of new bone. The most widely studied type of osteoinductive cell mediators is bone morphogenic proteins (BMPs). Bone graft material that is osteoconductive and osteoinductive will not only serve as a scaffold for currently existing osteoblasts but will also trigger formation of new osteoblasts, promoting faster integration of the graft.[2,3]

OSTEOPROMOTION

It involves the enhancement of osteoinduction without possession of osteoinductive properties. For example, enamel matrix derivative enhances the osteoinductive effect of demineralized freeze-dried bone allograft (DFDBA) but will not stimulate bone growth alone.[2,3]

OSTEOGENESIS

Osteogenesis occurs when vital osteoblasts originating from bone graft material contribute to the growth of new bone along with bone formation.[2,3]

CLASSIFICATION OF BONE GRAFTS BASED ON MATERIAL GROUPS

Types and Tissue Sources

Autograft

Autologous or autogenous bone grafting involves utilizing bone obtained from the same individual receiving the graft. Bone can be harvested from non-essential bones, such as from the iliac crest, mandibular symphysis (chin area), and anterior mandibular ramus (coronoid process). When a block graft will be performed, autogeneous bone is the most preferred because there is less risk of graft rejection as the graft is originated from the patients' body.[3] It would be osteoinductive and osteogenic, as well as osteoconductive. Disadvantage of autologous grafts is that additional surgical site is required, another potential location for post-operative pain and complications.[3]

All bones require blood supply in the transplanted site. Depending on where the transplant site is and size of the graft, an additional blood supply may be required. For these types of grafts, extraction of the part of the periosteum and accompanying blood vessels along with the donor bone is required. This kind of graft is known as a free flap graft.

Autogenous grafts can be cortical, cancellous, or corticocancellous.[2,3] The prime difference between cortical and cancellous (particulate) bone grafts is with respect to healing and the ability to be contoured and adapted to the recipient site.[3] Cancellous grafts undergo rapid incorporation (within weeks to months) and have greater osteogenetic potential compared to cortical grafts.[2] On the other hand, incorporation of cortical grafts is rather a slower process known as creeping substitution where the revascularization starts from the periphery toward the center. In fact, the remnant pieces of donor graft may persist as necrotic areas walled off by new bone.[3] It is easier to achieve primary stabilization with cortical grafts while cancellous grafts often require to be contained within membranes or titanium mesh due to the lack of rigidity.[1]

Harvesting Autogenous Grafts

Ramus graft

Local anesthesia

Mandibular nerve trunk anesthesia is supplemented with local infiltration in the area of coronoid process, mental foramen, and buccal part of the mandibular body reaching toward the mandibular base.[3]

Surgical technique

The incision extends from the medial aspect of the external oblique ridge to the first molar area. The concavity where the external oblique ridge meets the ramus is the prime landmark to facilitate locating the starting point of this incision. A mucoperiosteal flap is reflected to visualize the border between the external oblique ridge and ascending ramus. The lateral border of the ramus and the external oblique ridge is dissected free. The soft tissues are retracted along the anterior border of the ramus until the insertion fibers of the temporalis muscle are identified. The donor area is identified and the borders of the osteotomy cuts are marked by drilling holes through the cortex until the cancellous bone is identified by marrow bleeding. The superior border of osteotomy cut is made on external oblique ridge along the anterior border of the ramus approximately until one-third of the width of the ramus. The anterior cut is placed along the distal aspect of the first permanent molar. The inferior cut is placed approximately 4–5 mm superior

to the mandibular canal. Medially, the osteotomy cut is placed in the lateral cortex. After delineating the margins of the osteotomy cuts by drilling holes, the cuts are completed with either rotary or osteotome or piezotome. The latter is considered to be the best due to inherent low risks associated with its use, while osteotome is least preferred due to poor patient acceptance.[3] Following this, the lateral bone block is fractured with due care to avoid damage to the inferior alveolar neurovascular bundle.

Care of donor area and graft

A collagen membrane is used the fill the donor area defect, which is closed by running sutures after hemostasis. The graft is stored in blood-soaked gauze until it is particulated or transplanted.[3]

Chin/Symphysis Graft

Local anesthesia

Mandibular nerve block is supplemented with local infiltration in the anterior mandibular labial vestibule.

Surgical technique

The mucoperiosteal flap can be raised by vestibular or sulcular incision. The former is preferred as the latter is associated with post-operative gingival recession. The two-layer vestibular incision is made through the deepest part between the vestibule and lip. The lateral extent of the incision depends on the purpose of harvest. For local grafts, the incision is limited until the canines. On the other hand, for maxillary sinus grafting, the incision is extended until the premolars to locate the mental nerves. The superior osteotomy cut is placed at least 5 mm inferior to the apex of the mandibular teeth, and the inferior cut is placed approximately 4 mm superior to the inferior border of the mandible. Often, the graft is given a cut in the midline and is harvested in two parts using an osteotome.[3]

Care of donor area and graft

As described for ramus graft, the residual symphyseal cavity is packed with collagen membrane after achieving hemostasis. The closure is performed in two layers, i.e., periosteum and muscle layer followed by mucosa. The graft is handled in the same way as described for ramus graft.[3]

Tuberosity Graft

Local anesthesia

Posterior superior alveolar nerve block.

Surgical technique

The mid-crestal incision extending from the hamular notch to the second molar area is employed to gain access to maxillary tuberosity. Only a little amount of bone (1–3 mL) is removed using a rongeur or piezotome. The latter is again a preferred approach due to lesser risks.[3]

Care of donor area and graft

For maxillary tuberosity, primary closure can be achieved due to small residual defect. The graft should be harvested keeping a minimum of 2 mm clearance from the maxillary sinus. In case of oroantral communication, the closure can be achieved using either of the buccal sliding flap, buccal fat pad, or palatal finger flap.[3]

Allografts

Allograft is derived from humans. The difference is that allograft is harvested from an individual other than the one receiving the graft. Allograft bone is taken from cadavers that have donated their bone so that it can be used for living people who are in need of it; it is typically sourced from a bone bank.

There are three types of bone allograft available: Fresh or fresh-frozen bone, FDBA, DFDBA.[4]

The use of allografts for bone repair often requires sterilization and deactivation of proteins normally found in healthy bone. Contained in the extracellular matrix of bone tissue are the full cocktail of bone growth factors, proteins, and other bioactive materials necessary for osteoinduction and successful bone healing; the desired factors and proteins are removed from the mineralized tissue using a demineralizing agent such as hydrochloric acid. The mineral content of the bone is degraded, and the osteoinductive agents remain in a demineralized bone matrix (DBM).

Synthetic Variants

Flexible hydrogel-hydroxyapatite (HA) composite which has a mineral to organic matrix ratio, approximating that of human bone.

Artificial bone can be created from ceramics such as calcium phosphates (e.g., HA and tricalcium phosphate), bioglass, and calcium sulfate which are biologically active depending on solubility in physiological environment.[5] These materials combine with growth factors and ions such as strontium or mixed with bone marrow aspirate to increase biological activity. The presence of elements such as strontium can result in higher bone mineral density (BMD) and enhanced osteoblast proliferation.

Xenograft

Xenogratfs are bone grafts from a species other than human, such as bovine, and are used as a calcified matrix.

Alloplastic Grafts

Alloplastic grafts may be made from HA, a naturally occurring mineral (main mineral component of bone), made from bioactive glass. HA is a synthetic bone graft, which is the most used now due to its osteoconduction, hardness, and acceptability by bone. Some synthetic

bone grafts are made of calcium carbonate, which start to decrease in usage because it is completely resorbable in short time and makes breaking of the bone easier. Finally used is the tricalcium phosphate in combination with HA and thus giving effect of both, osteoconduction and resorbability.[5]

Growth Factors

Growth factor-enhanced grafts are produced using recombinant DNA technology. They consist of either human growth factors or morphogens (BMPs in conjunction with a carrier medium, such as collagen).

The factors and proteins that exist in bone are responsible for regulating cellular activity. Growth factors bind to receptors on cell surfaces and stimulate intracellular environment to act. In general, this activity translates to a protein kinase that induces a series of events, resulting in transcription of messenger ribonucleic acid and ultimately into the formation of a protein to be used intracellularly or extracellularly. The combination and simultaneous activity of many factors result in controlled production and resorption of bone. These factors, residing in extracellular matrix of bone, include transforming growth factor (TGF)-beta, insulin-like growth factors I and II, platelet-derived growth factor, fibroblast growth factor, and BMPs.[6,7] Cell-based bone graft substitutes: Stem cells are cultured in the presence of various additives such as dexamethasone, ascorbic acid, and β-glycerophosphate to direct the undifferentiated cell toward osteoblast lineage.

The addition of TGF-beta and BMP-2, BMP-4, and BMP-7 to the culture media can also influence the stem cells toward osteogenic lineage. Mesenchymal stem cells have also been seeded onto bioactive ceramics conditioned to induce differentiation to osteoblasts.

Ceramic-Based Bone Graft Substitutes

Majority of bone grafts available involve ceramics, either alone or in combination with another material (e.g., calcium sulfate, bioactive glass, and calcium phosphate). The use of ceramics, such as calcium phosphates, is calcium HA which is osteoconductive and osteointegrative and, in some cases, osteoinductive. They require high temperatures for scaffold formation and have brittle properties.[8,9]

Calcium sulfate is also known as Plaster of Paris. It is biocompatible, bioactive, and resorbable after 30–60 days. Significant loss of its mechanical properties occurs on its degradation; therefore, it is a questionable choice for load-bearing applications.

OsteoSet is a tablet used for defect packing. It is degraded in approximately 60 days.

Allomatrix is OsteoSet combined with DBM, which forms a putty or injectable paste. OsteoSet is a calcium sulfate tablet used for bone defect sites, whereas Allomatrix is a combination of calcium sulfate and DBM that forms an injectable paste or fable putty.

Bioactive glass (bioglass) is a biologically active silicate-based glass,[8] having high modulus and brittle nature; it has been used in combination with polymethylmethacrylate to form bioactive bone cement and with metal implants as a coating to form a calcium-deficient carbonated calcium phosphate layer which facilitates the chemical bonding of implants to the surrounding bone. Different types of calcium phosphates are tricalcium phosphate, synthetic HA, and coralline HA, available in pastes, putties, solid matrices, and granules.[8,9]

Such calcium phosphate products include Bio-Oss and OsteoGraft. Both products use HA, either as a particulate (Bio-Oss) or as blocks and particulates (OsteoGraft). Pro-Osteon is a unique product based on sea coral, which is converted from calcium carbonate to calcium HA. The advantage of this material is the structure of coral, which is similar to that of trabecular bone.

Polymer-Based Bone Graft Substitutes

This can be divided into natural polymers and synthetic polymers which is subclassified into degradable and non-degradable types. Polymer-based bone graft substitutes include the following:

Healos is a natural polymer-based product, a polymer-ceramic composite consisting of collagen fibers coated with HA and indicated for spinal fusions.[8,9]

Cortoss is an injectable resin-based product with applications for load-bearing sites.

Degradable synthetic polymers, such as natural polymers, are resorbed by the body. The benefit of having the implant resorbed by the body is that the body is able to heal itself completely without remaining foreign bodies.

Techniques of Ridge Augmentation

The various techniques of ridge augmentation can be differentiated either on the basis of the form of graft, i.e., block or particulate, guidance or use of membrane, i.e., GBR, transportation of vital structures, i.e., maxillary sinus lift and inferior alveolar nerve transportation.[10,11] None of these techniques are free from complications and all possess their unique advantages. A few of the technical considerations need to be borne in mind ubiquitously for all grafting procedures.

Onlay Grafting

Onlay grafting can either be block onlay grafting or particulate onlay grafting. The latter can further be

categorized as subperiosteal tunnel grafting or direct particulate onlay grafting.

Direct Particulate Onlay Grafting

Indications

The direct particulate onlay grafting is employed for correcting horizontal deficiencies in the anterior maxilla and for saddle depressions, i.e., vertical deficiency. The recipient sites with three-walled and four-walled defect morphology with an apical stop are considered to be best amenable to direct particulate onlay grafting.[12]

Technique

The direct particulate onlay grafting can be performed as a staged or simultaneous procedure. The planned recipient area is exposed by raising a mucoperiosteal flap to visualize the defect. It is important to place releasing incisions to ensure direct visualization of the defect and tension-free closure. After drilling holes in the recipient bed to ensure osseointegration, the particulate graft is condensed over the defect. For defects with poorly contained boundaries (i.e., maxillary sinus), demineralized grafts are preferred over mineralized grafts due to their slower resorption. The coverage with membranes is often recommended but can be omitted for small defects with sufficient neighboring walls to provide volume stability.[12] The malleability and workability of the particulate graft can be enhanced with tissue adhesives, i.e., fibrin sealants or protein-based regenerative gels (Emdogain; Straumann, Andover, MA, USA).

Subperiosteal tunnel grafting

Indications

Small-to-moderate buccal plate defects are best open to subperiosteal tunnel grafting. The morphology of such defects is characterized by wider buccal base with narrow crestal width (≤4 mm) and intact lingual wall with optimum vertical dimensions.

Technique

After administration of local anesthesia, access incision is placed distant (often mesially) from the recipient site. Subperiosteal tunneling from the incision to graft site is performed with the help of a periosteal elevator. The demineralized particulate bone graft is placed in this subperiosteal tunnel with the help of modified 1 mL carrier syringe. The graft may need digital manipulation to conform to the recipient bed in the desired form. The mesial incision is closed in a tension-free manner to ensure uneventful healing with minimal risks of dehiscence and graft exposure.

Block Onlay Grafting

Indications

Horizontal or vertical deficiency or combined horizontal and vertical deficiency.

Technique

This is one of the most commonly employed techniques for horizontal as well as vertical ridge augmentation. The block graft can be autogenous graft harvested from neighboring intraoral donor sites, distant extraoral donor sites, or commercially available xenografts or alloplastic grafts.[10] After raising the mucoperiosteal flap, the recipient bed is prepared by drilling multiple holes until the underlying spongiosa is reached. Depending on the type of defect, the graft is contoured to adapt in proximity to the recipient site as veneer and block, or inverted J Block graft is employed for the vertical defects while veneer graft is used in the case of horizontal defects. For combined defects, the graft is modified to the shape of the inverted letter J. Another modification is lamellar technique where only the cortical part of the graft is used as veneer, whereas the underlying defect is filled with particulate graft. After ensuring proper adaptation of the graft to the recipient bed, the voids can be filled with particulate bone graft material. It is imperative to stabilize the graft with two screw fixations to allow unimpeded integration while avoiding shearing of microvasculature and tender connective tissues. Due care should be taken to fix the screws passively as lateral pressure from screws may either fracture the block graft or result in undue resorption and graft failure. In case of insufficient soft tissue coverage, a membrane may be used for barricading from unwanted connective tissue and epithelial ingrowth. However, often the block grafts do not require the use of barrier membrane as the cortical part of the graft prevents the soft tissue from creeping into the grafted area.[12,13]

These grafts require a little longer time to integrate with the recipient bone, and thus, it is recommended that the staged approach of implant placement be preferred. It is preferable to allow healing 4–6 months before functional loading. However, if the basal bone is sufficient and the implant stability is not to be relied on the graft bone, immediate placement of the implant can be performed.[13,14]

Interpositional Bone Graft (Sandwich Grafting)

Indications

Vertical deficiency with pre-existing minimal vertical alveolar dimensions of 4–5 mm and without any soft tissue deficit.[10]

Technique

A vestibular incision is placed in non-keratinized mucosa to expose the facial aspect of the planned area of augmentation. First, vertical corticotomies and osteotomies are performed using micro reciprocating and see to the preservation of ≈2 mm of bone around the roots of neighboring teeth. This is followed by horizontal corticotomy and osteotomy to mobilize the

segment. A minimum clearance of ≈3–5 mm from vital structures such as the maxillary sinus or mandibular canal is essential. It is crucial to perform only as much advancement as permitted by the soft tissue envelope to achieve tension-free closure. The free segment can also be advanced buccally or lingually to achieve the desired prosthodontic position. After careful transportation preserving soft tissue attachments, the bone graft block (usually corticocancellous autogenous graft) is sandwiched between the transported segment and basal bone. The graft fixation is achieved with mini plates. Periosteal releasing incisions may be placed to aid tension-free closure.

Ridge-Split Technique

Indications

Horizontal deficiency requiring 2–5 mm of augmentation.[10,13]

Technique

This technique can be utilized in case of alveolar width ≥4 mm so that a minimum of 2 -mm thickness of outfractured buccal and lingual walls can be achieved.[10,13] This is essential for maintaining the vascularity of the outfractured segments. The mucoperiosteal flap to expose the donor area is raised by a crestal incision. A vertical osteotomy ≈10–12 mm in length is performed on the recipient alveolar crest with a clearance of 2 mm from the roots of adjacent teeth. After osteotomy is complete, the facial and lingual walls are spread apart using osteotomes to make space for placement of the implant. Residual voids are filled with particulate graft and the implant is submerged at least 1 mm apical to the alveolar ridge crest. The closure must be tension free, and in case of soft tissue deficit, collagen membrane with soft tissue graft can be used to close the defect.

The technique described above is conventional ridge-split technique where immediate implant placement is performed. It can be performed when horizontal deficiency exists at the crestal part and the ridge widens apically. However, it is not uncommon to encounter challenging ridge morphology, i.e., deficient ridge crest combined with severe facial concavity.[13] This may exist in case of chronic periapical infection where longstanding inflammation caused resorption of the labial cortical plate in the apical region. In such a condition, ridge splitting may lead to sudden fracture of the cortical plate at the apical region. Fortunately, with a little modification, the ridge-split technique is still feasible. The flap is raised only in the crestal part to be expanded, and the dehiscence in the apical area is left undisturbed. The crestal part is expanded and particulate graft is packed over facial dehiscence by the subperiosteal tunnel technique. The advantages of this technique include being less invasive and abolishing the need for placement of the barrier membrane.[13]

The best suited histological bone type amenable to ridge splitting and expansion is bone with medium density (maxillary bone), i.e., porous cortical bone with coarse/fine trabecular bone (D3/D4 bone). It is tricky to perform ridge splitting in case of dense cortical bone, i.e., the mandible where sudden fracture of cortical plates may happen during expansion. In mandibular ridge with dense cortical plates, ridge splitting can be performed using either two-stage or one-stage approach.[13] The choice between the two depends on the availability of armamentarium and surgeons' skill. The one-stage conventional approach is preferred only when the surgeon has adequate experience supported with suitable armamentarium, for example, piezosurgery. Only modification here in one-stage ridge splitting for mandibular ridge compared to conventional ridge split is raising flap from either buccal or facial side compared to both sides in conventional technique. Here, the intact mucoperiosteal flap protects in case of sudden fracture of the cortical plate. In two-stage approach of ridge splitting, an osteotomy is performed similar to the conventional ridge-split procedure. However, expansion is not performed at this stage; rather, the flap is sutured back. After a healing period of 3–4 weeks, the osteotomy area is accessed again. The new bone formed at the osteotomy site during this healing period is soft and expandable. Thus, ridge splitting and implant placement at reentry after 3–4 weeks become easier. Due care is taken to raise the flaps only minimally. The peri-implant spaces are filled with particulate graft and the lingual flap is coronally advanced and sutured back. Uncovering of implants and functional loading is done after 4–6 months.[14]

Ridge Expansion

Indications

About ≤6 mm width of the alveolar ridge crest.[15]

Technique

The alveolar ridge crest is exposed by raising a mucoperiosteal flap. Horizontal osteotomy is performed extending from 1 mm distance from neighboring tooth to 8–10 mm distal to the axis of the last implant.[15] The horizontal osteotomy is extended as deep as the length of the implants to be placed. Following this releasing, vertical osteotomy is performed. This is essential in case of dense cortical bone. The vertical osteotomy cuts are placed at the mesial and distal ends of the horizontal osteotomy cut. With a pilot drill, osteotomy holes (1.2–2 mm) corresponding to each implant site are placed. Then immediately expansion screws are placed. The maximum diameter of these screws is 2.5 mm, and ≈1 mm expansion of the buccal cortical plate is achieved. Next, differential preparation of the implant site is done by reducing the width of the lingual and

sometimes buccal cortical plate to reduce the need of expansion. This is possible if width of the alveolar crest is ≈4–5 mm. Second, expansion screws of 3.5 mm diameter are inserted in differentially prepared pilot osteotomy sites to enable additional expansion by 0.5 mm. Finally, implants corresponding to 4-mm diameter are placed. This results in an additional expansion of 0.5 mm and a net total expansion of 2 mm. The final outcome is net total alveolar crest width of 6 mm with 1 mm thickness of the buccal as well as lingual cortical plate.[15]

Distraction Osteogenesis

Indications

Significant vertical deficiency.

Technique

This technique allows significant augmentation of both hard and soft tissues in areas with extensive tissue loss in a staged manner.[15-18] A transport segment is mobilized in a similar manner as for interpositional bone grafting, preserving attachment to the crestal and lingual tissues.[17] The transport segment can be mobilized in multiple planes to allow simultaneous correction of buccolingual postions as well. The distractor is fixed to transported and basal bone segments with approximately 1–2 mm gap between the two segments. This is left *in situ* for a latency period of 5–7 days to allow the formation of soft tissue callus between the two segments, and then, activation is started at the rate of 0.5–2 mm/day for periodic distraction. After completion of the desired amount of distraction, the distraction device is removed and the quality of the bone is explored. The newly formed bone is hourglass shaped and placement of additional grafts may be required for proper implant placement at this time. The implant placement is performed after a period of 4–6 months.

Inferior Alveolar Nerve Transportation

Indications

To allow placement of dental implants in atrophic mandible with deficient vertical height as a substitute for grafting.[19-21]

Technique

This method involves lateral translocation of the contents of the mandibular canal to soft tissues of the mandibular vestibule. The implants can then be placed traversing the empty mandibular canal. This technique allows placement of 8–12 mm long implants without any grafting.[19,20]

Maxillary Sinus Lift With and Without Bone Graft

Indications

About ≤10 mm of bone height in the posterior maxilla.[22,23]

Technique

Lateral wall of the maxillary sinus is exposed by raising a trapezoidal flap with anterior releasing incision adjacent to the last tooth and posterior releasing incision in the posterior part of the infrazygomatic crest. A mid-crestal incision is placed and mucoperiosteal flap is reflected. A bone window approximately 15 mm×10 mm in size is created at least 5 mm superior to the sinus floor. A small round bur is used to outline the margins of the window by placing holes in the bone with due care to leave the underlying membrane intact. The holes are connected and the window is created by infracture of the outlined bone. The membrane is dissected free from the bone, i.e., anterior wall and floor of the sinus. After dissection and ensuring intactness of the mucosa, it is lifted and bone graft in particulate form is condensed to fill the created cavity, which is then closed by replacing the oral mucosa. Post-operative care includes refraining from sneezing and blowing of the nose and decongestants and antibiotic coverage. A modification of this technique involves filling the cavity with blood instead of graft material. The implant is placed traversing through the created cavity with the membrane resting on its top. A consolidation period of 3–4 months is recommended.

Guided Bone Regeneration

This technique is based on the principle of creating a barrier to the ingrowth of connective tissue and epithelial cells and space maintenance for osteogenesis. GBR, also known as guided tissue regeneration, is an evidence-based predictable approach for separating the bone graft material (usually particulate) from neighboring soft tissues to allow unimpeded bone formation. In this technique, a membrane is secured covering the graft material to stabilize the material, parting it from adjacent connective tissues, and limiting resorption. A plethora of membranes, resorbable/non-resorbable, and moldable or stiff is available.

The choice of membrane mainly depends on volume stability of the graft in a defect. Stiff membranes such as titanium mesh or metal-supported expanded polytetrafluoroethylene (e-PTFE) are suitable for complex defects, i.e., vertical defects. For small-to-moderate defects, resorbable collagen membrane or platelet-rich fibrin membranes are preferred. Non-resorbable membranes such as Ti-mesh and e-PTFE have an inherent problem of requiring second surgery to remove them. Further, with Ti-mesh, there is a risk of fibrous ingrowth and exposure of membrane through the gingiva. To limit this unwanted outcome, the use of collagen membrane to cover Ti-mesh as an adjuvant barrier is recommended. Another problem associated with membranes is premature exposure of membrane, resulting in infection and exposure of graft. This is observed more commonly

with alloplastic membranes, which are occlusive and may interfere with blood supply. Although mainly used in conjunction with particulate graft, the barrier technique may also be used for block graft.[24]

REFERENCES

1. Laurencin C, Khan Y, El-Amin SF. Bone graft substitutes. Expert Rev Med Devices 2006;3:49-57.
2. Giannoudis PV, Dinopoulos H, Tsiridis E. Bone substitutes: An update. Injury 2005;36 Suppl 3:S20-7.
3. Conrad EU, Gretch DR, Obermeyer KR, Moogk MS, Sayers M, Wilson JJ, *et al.* Transmission of the hepatitis-C virus by tissue transplantation. J Bone Joint Surg Am 1995;77:214-24.
4. Centers for Disease Control and Prevention (CDC). Septic arthritis following anterior cruciate ligament reconstruction using tendon allografts florida and Louisiana, 2000. MMWR Morb Mortal Wkly Rep 2001;50:1081-3.
5. Centers for Disease Control and Prevention (CDC). Update: Allograft-associated bacterial infections united States, 2002. MMWR Morb Mortal Wkly Rep 2002;51:207-10.
6. Valdes MA, Thakur NA, Namdari S, Ciombor DM, Palumbo M. Recombinant bone morphogenic protein-2 in orthopaedic surgery: A review. Arch Orthop Trauma Surg 2009;129:1651-7.
7. Mulconrey DS, Bridwell KH, Flynn J, Cronen GA, Rose PS. Bone morphogenetic protein (RhBMP-2) as a substitute for iliac crest bone graft in multilevel adult spinal deformity surgery: Minimum two-year evaluation of fusion. Spine (Phila Pa 1976) 2008;33:2153-9.
8. Waked W, Grauer J. Silicates and bone fusion. Orthopedics 2008; 31:591-7.
9. Bansal S, Chauhan V, Sharma S, Maheshwari R, Juyal A, Raghuvanshi S, *et al.* Evaluation of hydroxyapatite and beta-tricalcium phosphate mixed with bone marrow aspirate as a bone graft substitute for posterolateral spinal fusion. Indian J Orthop 2009;43:234-9.
10. Haggerty CJ, Vogel CT, Fisher GR. Simple bone augmentation for alveolar ridge defects. Oral Maxillofac Surg Clin North Am 2015;27:203-26.
11. Herford AS, Nguyen K. Complex bone augmentation in alveolar ridge defects. Oral Maxillofac Surg Clin North Am 2015; 27:227-44.
12. Hämmerle CH, Karring T. Guided bone regeneration at oral implant sites. Periodontol 2000 1998;17:151-75.
13. Singh AV, Shimada J. Block grafting for dental implants. Clin Implantol 2013;1:349-80.
14. Bell RB, Blakey GH, White RP, Hillebrand DG, Molina A. Staged reconstruction of the severely atrophic mandible with autogenous bone graft and endosteal implants. J Oral Maxillofac Surg 2002;60:1135-41.
15. Vercellotti T. Essentials in piezosurgery: Clinical Advantages in Dentistry. 1st ed. Milan: Quintessenza Edizioni; 2009. p. 65-107.
16. Herford AS. Distraction osteogensis: A surgical option for restoring missing tissue in the anterior esthetic zone. J Calif Dent Assoc 2005;33:889-95.
17. Elo JA, Herford AS, Boyne PJ. Implant success in distracted bone versus autogenous bone-grafted sites. J Oral Implantol 2009; 35:181-4.
18. Herford AS, Tandon R, Stevens TW, Stoffella E, Cicciu M. Immediate distraction osteogenesis: The sandwich technique in combination with rhBMP-2 for anterior maxillary and mandibular defects. J Craniofac Surg 2013;24:1383-7.
19. Bovi M. Mobilization of the inferior alveolar nerve with simultaneous implant insertion: A new technique. Case report. Int J Periodontics Restorative Dent 2005;25:375-83.
20. Kan JY, Lozada JL, Goodacre CJ, Davis WH, Hanisch O. Endosseous implant placement in conjunction with inferior alveolar nerve transposition: An evaluation of neurosensory disturbance. Int J Oral Maxillofac Implants 1997;12:463-71.
21. Proussaefs P. Vertical alveolar ridge augmentation prior to inferior alveolar nerve repositioning: A patient report. Int J Oral Maxillofac Implants 2005;20:296-301.
22. Goyal M, Mittal N, Gupta GK, Singhal M. Ridge augmentation in implant dentistry. J Int Clin Dent Res Organ 2015;7:94.
23. Boyne PJ. Augmentation of the posterior maxilla by way of sinus grafting procedures: Recent research and clinical observations. Oral Maxillofac Surg Clin North Am 2004;16:19-31, v-vi.
24. Retzepi M, Donos N. Guided bone regeneration: Biological principle and therapeutic applications. Clin Oral Implants Res 2010;21:567-76.

Source of support: Nil; Conflict of interest: None Declared