We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900
Open access books available

185,000
International authors and editors

200M
Downloads

Our authors are among the

154
Countries delivered to

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



Chapter 23

Concepts in Bone Reconstruction for Implant Rehabilitation

Hany A. Emam and Mark R. Stevens

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/53401

1. Introduction

The standard of care regarding tooth loss replacement is evolving towards the use of dental implants. The practice of fixed bridges and partial prosthesis can be and are iatrogenic to the existing teeth and bone. Prosthetics in the restoration of partial and complete edentulous conditions with implants has become the most important determinant. Because of this principle the emphasis has focused on optimization of the alveolus to receive a root form implant. Dental implants are a viable treatment option when there is sufficient quantity and quality of bone to achieve the desired functional and esthetic results. The reduction in bone volume has many etiologies. The most common are a result of: Periodontal disease, pneumatization of the maxillary sinus, long term ill-fitting dentures, and the general progression of osteoporosis with aging. Initially, malposition or short implants were used in areas of deficient bone volume. This often resulted in compromised prosthetic design and poor long term treatment outcomes. Today's treatment plans first consider the prosthesis options. This necessitates reconstruction and modifications of the pre-existing anatomy provide the ideal environment needed for optimal implant placement. The deformity is often a composite loss of both bone and soft tissue. The alveolar bone loss frequently occurs in a three dimensional pattern. Multiple options and techniques have been advocated for correction and reconstruction of the atrophied alveolar bones. They include the following: Guided bone regeneration (GBR), onlay bone grafting (OBG), interpositional bone grafting (IBG), distraction osteogenesis (DO), ridge- split (RS), and sinus augmentation techniques (SA). [1-3] The complexity of the defect dictates the selection of the appropriate technique. The reconstruction must also take into account the three dimensional spatial relation of one arch to the opposing arch.

INTECH
open science | open minds

© 2013 Emam and Stevens; licensee InTech. This is an open access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

2. Considerations for reconstruction

2.1. Bone density

The quality of bone in the jaws is dependent on location and position within the dental arches and alveolus respectively. The most dense bone is observed in the anterior mandible, followed by the anterior maxilla and posterior mandible. The least compact bone is typically found in the posterior maxilla. Misch classified these bone densities into a spectrum of four categories, ranging from D1 through D4. D1 bone primarily consists of a dense cortical structure. D4 on the other hand, is the softest, consisting primarily of cancellous bone with a fine trabecular pattern with minimal crestal cortical anatomy. The density of bone is an important quality in the initial stabilization of the implant and in the loading profile of the prosthesis. Literature review of clinical studies from 1981 to 2001 reveals that poor bone density may decrease implant loading survival rates. The decrease survival ranged from 16% to 40 %. The primary cause of these failures was directly attributed to the bone density, strength and a lower percentage of bone to implant contact. Bone in the posterior maxilla was found to be five to ten times weaker in comparison to bone in the anterior when compared to other bone densities. Lesser bone densities also influence stress pattern distribution. Stresses in "soft bone" demonstrate patterns which migrate further towards the apex. Bone loss is more pronounced and occurs along the implant body rather than crestally, as in denser bone. D4 bone exhibits the greatest difference in biomechanical modulus of elasticity when compared with titanium. Therefore, afterload results in higher strain conditions at the bone-implant interface accelerating bone resorption and implant failure (Fig. 1).

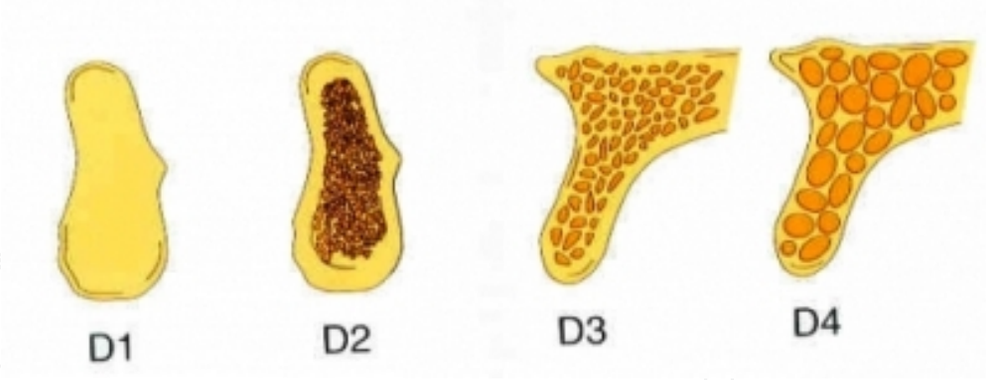


Figure 1. Types of bone densities

2.2. Bone graft materials and mechanism of bone regeneration

Various bone augmentation materials are used for alveolar reconstruction, they include: Autografts, allografts, alloplasts, and xenografts. Autogenous bone grafts can regenerate bone through all three mechanisms: *osteogenesis, osteoinduction, and osteoconduction;* This is the gold standard. Other bone substitute materials form bone from osteoinduction and or osteoconduction in varying degrees.

http://dx.doi.org/10.5772/53401

Osteogenesis is new bone formation. New bone forms from osteoprogenitor cells that are present in the graft. They survive the transplantation, proliferate and differentiate to osteoblasts. *This is termed phase I osteogenesis*. Autogenous bone is the only graft material with osteogenic properties. [4]

Osteoinduction involves new bone formation by stimulation and recruitment of osteoprogenitor cells derived from undifferentiated mesenchymal stem cells at the graft site, *this is called phase II osteogenesis*. The method of recruitment and differentiation occurs through a cascade of events triggered by graft- derived inducing factors called *bone morphogenic proteins* (BMP), which are members of the transforming growth factor-β superfamily. These BMPs are present in the matrix of the graft and are accessed after the mineral content of the graft has been removed by a chemical dissolution process and or osteoclastic activity. It has been shown that osteoinductive materials can induce bone formation even in ectopic sites (subcutaneous tissue). [5]

Osteoconduction is the ingrowth of the vascular tissue and mesenchymal stem cells into the scaffold structure provided by a graft material. Bone formation occurs by resorption or apposition from the existing or surrounding bone. This process is called *creeping substitution*; *and also classified as phase III osteogenesis*. This process must occur in the presence of vital bone or undifferentiated mesenchymal cells. Osteoconductive materials do not grow bone when placed in soft tissue. Instead, the material remains relatively unchanged or resorbs. [6]

2.3. Types of bone grafts

Autografts are grafts harvested from the individual. Autogenous bone uses all three known mechanisms of bone regeneration. They are also non immunogenic and its superiority comes from the transfer of osteocompetent cells. [7]Autogenous bone can be harvested from multiple sites within the body. The most common intra-oral sites are the symphysis, maxillary tuberosity, ramus, coronoid process, and or shavings from osteotomy preparations. The advantage of harvesting intra-orally are, ease of harvesting and the harvest site being within the same reconstruction field. The major disadvantage of intra-oral harvesting is the limited amount and quality of the harvested bone. Extra-oral bone graft harvesting is used to provide large volumes of the material and is indicated for major augmentation procedures. Iliac crests, tibia, fibula, and the cranial bone are common sites for graft harvesting. [8]

Allografts are grafts taken from the same species as the host, but is genetically dissimilar. The grafts are prepared as fresh, frozen, freeze-dried, mineralized and demineralized. There are numerous configurations of allograft bone, including powder, cortical chips, cancellous cubes, cortical struts, and others. Once the grafts are harvested, they are processed through different methods, including physical debridement, ultrasonic washing, treatment with ethylene oxide, antibiotic washing, gamma irradiation for spore elimination, and freeze drying. The goal of these steps is to remove the antigenic component and reduce the host immune response while retaining the biologic characteristics of the graft. However, the mechanical properties of the graft are often weakened (Table 1) [9]

Allogenic bone is principally osteoconductive, although, it may retain some osteoinductive capability. This quality is dependent upon how the material is processed. Urist in 1965

described the process of acid demineralization of bone before implantation by using hydrochloric acid. The organic bone matrix contains bone morphogenic proteins (BMPs). These proteins are responsible for the de novo bone formation. BMP is not acid soluble, however the calcium and phosphate salts of the HA can be removed from the bone in the acid- reducing process. This results in demineralization of the freeze-dried bone (FDB) and an increased exposure of the BMPs with its osteopromotive effect. FDB is primary osteoconductive while demineralized freeze dried bone (DFDB) is believed to be osteoinductive. [10] Results of studies performed using DFDB are conflicting. Controversy still exists about the osteopromotive effects of DFDB. Some reports raise the question of the concentration variability of BMPs in commercially available grafts. Osteoinductive properties of DFDB vary from one cadaver to another. The product fabrication may also have an effect on the osteoinductivity of the allograft where the demineralization process is very technique sensitive. For example, it has been shown that the osteoinductive properties of the grafts are removed, if the calcium content is less than 2% by weight. In addition, controversy persists about the use of ethylene oxide for sterilization of the graft materials and its possible destructive affects on the BMPs. [11]Demineralized cortical bone was found to have higher concentrations of BMPs than trabecular bone. Membranous cortical bone exhibits greater concentration of BMPs than endochondral cortical bone, consequently; the skull and facial bone represent a better source of inductive proteins than the remaining appendicular skeleton.

Routine studies are performed to evaluate the safety of allografts. According to the American association of tissue banks the probability of DFDB to contain HIV virus is 1 in 2.8 billion. When compared with the risk of 1 in 450,000 for blood transfusions, the risk of infection from allografts seems infinitesimal. Rigorous background checks are performed on the donor and his/her family before the donor is accepted into the program. Occasionally biopsy specimens of sites containing allograft from human patients sometimes show chronic inflammatory cells. These histologic appearances of a non-specific inflammatory condition cannot be attributed to an immune reaction with certainty.[6]

Xenografts are derived from the inorganic portion of bone of a genetically different species than the host. One of the most popular used xenografts is the bovine bone. It is a good bone bank material. The process requires complete de-proteinization at high temperature, (1100 °c). This results in total removal of the residual organics that might provoke an immune response (Table 2). [12]

A concern over the risk of disease transmission from cattle to humans through the bone graft material derived from bovine bone used for dental implants has been suggested. The recent incidents of *bovine spongiform encephalopathy* (BSE) in human have underscored this likelihood. Results from analysis conducted by the German Federal Ministry of Health and by the Pharmaceutical Research and Manufacturers Association of America showed that the risk of disease transmission was negligible and could be attributed to the stringent protocols followed in sourcing and processing of the raw bovine bone used in the commercial products. [13] One of the best known xenografts is *Bio-Oss* (Osteohealth, Shirley, NY). It has been treated by having all its organic material removed. This leaves a crystal structure that practically matches human cancellous bone in structure. In 1992, Klinge and colleagues, noted total resorption of Bio-Oss

http://dx.doi.org/10.5772/53401

granules at 14 weeks after placement in rabbit skulls. [14] However, Skoglund and colleagues reported that granules were present even after 44 months [15].

Another popular alternative xenograft is *coralline hydroxyapatite*, which is made from ocean corals. This material was created with the intension of producing a graft material with a more consistent pore size. Coral, which is composed mainly of calcium carbonate, is processed to remove most of the organic content. Then it is subjected to high pressure and heat in the presence of an aqueous phosphate solution. When this process is completed, the calcium carbonate skeleton is totally replaced with a calcium phosphate skeleton (hydrothermal exchange). The material is concurrently sterilized in this process. [16] The generation of biomimetic microenvironments, using scaffolds containing cell recognition sequences in combination with bone cells, offers tremendous potential for skeletal tissue regeneration. *PepGen P15* (DENTSPLY Friadent CeraMed, Lakewood, CO) is the first man engineered collagen I binding domain for potential osteoblasts and is able to multiply the complete regeneration cascade (Figs. 2,3). It is a combination bone replacement graft material composed of natural anorganic bovine-derived hydroxyapatite matrix (ABM) coupled with a synthetic cell-binding peptide (P-15). [17]

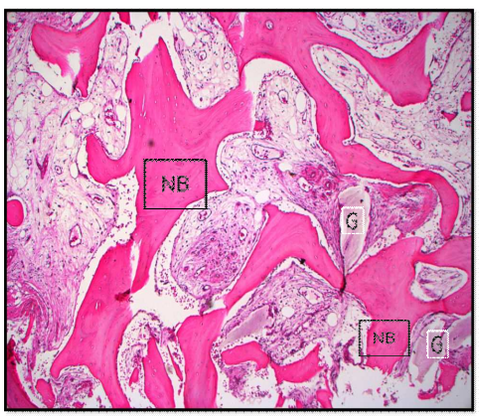


Figure 2. Microphotograph (16 weeks 5x 1.25 OP H&E) showing newly formed bone (NB) in an interconnecting trabecular pattern (bone bridging) surrounding the remaining graft particles G. (PepGen P-15).

Alloplasts are synthetic bone substitutes that posses osteoconductive potential. The ideal synthetic graft material should be biocompatible and elicit minimal fibrotic changes. The graft should support new bone growth and undergo remodeling. Other preferred attributes would include similar toughness, modulus of elasticity, and compressive strength compared to that of the host cortical or cancellous bone. Many synthetic materials are available including: Bioactive glasses, glass ionomers, aluminum oxide, calcium sulphate, calcium phosphates as α and β tricalcium phosphate (TCP), synthetic hydroxyapatite (HA), and synthetic absorbable polymers. [16] Synthetic bone substitutes offer many advantages; however, the greatest is the unlimited supply and avoidance of a secondary surgical procedure. The main disadvantage is the material's lack of the osteoinductive capabilities, experienced in autogenous grafts. Clinicians may prefer performing grafting procedures using *combination grafts*. This will combine the osteogenic potential of autogenous bone with the unlimited supply offered by



Figure 3. Microphotograph (8 weeks 5x 1.6 OP Paragon) showing the newly formed bone (NB) in an interconnecting trabecular pattern (bone bridging-arrows) surrounding the remaining graft particles G (PepGen P-15) supporting a dental implant.

bone substitutes which act as *expanders* or *fillers*. Combination grafts also minimize donor site morbidity that occurs more frequently when harvesting larger volumes of autogenous bone (Table 3).

Allografts				
Material	**Commercial source**	**composition**	**Bone Growth Method**	**Resorption time**
DFDB (Demineralized)	Pacific Tissue Bank Grafton MTF DynaGraft	Collagen + Growth factors	Mainly Osteoinduction varies based upon processing method	+/- 6 months
FDB (Mineralized)	MinerOss Puross	Minerals + Collagen	Mainly Osteoconduction	1 Yr +

Table 1.

Xenografts		
Material	**Brand name**	**Structure**
Deprotenized bovine bone mineral	Bio-Oss	Cancellous or cortical
Anorganic bovine HA+ cell binding peptide	PepGen P-15	Peptide + microporous HA
	Osteograft N	Micro + Macroporous
Coral (Ca carbonate)	Biocoral Interpore 200 (Coralline)	Natural coral

Table 2.

http://dx.doi.org/10.5772/53401

Alloplasts	
Ceramics	**Polymers**
β-tricalcium phosphate (β-TCP)	Methylmethacrylate (HTR synthetic bone)
Hydroxyapatite (HA), (Bone source, Norian)	Poly- α- hydroxy acids (PLA,PLGA)
Ca2So4 (Plaster of paris)	
Calcium phosphate cements (Ceredex, α-BSM)	
Bioactive glass (PerioGlass, BioGran)	

Table 3.

2.4. Properties of graft materials

It is important to consider the physical and chemical properties of the graft materials used in the augmentation procedures. *Physical properties* include the surface area or form of the product (block, particle), porosity (dense, macroporous, microporous), and crystallinity (crystalline, amorphous). *Chemical properties* are related to calcium –to- phosphorous ratio, element impurities (such as carbonate), and the pH of the surrounding region. These properties play a role in the rate of resorption and clinical applications of the material.[7] The larger the particle size, the longer the material will remain at the augmentation site. It was also reported that the greater the porosity, the more rapid the resorption of the graft material as this will give the chance for committed cells and blood vessels (bone modeling unit) to invade the spaces between the graft particles replacing the graft with the newly formed bone. However, dense HA may lack any micro or macro porosity within the particles with long resorption rate since the osteoclasts only attack the surface and cannot penetrate the dense material. With respect to crystallinity, the higher the crystalline structure the harder for the body to break down and absorb it.[7] The resorption of bone substitutes may be cell or solution- mediated. Cell mediated resorption requires living cells of the body to resorb the material mainly osteoclasts. A solution –mediated resorption is a chemical process; impurities like calcium carbonate permit solution – mediated resorption, which then increases the porosity of the graft. The pH in the region also affects the rate of graft resorption. As the pH decreases (due to infection) the HA components resorb by a solution – mediated resorption. Bone, dense HA, macroporous HA, microporous HA, crystalline HA, or amorphous HA may all resorb within a two-week period (Fig. 4).[7]

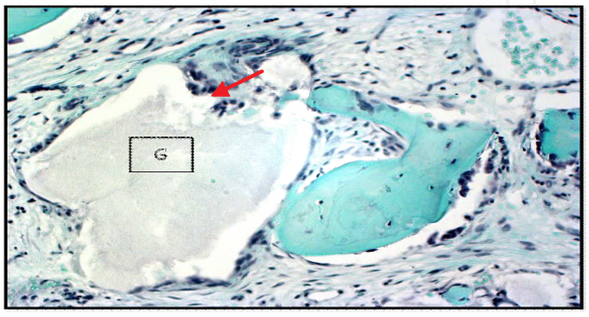


Figure 4. Showing the cell - mediated resorption of multinucleated cells (arrow) on the surface of the graft particle (G).

Close matching of the resorption rate to the bone deposition rate is important. Selection of graft material should be based on location of graft site, soft tissue environment, and its possible role in promoting and supporting future implant osseous integration. A rapidly resorbing scaffold might reestablish a void filled with connective tissue, whereas one that resorb too slowly, or not at all, would impede bone deposition and limit creeping substitution. There are, however clinical indications in which resorption is not desired, but rather, a permanent implant is preferred, such as craniofacial onlays for cosmetic augmentation.

2.5. Bone growth factors

The term growth factors comprises a group of polypeptides of approximately 6-45 KD (kilo Dalton) which are involved in cellular proliferation, differentiation and morphogenesis of tissues and organs during embryogenesis, postnatal growth, and adulthood. [18] Factors that are involved in the regeneration and induction of bone tissue have attracted attention as they possibly can facilitate skeletal reconstruction. These factors include platelet derived growth factor (PDGF), vascular endothelial growth factor (VEGF), insulin like growth factors (IGF), transforming growth factor β (TGF β), bone morphogenic proteins (BMPs), and platelet rich plasma (PRP).

Bone morphogenic proteins (BMPs), particularly BMP2, BMP4 and BMP7, appear to be the most reliable factors of all growth factors currently discussed with regard to enhancement of bone regeneration in reconstruction of the facial skeleton (Table 4). BMPs stimulate angiogenesis, migration, proliferation, and differentiation of mesenchymal stem cells into bone forming cells in the area of bone injury. Although a high washout effect of BMP during the first few hours in most of the carriers used has to be taken into account, this short-term signal appears to be sufficient for the initial induction of the cascade of endochondral bone formation to provide bone regeneration in the defects of the various models. Recombinant techniques are now used to provide large amounts of BMPs which are normally present in very small quantities within the organic matrix of bone (accounting for only approximately 0.1% of the mass of the organic matrix). [19] Bioactive Proteins, GEM 21S® is a combination of a bioactive proteins (highly purified recombinant human platelet derived growth factor, rhPDGF-BB) and a biocompatible osteoconductive matrix (beta-tricalcium phosphate, β-TCP). It is presently being used for periodontal regeneration procedures and offers a greater amount of growth factors as normally found in Platelet Rich Plasma (PRP).

The apparent strong desire of clinicians for the use of growth factors to facilitate reconstructive surgical procedures by obviating the need for procurement of autogenous grafts is contrasted by their limited availability for clinical application. This has prompted the application of autogenous growth factors by using *platelet rich plasma (PRP)* derived from the patient's own blood. This preparation has come widely into use recently, despite the fact that currently there is controversial scientific evidence about the benefit of using this preparation, especially, in reconstructive and preprosthetic bone grafting. According to the characteristics of the growth factors that are present in PRP and assigned for its biological activity, the use of PRP is supposed to increase proliferation of undifferentiated mesenchymal cells and to enhance angiogenesis, which then can support bone graft incorporation by enhancing of osteoproge-

http://dx.doi.org/10.5772/53401

nitor cells in the graft. It may as well improve soft tissue healing by increasing proliferation and matrix synthesis. [20] Recently, inorder to improve the handling characteristics of the graft materials to facilitate its use in several clinical situations, several commercial suppliers have begun to provide several matrices and delivery systems as carriers. The addition of the carrier changed the consistency of the material from a particulate consistency to a more coherent hydrogel form (flow) or clay like (putty) form with ease in handling during surgical application. The carrier must be nontoxic and biocompatible and should not impede any of the steps of the bone-forming cascade. Also, when used with growth factors they must first bind to them, permit their timed release, facilitate invasion of blood vessels and enable cellular attachment, finally promoting the deposition of new bone. Sodium hyaluronate, carboxymethylcellulose, poly-α- hydroxy acids, absorbable collagen sponges (ACS) and Lecithin are among the carrier materials used. In addition to the handling characteristics, it is assumed that the carrier material when added to a particulate graft will provide spaces between these particles (lower packing density), facilitating the capillary in-growth and the creeping substitution process leading to proper healing with optimum new bone formation in a shorter period of time.

BMPs approved for clinical use and indications
rhBMP-2 (Wyeth/Medtronic)
InductOs (CHMP approved)
Open tibia fracture, 2002
Interbony spinal fusion, 2005
INFUSE Bone Graft (FDA approved)
Interbony spinal fusion, 2002
Open tibia fracture, 2004
Oral/Maxillofacial, 2007
rhOP-1 (Stryker)
OP-1 Implant (FDA HDE & CHMP approved)
Recalcitrant long bone nonunions, 2001/2004
OP-1 Putty (FDA HDE approved)
Osteolateral (intertransverse) lumbar spinal fusion revision, 2004.
Bioactive proteins Gem 21S (Osteohealth), Periodontal defects

Table 4.

3. Treatment plan for bone augmentation

The treatment planning sequence for implant dentistry begins with the design of the final prosthesis. After the determination of the type of restoration, number and position of teeth to be restored and the patients force factors are then evaluated. The bone density in the region of the implant placement is then considered. The key implant positions and the number and ideal implant sizes are then selected. Finally the available bone volume is evaluated for implant placement according to the proposed treatment plan. Previous studies have shown that the

most common cause of implant failures are stress-related failures especially after loading. Mechanical stress can have both positive and negative consequences for bone tissue and, thereby, also for maintaining osseointegration of oral implants. Dental implants function to transfer occlusal loads to the surrounding biological tissues. If occlusal loads are within the bone physiologic tolerance zone, osseointegration will be maintained. On the other hand, if occlusal loads are excessive and beyond the bone physiologic tolerance limit, bone will ultimately resorb and failure of osseointegration result. Thus, as a general rule the goal of treatment planning should be to minimize and evenly distribute the mechanical stress in the implant system and the surrounding bone. [21] The magnitude of stress depends on two variables which are: The *force magnitude* that is hard to control by the dentist and the *functional cross-sectional area* which participate in load bearing and stress dissipation. This area should be considered when executing the treatment plan, where it should be adequate to allow optimum stress distribution and prevent stress concentration around dental implants. There are three types of forces may be imposed on dental implants within the oral environment namely compression, tension and shear forces. Bone is strongest when loaded via compression, 30% weaker when loaded via tension and 65% weaker when loaded with shear forces. Considering the *direction* of applied occlusal loads during implant placement is important; implants should be aligned in the oral cavity to convert these loads into more favorable compressive loads at the bone-implant interface. Therefore, in the treatment plan, implants should be oriented to receive axial forces parallel to the long axis of the implants as much as possible to avoid the destructive effects of angled forces. [22], [23]

3.1. Rationale for bone augmentation

From the previous discussion sufficient amount of bone volume should be available to provide the optimum biomechanical foundation for implant placement. Sufficient bone volume will allow placement of wide diameter implants with sufficient length and number as needed by the treatment plan instead of using small sized, short implants that were only used because of insufficient bone volume compromising the treatment outcome. Adequate bone volume allows placement and alignment of implants with optimum axial inclination to receive occlusal forces in a more favorable axial direction. In addition to providing optimum bone volume, bone augmentation procedures offered a solution in the avoidance of injuring vital structures that were present as obstacles when considering implant therapy as a treatment option, such as close proximity to the inferior alveolar canal and the maxillary sinus. It is worth mentioning that proper selection of the implant design is of paramount importance in achieving long term success. [24] Some areas in the oral cavity require special considerations, like the poor density maxillary posterior edentulous area. Wide diameter, threaded implants with optimum length should be used to increase the bone to implant contact ratio and the surface area, allowing proper stress distribution at the bone implant interface. This can only be done in the presence of sufficient bone volume to accommodate the selected implants otherwise bone augmentation procedures are mandatory. When considering esthetics, sufficient bone volume is also necessary to achieve the desirable aesthetic outcome especially in the aesthetic (anterior) zone. The emergence profile is greatly dependant on the bone surrounding dental implants allowing optimum soft tissue drape around the abutments for ideal esthetic results. Also, the presence

http://dx.doi.org/10.5772/53401

of sufficient bone volume allows flexibility in choosing the properly sized implant for better abutment emergence profile. [25]

4. Bone augmentation techniques

4.1. Socket preservation/ Guided bone regeneration

Physiologic bone resorption results in unpredictable loss of bone following teeth extraction. This can lead to less than ideal bone volume available for implant placement especially in prolonged cases of edentulism. Multiple types of grafting materials have been used to fill the extraction sockets immediately after extraction in order to maintain the space of the extraction site and prevent its collapse. This will allow for more organized bone healing maintaining the bone height and width necessary for implant placement. Following grafting the socket, barrier membranes are used to provide guided bone regeneration by protecting the underlying grafted site during healing from undesirable cellular population from the overlying soft tissues that might compromise the outcome (Figs. 5,6).



Figure 5. Socket preservation following teeth extraction.

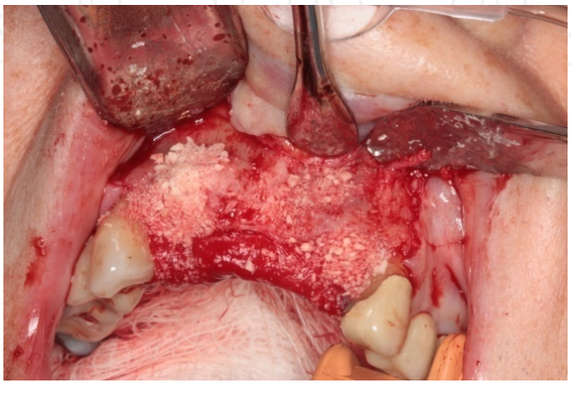


Figure 6. Grafting particulate bone

4.2. Block bone grafting technique

Block grafting approaches can be used to reconstruct significant deficiency in the vertical and horizontal dimensions of the alveolar ridge. Autogenous block grafting procedures remain the gold standard for ridge augmentation. However, donor site morbidity associated with graft harvest has turned the attention to using allogenic grafting materials. The locations for harvesting intraoral block grafts include the external oblique ridge of the posterior mandible (ramus), symphysis. With bone defects >2 cm, an extraoral donor site is warranted for harvesting larger bone volumes. The iliac crest (anterior and posterior), cranium, or tibia is often used as extraoral harvest sites. The detailed description of the harvesting techniques is beyond the scope of this chapter. Case reports have demonstrated success with FDBA and DFDBA block graft material. However, further research is warranted to evaluate the healing of these blocks histologically (Figs. 7-12).



Figure 7. Ramus bone harvest

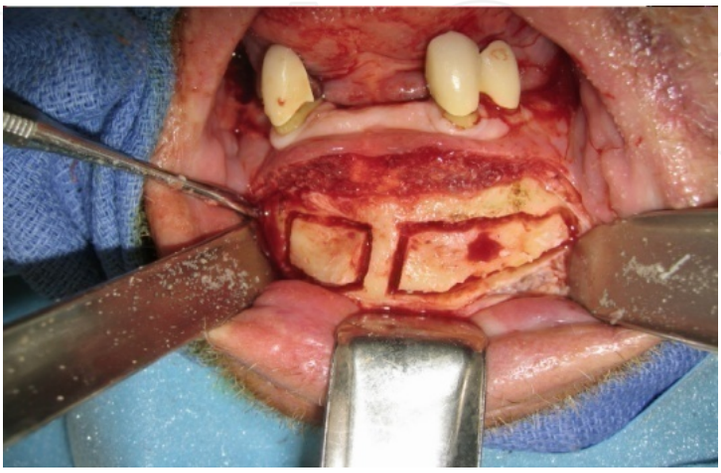


Figure 8. Symphysis bone harvest

http://dx.doi.org/10.5772/53401



Figure 9. Calvarial bone harvest



Figure 10. Anterior iliac crest bone harvest



Figure 11. Mandibular bone augmentation using block. grafts. Two screws are used to prevent rotation.

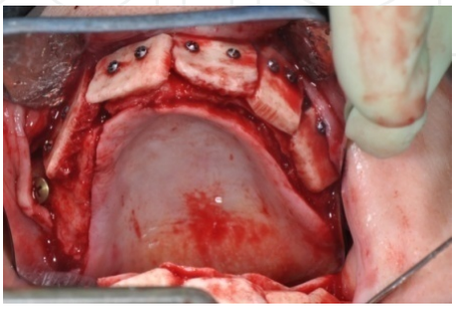


Figure 12. Maxillary ridge augmentation.

4.3. Ridge expansion (split) technique

With a narrow ridge, splitting the alveolar bone longitudinally, using chisels, osteotomes, or peizosurgical devices, can be performed to increase the horizontal ridge with, provided the facial and lingual plates are not fused and some intervening bone is present. With adequate stability of the mobile segment, sufficient interpositional grafting and soft tissue protection, comparable results to alternate techniques can be obtained. The decision to place the implants simultaneously with the split procedure or delayed placement following bone healing depend on the degree of stability of the expanded segment and the volume of remaining bone (Figs. 13-17).



Figure 13. Narrow maxillary ridge.



Figure 14. Osteotomy of the ridge

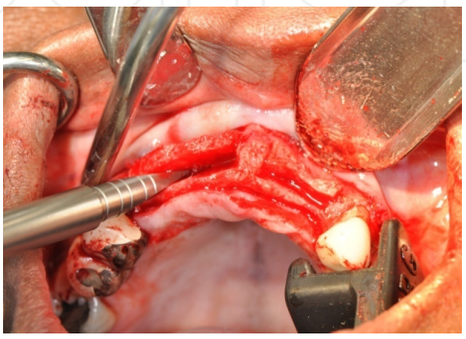


Figure 15. Ridge splitting.

http://dx.doi.org/10.5772/53401



Figure 16. Interpositioning graft between the buccal and the palatal plates of bone. Collagen membrane is used to cover the expanded site



Figure 17. The augmented maxillary ridge 5 weeks postoperatively

4.4. Sinus augmentation

The most commonly used technique use to access the maxillary sinus is the lateral window technique modifying the Caldwell-Luc operation, also called the hinge osteotomy technique, originally described by Tatum then first published by Boyne and James.

A window is then created using a round bur on the lateral wall of the sinus till the bluish hue of the sinus membrane reveals itself. Using specially designed sinus elevation curettes the sinus membrane is elevated from the bony floor and is freed anteriorly, posteriorly and medially to create a tension free elevation to minimize the possibility of perforation. The trap door (window) is intruded medially forming the new sinus floor and the space created below it is then grafted to provide the platform for implant placement. The flap is then repositioned and closed. Implants are placed either simultaneously with the graft (one- stage) or after a delayed period of up to 8 months to allow for graft maturation (two- stage). The decision about the two options mainly depends on the preexisting residual amount of bone required for initial primary stability of an implant. It was found that if the bone thickness is 4 mm or less, initial implant stability would be jeopardized. In 1994, Summers published a new less invasive conservative technique for sinus floor elevation using osteotomes in an attempt to overcome the drawbacks of the lateral window approach. The technique begins with a crestal incision to expose the alveolar ridge. An osteotome of the smallest size is then tapped into place by a mallet into the bone just shy from the sinus membrane fracturing and moving the sinus floor superiorly. Osteotomes of increasing sizes are introduced sequentially to expand the alveolus

and with each insertion of a larger osteotome, bone is compressed, pushed laterally and apically. Summers stated that the very nature of this technique improved the bone density of the posterior maxilla. Bone graft material is then introduced via the osteotomy followed by implant fixture insertion. The implant fixture should be slightly larger in diameter than the osteotomy site "tenting" the elevated maxillary sinus membrane. A minimally invasive antral membrane balloon elevation (MIAMBE) which is a modification of the osteotome technique has also been introduced with satisfactory results. It comprises the introduction of a balloon into the osteotomy site which is then slowly inflated to elevate the sinus membrane. This procedure showed predictable results and required a short learning curve. Recently, some authors have reported the use of a piezoelectric device in maxillary sinus surgery. Ultrasound has been increasingly used in many fields of medicine such as tumor enucleation, fragmentation of renal calculi and lithotripsy of gall bladder stones. Ultrasonic dissection has been classified as tissue-selective technique that might improve the efficiency of dissections and at the same time reduces the morbidity rate resulting from iatrogenic injuries. In addition, ultrasound energy can induce a cavitational effect in water containing tissues, which can in turn facilitate the tissue separation (Figs. 18,19).



Figure 18. Showing the lateral window approach

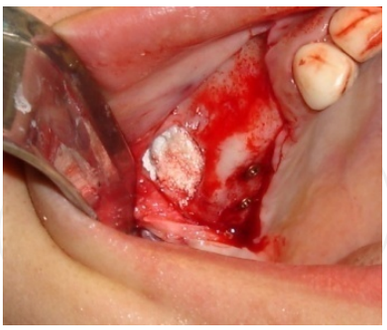


Figure 19. Sinus augmentation with immediate implant placement

4.5. Distraction osteogenesis

Distraction Osteogenesis (DO) uses the phenomenon that new bone fills in the gap defect created when two pieces of bone are slowly separated under tension. Distraction of the segment can be achieved in a vertical and /or horizontal direction on the basic principles involved in distraction which include a latency period of 7 days for initial soft callus formation,

http://dx.doi.org/10.5772/53401

a distraction phase during which the 2 segments of bone undergo incremental gradual separation at a rate ~ 1 mm per day to stretch the formed soft callus, and a consolidation phase that allows healing of the regenerated bone between the 2 segments. The prerequisites for optimal bone augmentation of defects using DO are minimum of 6-7 mm of bone height above vital structures, such as neurovascular bundles or air passages/sinus cavities, a vertical ridge defect of > 3 -4 mm, and an edentulous span of three or more missing teeth (Figs. 20,21).



Figure 20. Alveolar distraction of the anterior maxillary region

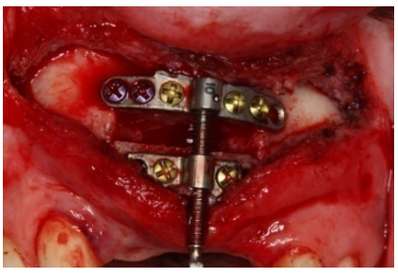


Figure 21. Note: the vertical osteotomy cuts should be divergent to avoid obstructing the path of distracting the transport segment.

4.6. Tent- Pole technique

Marx et al in 2002 advanced the approach of soft tissue matrix expansion using corticocancellous bone grafting with dental implants to treat severely resorbed mandibles that were shorter than 6 mm. Using this transcutaneous submental approach, 4 to 6 dental implants were placed to act as "tent poles" to maintain the height of the overlying mucosal soft tissue and prevent it from sagging around the iliac crest graft (Figs. 22, 23). [2]



Figure 22. Implant placement in the severely atrophic mandible through a submental approach



Figure 23. Corticocancellous bone graft around the implants tenting the soft tissue

4.7. Bone ring technique

Three dimensional bone augmentations with immediate dental implant placement can be done using this technique. Using trephine burs corresponding to the extraction socket diameters, bone rings can be harvested from the chin or iliac crest regions. The harvested rings can then be secured to the extraction socket using the dental implants restoring the deficient bone at the crestal portion in a 3D fashion (Figs. 24,25). [27]

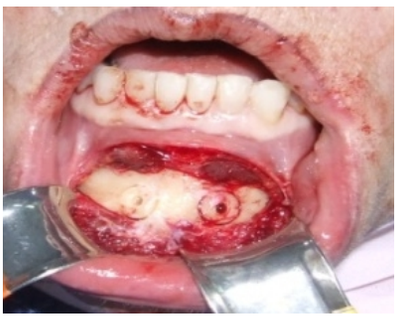


Figure 24. Three dimensional crestal bone augmentation using bone rings.

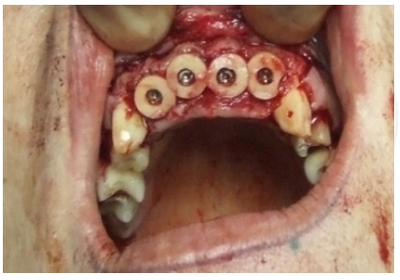


Figure 25. Immediate implant placement in the anterior maxilla

4.8. Reconstruction of segmental bony defects

Ablative loss of both bone and associated soft tissue from treatment of neoplastic or other pathologic processes represent a far different task from loss of bone from physiologic resorption, trauma or infection. The goals of reconstruction are to restore jaw continuity, provide

http://dx.doi.org/10.5772/53401

morphology and position of the bone in relation to its opposing jaw, provide adequate height and width of bone, and provide facial contour and support for soft tissue structures.

Graft malpositioning result in occlusal problems and presents a formidable task to the restorative dentist. The site of the graft harvest depends mainly on the size of the residual defect (Figs. 26-28).

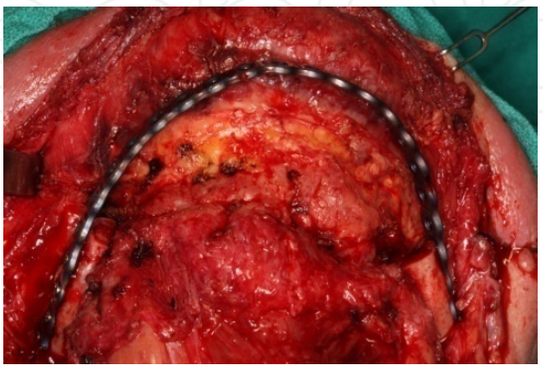


Figure 26. Reconstruction plate in place.



Figure 27. Free fibula graft.



Figure 28. Reconstruction of mandibular segmental bone defect using free fibula.

4.9. Combination grafts

In large defects, the use of grafting materials from different sources can be beneficial. Some techniques aim to combine the osteogenic potential of autogenous bone with the osteoconductive and space maintaining properties provided by the allogenic or alloplastic sources. Allogenic materials can provide constructs that are close in morphology as the resected part providing superior esthetic outcome following the grafting procedure (Fig. 29,30).



Figure 29. Hemimandibular reconstruction using a cadaveric mandible in combination with cancellous bone graft harvested from the iliac crest.



Figure 30. Graft in position.

4.10. Future augmentation approaches

Future bone augmentation approaches likely will use molecular, cellular, and genetic tissue engineering technologies. Gene therapy is a relatively new therapeutic modality based on the potential for delivery of altered genetic material to the cell. Localized gene therapy can be used to increase the concentration of desired growth or differentiation factors to enhance the regenerative response. Cellular tissue engineering strategies that include the in vitro amplification of osteoprogenitor cells grown within three dimensional constructs is currently of particular interest. The use of mesenchymal stem cell for construct seeding showed promise for bone regeneration. These approaches may lead to further refinement and improvement in alveolar bone augmentation techniques.

http://dx.doi.org/10.5772/53401

5. Surgical caveats for bone grafting

There are several factors that may improve the success and predictability of bone graft procedures, they include the following:

5.1. Surgical asepsis and absence of infection

Contamination of bone grafts due to endogenous bacteria, lack of aseptic surgical technique, inadequate soft tissue closure and salivary exposure may lead to infection with subsequent lowering of the pH. Solution –mediated resorption will follow with resultant graft loss. Some clinicians prefer including antibiotics locally within the graft materials to guard against bacterial contamination as no blood supply is present early in the graft. Primary soft tissue closure is also mandatory for the success of the grafting procedure. It allows healing by primary intension protecting the graft from any surrounding contamination until healing. Dehiscence with graft loss is one of the most common complications in bone grafting procedures. Therefore, careful surgical flap planning which ensures adequate blood supply to the site with minimal trauma and primary soft tissue closure without tension are required.

5.2. Space maintenance

Creation of a desired contoured space for bone formation is very important in the grafting procedure. If the graft material resorbs too rapidly compared with the time required for bone formation, the site may fill with connective tissue rather than bone. Therefore, the space must be maintained long enough without collapse for bone to fill the desired area. Titanium-reinforced barrier membranes, tent screws elevated above the bone at the desired height covered by a membrane, block grafts (covered by membrane or not) are all used to create and maintain space for bone growth.

5.3. Graft stability

For predictable bone augmentation, graft stability is a paramount. Bone remodeling and graft healing requires rigid interface for blood clot adhesion with its associated growth factors. If a graft become mobile its vascularity will be compromised followed by fibrous encapsulation and often sequestrate. If block grafts are used fixation can be achieved using titanium screws or the graft can be fixed using the inserted implants itself. If particulate graft is used, it can be covered with a barrier membrane fixed with membrane tacks to avoid dislodgement of the graft particles.

5.4. Regional acceleratory phenomenon (RAP)

The host site during bone augmentation procedures should be decorticated to establish bleeding points in the cortical bone prior to graft placement. This procedure will provide access for trabecular bone vessels, encourage revascularization, bring growth factors to the graft site and increase the availability of osteogenic cells promoting graft union and shorten the healing time.

Acknowledgements

The authors would like to extend their gratitude and acknowledgement to **Drs. Solon Kao DDS and Henry "Butch" Ferguson DMD**, for allowing the use of several clinical surgical cases. Their photographic documentation of specific bone grafts and regenerative techniques was instrumental in providing comprehensive examples of implant site reconstructions.

Author details

Hany A. Emam[1,2] and Mark R. Stevens[1]

*Address all correspondence to: hemam@georgiahealth.edu; mastevens@georgiahealth.edu

1 Oral and Maxillofacial Surgery Department, Georgia Health Sciences University, Augusta, Georgia, USA

2 Oral and Maxillofacial Surgery, Cairo University, Egypt

References

[1] Aghaloo, T. L, & Moy, P. K. Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement? Int J Oral Maxillofac Implants (2007). Suppl:, 49-70.

[2] Jensen, J, Sindet-pedersen, S, & Oliver, A. J. Varying treatment strategies for reconstruction of maxillary atrophy with implants: results in 98 patients. J Oral Maxillofac Surg (1994). discussion 16-8., 52(3), 210-6.

[3] Isaksson, S, & Alberius, P. Maxillary alveolar ridge augmentation with onlay bone-grafts and immediate endosseous implants. J Craniomaxillofac Surg (1992). , 20(1), 2-7.

[4] Giannoudis, P. V, Dinopoulos, H, & Tsiridis, E. Bone substitutes: an update. Injury (2005). Suppl 3:S, 20-7.

[5] Browaeys, H, Bouvry, P, & De Bruyn, H. A literature review on biomaterials in sinus augmentation procedures. Clin Implant Dent Relat Res (2007). , 9(3), 166-77.

[6] Khan, S. N, & Cammisa, F. P. Jr., Sandhu HS, Diwan AD, Girardi FP, Lane JM. The biology of bone grafting. J Am Acad Orthop Surg (2005). , 13(1), 77-86.

[7] Misch, C. E, & Dietsh, F. Bone-grafting materials in implant dentistry. Implant Dent (1993). , 2(3), 158-67.

[8] Clavero, J, & Lundgren, S. Ramus or chin grafts for maxillary sinus inlay and local onlay augmentation: comparison of donor site morbidity and complications. Clin Implant Dent Relat Res (2003). , 5(3), 154-60.

[9] Marx, R. E. Bone and bone graft healing. Oral Maxillofac Surg Clin North Am (2007). v., 19(4), 455-66.

[10] Wikesjo, U. M, Sorensen, R. G, Kinoshita, A, & Wozney, J. M. RhBMP-2/alphaBSM induces significant vertical alveolar ridge augmentation and dental implant osseointegration. Clin Implant Dent Relat Res (2002). , 4(4), 174-82.

[11] Zhang, M, & Powers, R. M. Jr., Wolfinbarger L, Jr. Effect(s) of the demineralization process on the osteoinductivity of demineralized bone matrix. J Periodontol (1997). , 68(11), 1085-92.

[12] Kao, S. T, & Scott, D. D. A review of bone substitutes. Oral Maxillofac Surg Clin North Am (2007). vi., 19(4), 513-21.

[13] Sogal, A, & Tofe, A. J. Risk assessment of bovine spongiform encephalopathy transmission through bone graft material derived from bovine bone used for dental applications. J Periodontol (1999). , 70(9), 1053-63.

[14] Klinge, B, Alberius, P, Isaksson, S, & Jonsson, J. Osseous response to implanted natural bone mineral and synthetic hydroxylapatite ceramic in the repair of experimental skull bone defects. J Oral Maxillofac Surg (1992). , 50(3), 241-9.

[15] Skoglund, A, Hising, P, & Young, C. A clinical and histologic examination in humans of the osseous response to implanted natural bone mineral. Int J Oral Maxillofac Implants (1997). , 12(2), 194-9.

[16] Moore, W. R, Graves, S. E, & Bain, G. I. Synthetic bone graft substitutes. ANZ J Surg (2001). , 71(6), 354-61.

[17] Nguyen, H, Qian, J. J, Bhatnagar, R. S, & Li, S. Enhanced cell attachment and osteoblastic activity by peptide-coated matrix in hydrogels. Biochem Biophys Res Commun (2003). , 15.

[18] Schilephake, H. Bone growth factors in maxillofacial skeletal reconstruction. Int J Oral Maxillofac Surg (2002). , 31(5), 469-84.

[19] Wikesjo, U. M, Huang, Y. H, Polimeni, G, & Qahash, M. Bone morphogenetic proteins: a realistic alternative to bone grafting for alveolar reconstruction. Oral Maxillofac Surg Clin North Am (2007). vi-vii., 19(4), 535-51.

[20] Marx, R. E, Carlson, E. R, Eichstaedt, R. M, Schimmele, S. R, Strauss, J. E, & Georgeff, K. R. Platelet-rich plasma: Growth factor enhancement for bone grafts. Oral Surg Oral Med Oral Pathol Oral Radiol Endod (1998). , 85(6), 638-46.

[21] Isidor, F. Influence of forces on peri-implant bone. Clin Oral Implants Res (2006). Suppl , 2, 8-18.

[22] Misch, C. Contemporary Implant Dentistry. Mosby Inc., Elsevier (2008). Third Edition., 200-229.

[23] Bidez, M. W, & Misch, C. E. Issues in bone mechanics related to oral implants. Implant Dent (1992). , 1(4), 289-94.

[24] Rieger, M. R, Adams, W. K, Kinzel, G. L, & Brose, M. O. Finite element analysis of bone-adapted and bone-bonded endosseous implants. J Prosthet Dent (1989). , 62(4), 436-40.

[25] Jivraj, S, & Chee, W. Treatment planning of implants in the aesthetic zone. Br Dent J (2006). , 201(2), 77-89.

[26] Marx, R. E, Shellenberger, T, Wimsatt, J, et al. Severely resorbed mandible: Predictable reconstruction with soft tissue matrix expansion (tent pole) grafts. J Oral Maxillofac Surg 60:8, (2002).

[27] Stevens, M. R, et al. Implant bone rings. One-stage three-dimensional bone transplant technique: a case report. J Oral Implantol, (2010). , 69-74.

IntechOpen