REVIEW ARTICLE

Bone Augmentation Materials: A Literature Review

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Abstract

Bone augmentation materials have been a backbone of Surgical Prosthodontics and Implant Dentistry. The need for better healing and availability of bone for various prosthesis bone grafts have been extracted or manufactured from various sources. Advancements in the properties of bone grafts has lead to improvement in the success rates and better treatment outcomes.

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Key words: Bone Augmentation, Autografts, Allografts, Xenografts, Osteogenesis, Osteoinduction, Osteointegration, DFDBA, FDBA.

Definition

According to Glossary of Prosthodontic terms a tissue or material used to repair a defect or deficiency.

The dense, semi-rigid, porous, calcified connective tissue forming the major of the skeleton of most vertebrates.

Introduction

The dense, semi-rigid, porous, calcified connective tissue forming the major portion of the skeleton of most vertebrates are used as bone augmentation materials.

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Now-a-days Medical world is in a transition from curing damaged organs of the patient by lengthy surgical operations to replacing the damaged organ completely with in vitro synthesized implants. Artificial soft tissues and organs are product of the research on the growth of stem cells on bioactive scaffolds and will be commonly available soon following extensive biomedical research and development. Hard tissue and bone replacements are synthesized mainly from bioactive and strong materials with similar chemical and phase structure to the hard tissues.

Bone graft is the second most common transplantation tissue, with blood being by far the commonest. More than 2.2 million bone grafting procedures are performed worldwide annually in order to repair bone defects in Orthopedics, Neurosurgery and Dentistry. Bone grafting is usually required to stimulate bone healing. Several types of materials for reconstructing defective bones are available namely using Autografts, Allograft, Demineralized bone matrix, Hydroxyapatite Calcium Phosphate, Autologus Bone Marrow Aspirates, Bone Morphogenetic Proteins, and several other related growth factors (Table 1).

Table 18–1. Categories of Materials

	Values	Shortcomings
A *Autografts* This type of bone is "self–donated" by your patient. Source:		
a Iliac crest	Patient's own bone Osteogenic Availability	Second site morbidity Requires general anesthesia Prolonged postoperative recover
b Ascending ramus or symphysis of mandible	Patient's own bone Osteogenic Availability	Second site morbidity Prolonged postoperative recover
c Torus	Patient's own bone Osteogenic	Host site availability Second site morbidity
d Rib or tibial plateau	Patient's own bone Osteogenic Availability	Second site morbidity Requires general anesthesia Prolonged postoperative recover
B *Homografts/Allografts* This type of bone is donated from a human source other than the patient. Source: bone banks Types available:		
a Demineralized freeze-dried bone	Availability Osteoconductive Biologic acceptability Replaced by patient's own bone	Cost Patient may not accept
b Bone morphogenic protein	Osteogenic Replaced by patient's own bone	Cost Not readily available
c Demineralized bone matrix	Osteogenic Replaced by patient's own bone	Cost Not readily available
C *Xenografts* This type of bone is donated from a species other than man. Source: Bovine Types:		
a Bio-Oss	Availability Osteoconductive Patient acceptance Biologic acceptability	Cost Unproven track record
D *Alloplasts* These are synthetic bone materials. Source: a variety of manufacturers Types: a Nonresorbable		
1. Polymer: Bioplant Inc., HTR (hard tissue replacement; U. S. Surgical Cooperation)	Availability Osteoconductive Hydrophillic Patient acceptance Biologic acceptability Nonresorbable	Cost nonresorbable
2. Ceramic: HA (Calcitek Orthomatrix, Interpore, Ceramed)	Availability Osteoconductive Patient acceptance Biologic acceptability Nonresorbable	Cost nonresorbable
b Resorbable (TCP) ceramic; Osteogen, Synthograft	Availability Osteoconductive Patient acceptance Biologic acceptability	Cost Absorbability Questionable predictability

Research on synthesis of new biomaterials involves the use of present biomaterials in a new composite material with enhanced properties, modifications of the microstructure of the present biomaterials and chemical synthesis of new novel biomaterials. Material scientists are currently working on projects for the synthesis of biocompatible materials which mimic the properties of natural bone.

Bone formation in grafting is characterized by three types of bone growth: Osteogenesis (Fig. 1), Osteoinduction and Osteoconduction (Fig. 2). Osteogenesis is the formation of new bone by Osteoblasts derived from the graft material itself. Osteoinduction is the ability of a material to induce the formation of Osteoblasts from the surroundings tissue at the graft host site, which results in bone growth. Osteoconduction is the ability of a material to support the growth of bone over a surface.

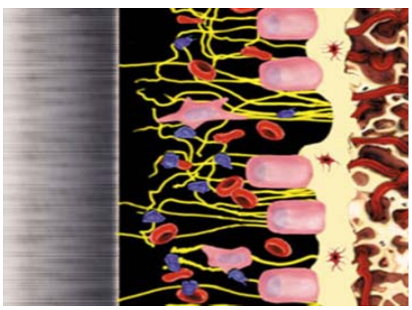

Fig. 1: Osteogenesis

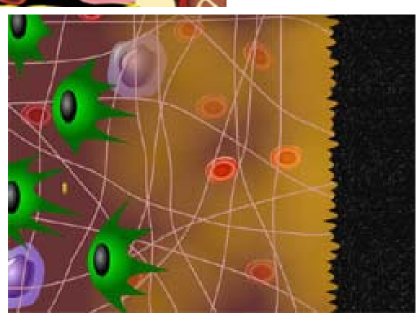

Fig. 2: Osteo-conduction

Although not directly responsible for bone formation, an additional characteristics, Osteointegration (Fig. 3), which is the ability to chemically bind to the surrounding bone, is desirable to aid in the incorporation of the graft at the host site.

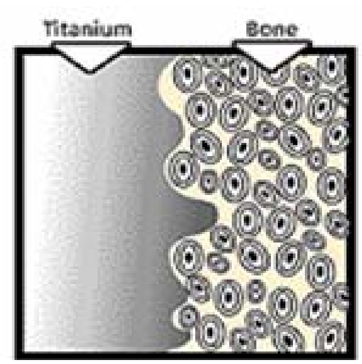

Fig. 3: Osteo-integration

Applications include:

- Extraction socket grafting
- Ridge and sinus augmentation
- Bone augmentation around implant
- Bony defects
- Periodontal regeneration

Materials for bone graft

Autogenous bone grafts

Autogenous bone grafts, also called Autografts, are bone grafts transferred from one site to another site within same individual. Autogenous graft can be cortical or cancellous or a combination of both. The disadvantages of Autogenous grafts are the amount of available graft material and the morbidity associated with their harvest. These disadvantages have led to the development of myriad grafting materials that can be classified into following categories:

Allografts, also called **Allogenic**, **Homologus**, or **Homografts**, are composed of materials taken from another individual of the same species. **Xenograft/heterografts** or **xenogenic** grafts, are materials derived from another species. Alloplastic grafts, or synthetic grafts, are artificial or manufactured materials and can be subdivided based upon their origin and chemical composition.

Allografts

Allografts are cadaveric in source of origin. This type of grafting material is attractive because it closely matches the recipient in constitutional elements and architecture and is theoretically available in unlimited quality. The fundamental problems of this grafting material are antigenicity and the potential for transmission of diseases. Allografts for maxillofacial and periodontal use generally come as Demineralized Freeze-Dried Bone Allografts (DFDBA) or Mineralized Freeze-Dried Bone Allografts (FDBA). Human studies and case reports for the use of these materials in the maxillofacial region have indicated that:

Ridge augmentation and sinus grafting with freeze-dried bone allograft in combination with platelet-rich plasma provides a therapeutic alternative for implant placement.[12] Additionally mineralized solvent dehydrated cancellous bone allografts were replaced by newly formed bone significantly faster and in greater quantities in the maxillary sinus when compared to a composite of DFDBA and deproteinized bovine bone xenografts.[16]

Minichetti and colleagues[15] studied the grafting of extraction sockets with particulate mineralized bone allograft and concluded that it demonstrated the formation or remodeling of bone and was clinically useful in maintaining bone volume for implant placement after extraction.

Xenografts:

Disease transmission, antigenicity, deficit supply and psychological aversion, for allografts has led to the exploration of xenografts as an alternative grafting material. Studies on animal have revealed: Bovine bone granules possess better osteoconductive potential than bioglass crystal and hydroxyapatite when tested in New Zealand on rabbits[1]. Human use of xenografts demonstrated: Excellent integration of inorganic bovine material with newly formed bone suggesting the material's utility for onlay grafting procedures.[17] Biocompatibility and successful use facilitates rebuilding atrophic alveolar ridges when supported by a configured titanium mesh.[2]

Alloplasts

Alloplastic materials that have been investigated and manufactured include hydroxyapatite, coral-and algae-derived hydroxyapatite, calcium phosphates, calcium sulfates, collagen and polymer. It has the advantages of: Absence of antigenicity, No potential for disease transmission and unlimited supply. Human studies have revealed that: Hydroxyapatite bone cement seems to hold great promise as a grafting Alloplastic material for sinus floor augmentations.[14] Hydroxyapatite can be used as a porous ceramic or as a paste/cement bone graft material in human hand[11], cranium[21], and tibia[9].

Coral and algae derived hydroxyapatite:

Like other synthetic materials, coral and algae derived hydroxyapatite are not osteoinductive or osteogenic.[7] Its structure and composition mimic natural bone, however pore size[5] and inter-connectivity and particle size have shown to influence bone regeneration and growth.[18] Ewers and colleagues reported that marine derived hydroxyapatite material combined with 10% autogenous bone and plasma-rich protein produced comparable and in some cases better results than autogenous grafts in sinus augmentation procedures.

Bioactive glass

They were introduced more than 30 years ago as bone substitutes. The designation "bioactive" relates to their ability to bond to bone and enhance bone-tissue formation. This bioactivity depends on an intimate contact with bone and is limited in nature. When this material was looked at for improved healing in extraction sockets or sinus floor augmentation, either alone or in combination with other grafting materials (DFDBA, Autogeneous bone) it was found to be effective for bone regeneration.[6,8,19,20,22]

Calcium phosphate

Linhart and colleagues[13] concluded that calcium phosphate cement represents a good alternative to autogenous bone transplantation, especially in elderly patients when tri-calcium phosphate was compared with inorganic bovine bone in dog's with mandibular defects, tricalcium phosphate showed significantly greater bone formation at 12 and 24 months and better resorption than inorganic bovine bone.[3]

Calcium sulphate

Human studies most recently have concentrated on the use of this material in combination with other graft materials. Borrelli and colleagues[4] concluded that medical grade calcium sulfate increases the volume of graft material, facilitates bone formation, and is safe in the treatment of non-unions and fractures with osseous defects. Herron and colleagues[10] demonstrated resorption of calcium phosphate and its replacement with bone in rabbits.

Future trends

Future research may take place in directions of molecular biology and the effect of various influencing factors in changing the molecular architecture and physiology; the progenitor cell use; and biomimetic scaffolds.

Summary

A plethora of products in the market are designed to be used for the replacement or grafting of human bone. Each clinician must select the best product for its particular advantages when used for a defined purpose in patients. As our understanding of these processes matures, there is great hope for the development of the “ideal” substitute for the autogenous bone graft.

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