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# RESEARCH ARTICLE

## BONE GRAFT MATERIALS USED FOR REGENERATION OF RESORBED RESIDUAL RIDGE- A REVIEW

**[1]Bommareddy Radha Geethika, [2] Kalyan Chakravarthy, A., [3]Veerendra Prasad Budige, [4]Ramavarapu Avinash, [5]Bhanu Chander, V. and [6]Satya Sri, L.**

[1]MDS, Post Graduate, Department of Oral and Maxillofacial Prosthodontics and Implantology, Meghna, Institute of Dental Sciences, Mallaram, Nizamabad -503230.
[2]MDS, Professor and HOD, Department of Oral and Maxillofacial Prosthodontics and Implantology, Meghna Institute of Dental Sciences, Mallaram, Nizamabad -503230.
[3]MDS, Reader, Department of Oral and Maxillofacial Prosthodontics and Implantology, Tirumala Institute of Dental Sciences and Research Centre, Nizamabad -503230.
[4]MDS, Associate Professor, Department of Oral and Maxillofacial Prosthodontics and Implantology, Meghna Institute of Dental Sciences, Mallaram, Nizamabad -503230.
[5]MDS, Reader, Department of Oral and Maxillofacial Prosthodontics and Implantology, Army College of Dental Sciences, Yapral, Hyderabad-500087.
[6]MDS, Sr. Lecturer, Department of Oral and Maxillofacial Prosthodontics and Implantology, Meghna Institute of Dental Sciences, Mallaram, Nizamabad -503230.

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**Corresponding author:*
*Bommareddy Radha Geethika*

**ABSTRACT**

Bone grafting replaces a patient's missing bone with both natural and artificial materials. Biocompatibility, bioresorbability, structural stability, availability, ease of handling, and cost are all factors to consider when choosing an augmentation material for grafting. Osseointegrative ability refers to the graft's ability to integrate and bond with the host. There is currently no complete bone substitute that meets the requirements for biocompatibility, bioabsorption, and volume maintenance. The bioabsorbability of leftover bone substitutes and the volume maintenance of the augmented tissue are inversely related over time. An allograft is a type of human tissue obtained from someone other than the recipient of the graft. Fresh or frozen bone, FDBA, DFDBA, and cortico-cancellous bone allografts are the three types of bone allografts available. The mineral to organic matrix ratio of hydroxyapatite (HA) is similar to that of human bone. The granular form is sterile and ready to use in periodontal and other bony defects treatment, as well as bone maintenance. Cancellous bone is resorbable, and new bone will gradually replace it. Alloplastic grafts can be made with bioactive glass or hydroxyapatite. When calcium sulphate deteriorates, it loses a lot of its mechanical properties, making it a risky choice for load bearing applications. To supplement residual alveolar ridges, porous tricalcium phosphate ceramic could be used. In apical resection areas, cystic defects, extraction sockets, and alveoli, bioactive glass particles with a narrow size range promote osteogenesis. Synthetic polymers, like natural polymers, are resorbed by the body. PRF is a fibrin matrix that traps and releases platelet cytokines, growth factors, and cells over time. PRP has been shown to help with periodontal and oral surgery outcomes. PRP may aid the body's natural wound-healing mechanisms when used in dentistry.

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# INTRODUCTION

Bone grafts are bio-resorbable and have no antigen antibody reaction. Bone tissue can regenerate completely if given enough room. When a patient's bone is missing, bone grafting uses both natural and artificial materials to replace it. As the natural bone replaces the graft material, a new bone region is formed.[1] Bone grafts are often necessary to restore missing tissue and to provide structural support for implants. Alveolar bone remodeling/resorption after tooth extraction can make it difficult to place implants in adequate bone. This can result in a poor aesthetic outcome and possible premature loss of the implants.[2] The need for maxillary and mandibular bone grafting is often necessary to provide adequate bone for implant placement. Various types of grafting material can be used to augment the deficient alveolus, including the use of autogenous bone.[3] Bone heals by cellular regeneration and it is this cellular regeneration that allows bone grafts to form bone rather than forming scar. The osteogenic properties of autogenous bone make it an ideal choice for bone grafting and is more predictable when grafting large defects. Selecting an augmentation material for grafting requires knowledge of the material being used with regards to biocompatibility, bioresorbability, structural stability, availability, ease of handling, and costs.[3]

## DEFINITIONS PROPOSED BY MUSCHLER AND LANE

**Bone graft material:** It is any implanted material that, alone or in combination withother materials, promotes a bone healing response by providing osteogenic, osteoconductive, or osteoinductive activity to a local site.

An osteogenic material can be defined as one which contains living cells that are capable of differentiation into bone. An osteoconductive material promotes bone apposition to its surface, functioning in part as a receptive scaffold to facilitate enhanced bone formation. An osteoinductive material provides a biologic stimulus that induces local ortransplanted cells to enter a pathway of differentiation leading to matureosteoblasts.[4]

### Bone graft properties

**Osteogenesis:** grafts containing osteogenic cells have the necessary synthetic machinery, osteoblasts or progenitor cells, to produce new bone after transplantation. The environment of growth proteins required to induce differentiation of host progenitor cells into bone-producing cells is known as osteoinduction. Multiple signaling factors, including the transforming growth factor (TGF) superfamily, are involved in this complex process. Osteoconduction is a bioactive matrix that creates the ideal environment for bony growth. This matrix encourages and supports fibrovascular ingrowth, migration of host progenitor cells into the scaffold, osteoblast attachment, and the eventual formation of new bone. Direct contact with exposed bony surfaces is required for this passive ability. Structural integrity refers to the grafted material's compressive strength as well as torsion and shear resistance. The ability of the graft to integrate and bond with the host is known as osteointegrative ability.[5] Current bone substitute materials should be made more biocompatible. Degradation of the extracellular matrix (irregular arrangement of endogenous collagen fibres), generation of micro- or nanoparticulates, and excessive calcium ion release are thought to cause reduced biocompatibility. The volume maintenance of the augmented tissue and the bioabsorption of leftover bone substitutes are inversely related over time. [6] Bioabsorbability of bone substitutes is arranged as follows: DFDBA>> FDBA > (autogenous bone) >>CD-BB > TD-BB. There is currently no complete bone substitute that satisfiesbiocompatibility, bioabsorption, and volume maintenance requirements. [6]

## AUTOGRAFT

The "gold standard" among various graft materials is autologous or autogenous bone grafting, which involves using bone obtained from the same individual receiving the graft that is osteoinductive, osteogenic, and osteoconductive, resulting in a lower risk of graft rejection and a success rate of >95 percent.[1,6,8,9,10,12,13]

The rates of major and minor complications associated with autogenous bone graft harvest were reported to be 8.6% and 20.6 percent, respectively. [8] Nonessential bones, such as the iliac crest, mandibular symphysis (chin area), and anterior mandibular ramus, can be harvested for bone (coronoid process). The disadvantage of autologous grafts is that they require an additional surgical site, which increases the risk of postoperative pain and complications.[1] One of their disadvantages is the creation of a second trauma, which can have a negative impact on the patient's systemic health and lead to increased morbidity, especially in cases where a large amount of bone volume is collected.[7] Autogenous bone can be fixed to residual bone in block form with screws or metal mesh. Guided bone regeneration (GBR) techniques, which use semipermeable membranes to control epithelial and connective tissue cell proliferation and migration into the defect, can be used to apply bone material in particulate form. In both horizontal (lateral) and vertical augmentation, bone blocks have been used with varying clinical results.[10] The most common anatomical donor areas are the ramus and mandibular symphysis, which provide significant bone harvesting opportunities.

### Allografts

Allograft is a type of human tissue that is harvested from someone other than the person who will receive the graft. It is extracted from cadavers so that it can be used for living people who require it. It is obtained from a bone bank after extensive donor screening, which includes a detailed social and medical history as well as serological tests.[1,7,12]It's also available in Cortical,Cancellous,Cortico-cancellous.[7] There are three different types of bone allografts. A fresh or frozen bone, FDBA, DFDBA. [1,7,6,12,13]

- **Fresh frozen bone (FFB):** frozen at 8000 degrees Celsius to avoid enzyme degradation and to avoid further irradiation, lyophilization, or demineralization.. Due to disease transmission and a strong immune response, it is no longer used. [7]
- **Freeze dried bone allograft (FDBA):** dehydrated and frozen without demineralization, resulting in antigenicity reduction. It only has osteoconductive properties.[7]
- **Demineralized freeze dried bone allograft (DFDBA):** the inorganic part of the bone is removed, leaving only the organic part, which contains BMPs. These materials have osteoconductive as well as inductive properties.[7,13]

**Advantages:** Availability in sufficient quantities, sizes, and shapes, as well as predictable results and the elimination of a second donor site surgery are all advantages. Donor site surgery was eliminated, which resulted in less anaesthesia and surgery time, as well as less blood loss. Although the risk of disease transmission from the donor to the recipient is extremely low, additional testing for HIV, Hepatitis B virus, Hepatitis C virus, and Treponema serologic markers should be done. [7]

**Disadvantages:** When compared to autologous grafts, there is a higher rate of absorption and immunogenic response, as well as less revascularization and incorporation.[7] Allografts have a disadvantage in terms of quality, as the osseoconductivity of the graft material can vary.[2]

**Bone grafts classified according to their source of origin.[7]**

| Graft category | Graft type |
|---|---|
| Autografts +Isografts | Extra-oral: Cranium, Fibula, Iliac crest,<br>Radius, Rib, Tibia<br>Intra-oral: Anterior maxillary sinus wall,<br>Anterior nasal spine, Ascending ramus,<br>Coronoid process, Incisive fossa,<br>Mandibular symphysis, Maxillary tuberosity, Palate, Torus, Zygomatic body |
| Allografts. | Fresh and/or frozen bone<br>Freeze dried bone<br>Demineralized freeze dried bone |
| Xenografts | Bovine<br>Porcine<br>Equine<br>Coralline<br>Algae |
| Synthetic bone substitutes | Calcium phosphate<br>Hydroxyapatite<br>Calcium carbonate<br>Calcium sulphate<br>HTR polymer<br>Bioactive glasses |

**Comparison between autogenous bone grafts and bone graft substitutes[11]**

**Autogenous Bone**

| Advantages | Disadvantages |
|---|---|
| Osteoinductive<br>Osteoconductive<br>Osteogenic<br>No disease transmission | Nerve Injury<br>Infection<br>Hematoma<br>Fracture<br>Tooth injury Limited graft size |

**Bone Substitutes**

| Advantages | Disadvantages |
|---|---|
| Osteoinductive<br>Osteoconductive<br>Unlimited amount<br>No donor site | Less predictable<br>Disease transmission<br>Immune response |

**Hydroxyapatite**

**Indications**

- Filling concavity-shaped defects on residual medial and lateral surfaces
- alveolar ridges that have a sufficient ridge height
- To restore the contours of residual alveolar ridges where part of the ridge has been lost due to trauma or surgical excision.
- To fill postoperative central osseous defects that have taken a long time to heal after enucleation or marsupialization.

Autologous bone will graft successfully to the mandible and maxilla to provide residual alveolar ridge forms for full ridge augmentation.[14]

**Synthetic variants:** Hydroxyapatite (HA) hydrogel composite with a mineral to organic matrix ratio similar to that of human bone. Artificial bone can be made from ceramics such as calcium phosphates (e.g., HA and tricalcium phosphate), bioglass, or calcium sulphate, depending on their solubility in the physiological environment.[1,6] When these materials are combined with growth factors, ions such as strontium, or bone marrow aspirate, their biological activity is enhanced.[1]

**Hard Tissue Replacement (HTR) graft:** The granular form is sterile and ready to use in the treatment of periodontal and other bony defects, as well as in bone maintenance to preserve the alveolar ridge following tooth extraction. The dentist creates the moulded form during the construction of a tooth root or during augmentation of an edentulous ridge, chin, or cheekbone. The moulded HTR augmentation can be up to 34 inches in height and width (or greater). A provisional denture can be placed immediately for aesthetics and limited function due to the strength of the moulded HTR ridge. [15]

**Xenograft:** Bone grafts from animals other than humans, such as bovine, are used as a calcified matrix and are frequently combined with growth factors or bone grafts from other sources.[1,6,7,13] The fact that bone characteristics differ from those of humans, and that their processing procedure, as in the case of allografts, may affect their physicochemical properties, as well as the possibility of disease transmission and immunogenicity stimulation, is a disadvantage.

**Bovine substitutes:** The first xenografts used on patients are among the most well-documented materials in this category, with a wide range of products commercially available. Deproteinized and lyophilized, with no immune response. These materials' granules are thought to have poor or slow absorption and are surrounded by neoplastic bone tissue rather than going through the normal bone remodelling process. Processing at high temperatures modifies the structure of hydroxyapatite, resulting in reduced absorption potential and immune reactions, allergies, and infectious diseases like spongiform encephalopathy.[7] Processing at high temperatures modifies the structure of hydroxyapatite, resulting in reduced absorption potential and immune reactions, allergies, and infectious diseases like spongiform encephalopathy.[7]

**Equine substitutes:** While being absorbed by osteoclasts, they are able to induce osteoblastic differentiation and angiogenesis. In cases of successful sinuslift, the presence of neoplastic bone with remodelling effects was observed 6 months after surgery. [7]

**Porcine substitutes:** Given the similarity of human and porcine genomes, osteoconductive properties, and a low risk of disease transmission, exhibit structural and formation similarities to human bone. These materials' absorption capacity has been reduced over time, and neovascularization

has been slow to develop. Sinus lift procedures have been performed, with good augmentation results and a high reabsorption rate six months after surgery. [7]

**Algae substitutes:** These have been combined with growth factors such as BMPs and TGF1 because they lack antigenicity and an inflammatory host response. Increased cancellous bone around biomaterial particles resulted in successful sinus augmentation. It is resorbable and will be gradually replaced by newly formed bone. [7]

**Coral substitutes:** Porites, Acropora, Lobophyllia, Goniopora, Polyphillia, and Pocillopora are examples of madreporic corals that have striking similarities to cancellous bone. It has osteoconductive properties and acts as a carrier for growth factors, which helps to improve bone formation. They have a low mechanical strength at first, are dependent on the recipient's blood supply, and have a high resorption rate. Several studies have shown that this material can be used in dentoalveolar reconstruction with positive results.[7]

**Alloplastic grafts:** Bioactive glass or hydroxyapatite can be used to make alloplastic grafts. Because of its osteoconduction, hardness, and bone acceptability, hydroxyapatite is now commonly used. Calcium carbonate is used in some synthetic bone grafts, but it is becoming less popular because it is completely resorbable in a short period of time and makes bone breaking easier. Tricalcium phosphate is used in conjunction with hydroxyapatite to provide both osteoconduction and resorbability. [1,13]

**Bone graft substitutes made of ceramic:** The majority of available bone grafts use ceramics, either alone or in combination with another material (e.g., calcium sulphate, bioactive glass, and calcium phosphate) with osteoconduction, osteointegration, and, in some cases, osteoinduction properties. They have brittle properties and require high temperatures to form scaffolds. [1,12]Calcium sulphate is a dubious choice for load bearing applications because it loses a lot of its mechanical properties when it deteriorates.[1,7] OsteoSet is a defect packing tablet. It degrades in about 60 days. Allomatrix is a putty made of Osteoset and DBM. Allomatrix is an injectable paste made of calcium sulphate and DBM. OsteoSet is a calcium sulphate tablet used for bone defects, while allomatrix is a calcium sulphate and DBM injectable paste. [1] It can be used to treat periodontal, dentoalveolar, or extraction issues.[7] Composite bioceramics combine calcium sulphate, calcium phosphate, tricalcium phosphate, and coralline hydroxyapatite to improve material properties. Calcium phosphate is the best choice for elevating the joint surface of tibial plateau fractures. [8] TCP is biocompatible and osteoconductive, but not osteogenic or osteoinductive. Its porous structure allows for phagocytosis, absorption, vascularization, and bone regeneration. Compared to other calcium phosphate preparations, it is brittle and weak under tension and shear but resistant to compression. TCP is less mechanically stable than HA. TCP and HA are mixed in various concentrations to achieve desired mechanical and absorption properties (BCP). [7]Porous tricalcium phosphate ceramic could be used to augment residual alveolar ridges. It is inert and does not show signs of alveolar bone resorption. Tissue penetration into ceramic pores is similar to "normal" wound healing. It's ceramic and blooded. [16]

**Bioactive glass:** Bioactive glass is biocompatible and promotes osteogenesis. Bioactive glass promotes osteogenesis, according to Schepers et al. It has been shown that bioactive glass particles with a narrow size range promote osteogenesis in apical resection areas, cystic defects, extraction sockets, and alveolar ridge defects.[17] Glass resorption depends on the relative amounts of sodium oxide, calcium oxide, silicon dioxide and phosphorus.[7]

**Polymer bone graft substitutes:** Polymers come in two varieties: natural and synthetic. categorised into biodegradable and nonbiodegradable. Some polymer-based bone graft substitutes include:

Cortoss is an injectable resin-based load-bearing product. Composed of collagen fibres coated with hydroxyapatite, it is used for spinal fusions. Synthetic polymers are resorbed by the body like natural polymers. The implant being resorbed by the body allows the body to heal completely without foreign bodies. [1]

**Bone graft substitutes based on PaCells**: Stem cells are cultured with dexamethasone, ascorbic acid, and b-glycerophosphate to direct undifferentiated cells towards the osteoblast lineage. TGF-beta, BMP-2, BMP-4, and BMP-7 can influence stem cells to adopt an osteogenic lineage. Mesenchymal stem cells have also been seeded onto osteoblast-differentiating bioactive ceramics.[1] BMPs have long been linked to embryonic skeletal development and fracture healing. BMP-2 and BMP-4 signal osteoblastic commitment of adult bone marrow mesenchymal precursors. TGFb, PDGF, IGFs, and FGFs can influence the replication and differentiation of committed osteoblast progenitors toward the osteoblastic lineage, but not uncommitted progenitors.[18] Because bone cells produce multiple growth factors, the microenvironment of bone cells may contain multiple growth factors at any given time. Kasperket et al discovered that IGF-II interacts synergistically with FGF and TGF- in primary cultures of mouse calvaria bone cells. TGF- and FGF interact synergistically in cells isolated from foetalcalvaria and newborn mouse calvaria. Noda and Vogel found that basic FGF increased TGF-1mRNA in mouse calvaria-derived MC-3T3-El and human osteosarcoma SaOS-2 cells.[19]

**Platelet-rich fibrin:** PRF is a fibrin matrix that traps platelet cytokines, growth factors, and cells and releases them over time. It can also be resorbable. Choukroun and his colleagues used the PRF protocol to improve implant bone healing in oral and maxillofacial surgery. Human PRF is thought to be a healing biomaterial. Encapsulated platelets release growth factors that stimulate the periosteal mitogenic response for bone repair.[20]

**Platelet-rich plasma:** Platelet-rich plasma (PRP) has shown promise in dentistry for wound healing. After surgery, blood clots help hard and soft tissues heal. Using PRP in dentistry may help the body's natural wound-healing mechanisms. PRP and the growth factors expressed by the platelets concentrated in PRP, PDGF and TGF-, are used to help heal postsurgical wounds. [21] Both PDGF and TGF- have been shown to speed wound healing in vivo. A surgical adjunct, autologous PRP retains high levels of desired growth factors after preparation and is clinically effective in accelerating postsurgical healing in periodontal and oral surgery applications. PRP has been shown to improve surgical outcomes.

**Kieler bone graft:** Kieler bone graft is a type of bone graft that is used in minor oral surgical procedures because it is osteogenic and antigen-free (Kemkes&Kienholz 1956). They sell it as spongiosa, cortical bone, and a mix of both. The bone is placed in presumptive reciprint blood or sterile physiological saline for a short time before being cut to shape. [22] Koch and Dahmen claim that spongy Kieler bone grafts take and heal faster than cortical ones (1962). The spongy type should also be used with large pieces, as small pieces slow the healing process. [22]

# CONCLUSION

In dentistry, bone graft and substitute materials in the form of particles or blocks are used to regenerate missing hard tissue structures. New and more efficient dental grafting materials are in high demand. Current bone graft and substitute materials only satisfy the osteoconductivity criteria. Also, all non-autograft-derived materials have potential graft vs. host issues. However, as tissue engineering research advances, new developments such as ceramic and polymeric-based bone substitutes with growth factors or modified with living osteogenic progenitor cells have emerged. Our molecular understanding of these materials and growth factors improves our ability to control and modify their structure, surface properties, and interaction with other materials and the physiological environment. However, more research is required to develop dental biomaterials with porous structures, mechanical stability, controlled degradation, and remodelling ability comparable to new bone formation.

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