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Research Article

ALLOPLASTIC BONE GRAFTS

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A B S T R A C T

Periodontal disease is characterized by the destruction of periodontal tissues including periodontal ligament, alveolar bone and cememtum with subsequent loss of tooth. Conventional open flap debridement provides an access to evaluate and detoxify root surface as well as to improve periodontal form and architecture. Periodontal regenerative therapy aimed at regeneration of lost periodontal tissue with the help of use of barrier membranes, bone replacement grafts, growth factors and the combination of these procedures have been investigated. Bone replacement grafts include autografts, allografts, xenografts and allografts. These graft materials are being widely used to promote new bone formation and periodontal regeneration in periodontal therapy. This article reviews various synthetic bone substitutes available for clinical applications used for periodontal regeneration.

INTRODUCTION

To promote periodontal regeneration and bone formation various bone replacement grafts are being used widely to function as scaffold for attachment and proliferation of anchorage dependent osteoblasts. A graft is defined as any tissue or organ used for implantationor transplantation or a piece of living tissue placed incontact with injured tissue to repair a defect or supplya deficiency. [1]The use of bone grafts for reconstructing intra-osseous defects produced by periodontal disease dates back to Hegedus in 1923 [2]. Then revived in 1965 by Nabers and O'Leary. [3]Historically, autografts were the first bone replacement grafts to be reported for periodontal applications. Allogenic freeze-dried bone was introduced to periodontics in the early 1970's, while demineralized allogenic freeze-dried bone gained wider application in the late 1980's. The introduction of xenografts and alloplasts for periodontal use occurred during the same time .[4]

The purpose of this review is to provide an overview of synthetic graft materials as bone replacement grafts for periodontal regeneration.

Ideal Characteristics of a Bone Graft materials are[3,5]

1. Nontoxic,
2. Nonantigenic,
3. Resistant to infection,
4. No root resorption or ankylosis,
5. Strong and resilient,
6. Easily adaptable,
7. Ready and sufficiently available,
8. Minimal surgical procedure,
9. Stimulate new attachment and
10. Be able to trigger osteogenesis, cementogenesis and formation of a functional periodontal ligament.

Objectives of Bone Grafts

The Objectives of Periodontal Bone Grafts are:[6]

I. Probing depth reduction,
II. Clinical attachment gain,
III. Bone fill of the osseous defect and
IV. Regeneration of new bone, cementum and periodontal ligament

Classification

Various researchers have classified bone graft materials in different ways.

Hyatt and Butler[7] have Classified tissue Grafts as Follows

1. Autograft: Tissue taken from one operative site and grafted in another operative site within the same individual
2. Homograft/allograft: Tissue taken from one operative site in one individual and grafted in the operative site in another individual of the same species
3. Heterograft/xenograft: Tissue taken from one individual and grafted in the operative site of another individual of the different species
4. Syngensio grafts: Tissue graft removed from blood‑related relatives
5. Orthotopic graft: Tissue grafted into an anatomical site normally occupied by that tissue, for example, bone to bone and skin to skin.

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Carranaza and Newman[8] have broadly classified graft materials as

Autogenous bone	Allograft	Xenograft	None bone graft materials	Alloplast
Bone from intraoral Bone from extra-oral site-sites- Osseous coagulum Iliac crest Bone blend Tibia Intraoral cancellous bone marrow transplant Bone swaging	Freeze dried Decalcified freeze dried bone	Calf bone Kiel bone Anorganic bone	Sclera Cartilage Plaster of paris Calcium phosphate biomaterials Hydroxyl apatite Tricalcium phosphate	Porous hydroxyapatite Non-porous hydroxyapatite HTR polymer Betatricalcium phosphate Bio-active glass ceramics

Bone replacement grafts can also be broadly classified into human bone and bone substitutes. This canbe further classified into autografts, allografts, xenografts, and alloplasts [4]

Human Bone

Autografts or Autogenous grafts

- Extraoral
- Intraoral

Allografts or Allogenic Grafts

- Fresh frozen bone
- Freeze-dried bone allografts (FDBA)
- Demineralized freeze-dried bone allografts (DFDBA)

Bone Substitutes

Xenografts or Xenogenic Grafts

- Bovine-derived hydroxyapatite
- Coralline calcium carbonate

Alloplasts or Alloplastic grafts

- Absorbable
- Nonabsorbable

	Osteoconductive	Osteoinductive	Osteogenic
Autograft	+	+	+
Allograft	+	+/-	-
Xenograft	+	-	-
Alloplast	+	-	-

Alloplastic Grafts

Alloplast is a synthetic graft or inert foreign body implanted into tissue. [1]Being a biocompatible, inorganic synthetic bone grafting material they primarily function as defect fillers. They are manufactured either completely synthetically, or produced byextensive physical or chemical processing of xenogeneic (not species-related) types of tissueand/or structures.

According to Ashman (1992)[9], an Ideal Synthetic Bone Material Should be

1. Biocompatible
2. Able to serve as a framework for new bone formation
3. Resorbable in the long term and have potential for replacement by host bone
4. Osteogenic, or at least facilitate new bone formation
5. Radiopaque
6. Easy to manipulate clinically
7. Not support the growth of oral pathogens
8. Hydrophilic
9. Available in particulate and molded forms
10. Have surface electrical activity (i.e., be charged negatively)
11. Microporous and provide added strength to the regenerating host bone matrix, and permit biological fixation
12. Readily available
13. Nonallergenic
14. Adapt to be effective in a broad range of medical situations (e.g., cancer, trauma and infective bone destroying diseases)
15. Act as matrix or vehicle for other materials (e.g., bone protein inducers, antibiotics and steroids)
16. Have high compressive strength

Alloplastic grafts are indicated for the patients who have the time for a rigorous treatment regimenand postsurgical maintenance program. Patient acceptance , financial factors, availability of graft material, and past experience with bone-grafting procedures are the other factors to be considered for the selection of alloplasts to be used.Advantages of alloplastic graft materials include unlimited availability , unlimited durability , notransfer of pathogens and no immune reaction. Disadvantages of alloplastic graft materials include no osteogenesis, no osteoinduction, nodefinable absorption and transformation rates, different mechanic capacity and risk of infection.

The available alloplastic materials are Plaster of Paris, polymers, calcium carbonate, and ceramics. Ceramics can be classified into resorbable (e.g., tricalcium phosphate and resorbable HA) and nonresorbable (dense HA, porous HA, and bioglass).[10]

Polymethy lmethacrylate And Polyhydroxy lethyl methacrylate (Pmma-Phema) Polymers

They consist of particles of calcium layered with polymethyl methacrylate and hydroxylethylmethacrylate. They are divided into natural polymers and synthetic polymers. These, in turn, can be divided further into degradable and nondegradable types [11].At present, a biocompatible microporous polymer available as a bone grafting material for the treatment of periodontal defects is HTR™ Synthetic Bone .This composite is prepared from a coreof PMMA (polymethylmethacrylate) and PHEMA (polyhydroxylethylmethacrylate) with acoating of calcium hydroxide [12]. It forms calcium carbonate apatite when introduced into the body and interfaces with bleeding marrow[13]. PMMA-PHEMA polymer has properties like marked hydrophobicity, extensive microporosity, biocompatibility, good compressive strength (50,000–60,000 psi) and negative surface charge(-8 to -10 mV), which is believed to impede development ofinfection[14] and allows adherence to bone. It appears to serve as a scaffold for bone formation when in close contact with alveolarbone[4] . PMMA-PHEMA polymer does not produce an inflammatory or immune response afterprolonged contact with bone or soft tissue[15].

Hydroxyapatite (Ha)

Synthetic hydroxyapatite can be found as porous or nonporous andin ceramic or nonceramic forms [16]with remarkable biocompatibility.Healing was characterized primarily by formation of a longjunctional epithelium with encapsulation of HA graft materials in connective tissue with no indication of new periodontal attachment, osteogenesis or cementogenesis.The advantages of using hydroxyapatite are that immunoreaction can be ignored; postoperativechanges and volume decreases do not occur and postoperative adsorption of hydroxyapatite, if any, is slight and slow and is replaced by bone, The disadvantages of hydroxyapatite particles are that it does not to stay in place in a bleeding site, and has relativelyslow restoration of bone within the assemblage of particles [17].

Various Available forms of Hydroxyapatite Include

1. The polycrystalline ceramic form of pure densely sintered HA
2. The coralline porous non-resorbable hydroxylapatite
3. The resorbable nonceramic hydroxylapatite
4. Nanocrystalline hydroxyapatite (NHA).
5. Fluorohydroxyapatitic (FHA) biomaterial.

Polycrystalline Ceramic Form of Pure Densely Sintered HA

It is non-resorbable, osteoconductive,has a low microporosity and act primarily as inert biocompatible fillers [18]. It is prepared in relatively large particle size and commerciallyavailable as Calcitite, OsteoGraf/D300 or OsteoGraf/D700.

Coralline Porous non-Resorbable Hydroxylapatite: After the organic components of the marine coral skeleton is removed, the aragonite of the coralskeleton is converted to HA by treatment with an ammonium phosphate at elevated temperatureand pressure to form as small crystals. It is marketed in different trade names like Interpore 200 and Pro-Osteon500.

Resorbable Nonceramic Hydroxylapatite: Highly microporous, non-sintered (nonceramic) formcomposed of small particles measuring 300–400 mm . The material appears to be very biocompatible in both hard and soft tissues[19].It is marketed in different trade names like: Osteogen® , OsteoGraf/LD-300 and Cerabone®.

***Nanocrystalline Hydroxyapatite (NHA*)**: **has** improved osseointegrative properties and completeresorption of the material occurs within 12 weeks, being resorbed by osteoclasts. NHA exhibits good biocompatibility comparable tothat of cancellous bone [20]Example of nanocrystalline hydroxyapatite include Ostim™ .

Fluorohydroxyapatitic (FHA) Biomaterial

It is made from calcifying marine algae. The commercially availableporous biomaterial FRIOS® Algipore®, and biostite® (a mixture of synthetic HA (88.0%,), equine type I collagen (9.5%) and chondroitinsulfate (2.5%)).

Calcium Phosphate Cement (Cpc): CPC are used as bone substitutes as theydo not evoke any inflammatory responseand act as bioabsorbable barrier forguided tissue regeneration in periodontal defects[21].Problems with CPC include prolonged setting time and the inability to set in the presence ofblood. Resorption ofcalcium phosphate ceramics occurs by dissolution or is cell mediated.[22] Commercially CPCs are available under the trade names as Biobon .Bone Source Powder, Cementek Powder ,Cementek LV and others . CPCs can be used as carriers for local and controlled supply of drugs and can beuseful in treatments of different skeletal diseases thus gaining special interest.

The incorporation of platelet-derived growth factor-BB (PDGF-BB) with b-tricalcium phosphate was approved by the FDA in 2004.GEM-21 S™ is a completely synthetic grafting system for bone and periodontal regeneration launched in 2005. This system is composed of a purified plateletderived growth factor-BB (PDGF-BB) and β-tricalcium phosphate matrix .[22]

B-Tricalcium Phosphate (tcp):

Tricalcium phosphate, a porous calcium phosphate compound has alpha andbeta forms produced similarly with different resorptionproperties. The crystal structure of alpha tricalcium phosphate is monoclinic with column of cations, while the beta tricalcium phosphate has a rhombohedral structure.β-phosphate (β-TCP) is a porous form of calcium phosphate, with similar proportions of calciumand phosphate to cancellous bone .[12]

Physicochemically, β-TCP is a resorbable material with controversial resorption mechanism.In human histological studies, the TCP particles were encapsulated by fibrous connectivetissue, but the particles did not stimulate new bone growth, with residual graft particlesevident 18 months following treatment. Although new cementum was observed, there waslimited evidence of new attachment [23].

Several Commercial Available TPC Products are Available on the Market

1. Bioresorb® is available as porous granulate (particle size: 0.5–2 mm) mainly for dentalapplication.
2. Chronos and Ceros® are also granular materials with aparticle size of 0.5–1.4 mm, also mainly for dental application.
3. Vitoss is a porous granulate (particle size 3–5 mm) for dentalapplication
4. Synthograft™ is available in two particle sizes: 50–500 mm and500–1,000 mm.
5. Cerasorb® available as porous granulate ,in particle sizes of 0.05–2 mm ,for dentalapplication and as machined macroporous blocks for orthopedic applications .

Calcium Sulfate

It is one of the oldest ceramic bone substitutematerial and resorbs quickly. The rapid resorption rate is a potential problem as its volume may not be maintained for a sufficiently long period of time to yield reliablegrafting results in the esthetic zone .[24]Calcium sulfate appears to function as a resorbable osteoconductive scaffold that provides thestructural framework necessary for angiogenesis and osteogenesis while preventing soft tissueinvasion by acting as a space filler.

It is inexpensive, readily available, easy to sterilize, safe and simple to use, eliciting little or no macrophagic reaction, does not adversely impact the cell proliferation kinetics [25]Example of commercially available calcium sulfate graft is Capset®,Cal Forma™ , Cal Matrix and Osteoset® (calcium sulfate impregnated with tobramycin).

***Bioactive Glasses (bg)**:*

Invented by Hench *et al*. (1971)[26] bioactive glasses are clinically used in restorative orthopaedics and dentistry. The originalcomposition of bioactive glass approved by the FDA, designated 45 S5, was composed of 46.1mol% SiO_2, 26.9 mol% CaO, 24.4 mol% Na_2O, and 2.5 mol% P_2O_5.Five inorganic reaction stages are commonly thought to occur when a bioactive glass is immersed in a physiological environment:

1. Ion exchange in which modifier cations (mostly Na+) in the glass exchange with hydroniumions in the external solution.
2. Hydrolysis in which Si-O-Si bridges are broken, forming Si-OH silanol groups, and the glass network is disrupted.
3. Condensation of silanols in which the disrupted glass network changes its morphology toform a gel-like surface layer, depleted in sodium and calcium ions.
4. Precipitation in which an amorphous calcium phosphate layer is deposited on the gel.
5. Mineralization in which the calcium phosphate layer gradually transforms into crystalline hydroxyapatite, that mimics the mineral phase naturally contained with vertebrate bones.

It forms acohesive mass when wetted with blood , thus easy manipulation and packing into the extractionsockets or periodontal defects .[27]It is hemostatic , bonds to connective tissue and bone without an intervening fibrous connective tissue interface .[28]

Bioactive glass has antibacterial effect against on a large panel of clinically important bacterial species (A. actinomycetemcomitans, P. gingivalis, Actinomyces naeslundii, Fusobacteriumnucleatum, Prevotella intermedia, Streptococcus mutans, and Streptococcus sanguis, Candidaalbicans) .[29]Inaddition to its osteoconductive properties, it also has an osteostimulatory effect showing bone growth within eroded particles.

Commercially available bioactive glass include PerioGlas®(A synthetic absorbable osteoconductive bone graft intended for dental intraosseous, oral and cranio-/maxillofacial bony defects.), PerioGlas® Plus (synthetic resorbable osteoconductive bone graft) , Biogran™ (is a particulate resorbable bioactive glass, consisting of 300–355 mm diameter particle size) and Unigraft® (is a synthetic bioactive glass manufactured as irregular-shaped synthetic granules,sized from about 200 mm to about 420 mm).

Oily Caoh$_2$ Suspension

Its a product of lime slaking from quicklime (CaO), usedextensively in endodontics where it has been shown to support hard tissue repair for indirect and direct pulp-cappingprocedures and as a temporary root-filling material. Recently, a non-setting oily $CaOH_2$suspension, Osteoinductal®, has been introduced for application in jawbone surgery. It contains $CaOH_2$, liquid and solid carbohydrate chains and variousfatty acids (e.g., oleic, palmitoleinic, gadoleinic, margarine, pentadecane, myristic, linolenic,stearic, arachidic, lauric) esterified with glycerol, while the oily part consists of a natural productof porcine origin, oleum pedum and vaselinum album [30]. Oily calcium hydroxide suspension when applied to the root surface inconjunction with surgical periodontal therapy may promote periodontal regeneration[31]. The topical subgingival application of Osteoinductal after nonsurgical periodontal therapy improvedearly periodontal wound healing.

Porous Titanium Granules

Recently, a non-resorbable, osteoconductive bone substitute, was proposed to be used inin the surgical treatment of peri-implant osseous defects.[32] Tigran™ PTG is an irregularly shaped, porous granules manufactured using commercially puretitanium. The granules are 0.7 mm -1.0 mm in size , non-resorbable having porosity of about80% and an osteoconductive surface structure, creating a scaffold for bone generation that stimulates osteoblast colonization and osseointegration. The titanium granules do not set (i.e., no risk of heat injury to the bone) and can therefore behandled without time pressure during surgery [33].No randomized clinicaltrials are presently available regarding the efficacy of porous titanium granules in the treatment of periodontal defects.

Composite Grafts

It is the most promising emerging surgical option that can be an alternative for an autograft. A composite graft combines an osteogenic cells along with a synthetic osteoconductive matrix . The osteo-conductive matrix becomes a delivery system for bioactive agents, requiring less chemotaxis and less migration of osteoblast progenitor cells to the graft site. The direct infusion of progenitor cells should lead to more rapid and consistent bone recovery. Such potential composite grafts are: bone marrow/synthetic composites, ultraporous b-TCP/ BMA composite, osteo-inductive growth factors and synthetic composites, BMP/polyglycolic acid polymer composites and BMA/BMP/polyglycolic acid polymercomposite.[34] Commonly used commercially available composite grafts are Healos® , Collagraft® and Tricos® .

In addition to these materials, research is continuing to modify the products with hopes of creating a graft that incorporates faster, resorbs and yields a bony union that resembles natural form and structure.[16]

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