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Mini-Review

Bone Grafting Materials in Dentistry: A Brief Review

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Abstract:

Bone grafting is a surgical procedure for the replacement of missing bone resulting from bone defects. These defects can result from any tumors, accidents, advancing age, general disease, congenital abnormalities, and jaw abnormalities. Bone is considered the second most transplanted tissue after blood. Various methods have been used to eliminate these defects such as stem cells, bone graft, guided bone regeneration. Grafts help in maintaining normal anatomic outline, aesthetic restoration, eliminating space, and implant placement. This article reviews various bone graft materials, advantages, and limitations.

***Keywords:** Bone defects, bone grafts, aesthetic restoration, implant placement*

Introduction

Bone is a mineralized tissue that provides structural support. It can regenerate completely but required some sort of scaffold to do so. According to the Oxford Dictionary graft is a piece of living tissue, organ, etc. transplanted surgically. The Graft is a viable tissue that after removal from a donor site is implanted within a recipient is then restored, repaired and/or regenerated. According to the United States Food and Drug Administration (USFDA) bone Grafting is a surgical procedure in which new bone or replacement material, is placed into bone fractures or bone defect to aid in healing. Bone grafting is also defined as a surgical procedure that replaces the missing bone with material from the patient's own body, an artificial, synthetic, or natural substitute.[1]

Bone grafts are placed at different locations depending upon their indications. They act as a filler and scaffold to help bone formation to promote healing. Integration of grafts to the recipient site includes the following stages- inflammation, revascularization, osteoinduction, osteoconduction, and finally remodeling.[2] Worldwide, autogenous and allografts are used in approximately 2.2 million orthopedic procedures annually.

Rationale

1. To generate a regenerative capacity of bone
2. Achieve new attachment apparatus
3. To provide sufficient bone volume and biologic quality[3].

Indications

1. To fill bone defects resulting from cysts, tumors, or any neoplasm.
2. For implant placement in esthetic regions.
3. In alveolar sockets post-extraction

4. To fill a peri-implant defect due to peri-implantitis
5. For horizontal or vertical augmentation of the maxilla and mandible.
6. In conditions of periodontal inflammation.
7. During immediate Implant placement[3,4]

Classification

1. Depending upon Source[5]
   - Autograft
   - Allograft
   - Xenograft
   - Synthetic bone substitute
2. Depending upon the content
   - **Cortical-** stimulate stability
   - **Cancellous-** stimulate osteogenesis
   - **Cortico-cancellous**-stimulate both stability as well as osteogenesis
3. Based on vascularity[6]
   - **Vascular-**in cases with previous radiation therapy with the bone but more donor site morbidity.
   - **Non-vascular-** less expensive and less donor site morbidity.
4. Based on the Method of Preservation
   - **Fresh or fresh frozen**- Frozen at -80 degree centigrade to avoid degradation by enzymes. It is acellular and has the highest osteoconductive and osteoinductive properties.
   - **Freeze-dried**- Graft undergoes dehydration and freezing without demineralization leading to decreased antigenicity.
   - **Demineralized freeze-dried**- Graft undergoes dehydration, freezing, and inorganic part of the bone is eliminated leaving only organic part.
5. Based on their Mode of Action[7]:
   - **Osteogenic Grafts** - means the new bone is formed by bone-forming cells (osteoblasts) within the graft.
   - **Osteo-inductive Grafts** - means bone formation is induced in the surrounding soft tissue adjacent to the graft.
   - **Osteo-conductive Grafts**- means the graft material acts as a scaffold but itself does not contribute to bone formation.
   - **Osteo-promotive Grafts** -means graft that increases osteoinduction without possessing osteoinductive property.

Autograft

In 1923, Hegedus use bone graft for reconstruction of osseous defect[8]. Graft transferred from one position to another within the same individual. Autogenous bone is best since it may have both osteogenetic and osteoinductive potency. It is considered a gold standard grafting procedure. They are resorbed and replaced by a few variable bones. They can be harvested from both extraoral and intraoral sites and can be cortical or cancellous bone.

Advantages

1. Offer minimal immunological reaction
2. Complete histocompatible
3. Best Osteogenetic, Osteoinductive, Osteoconductive property
4. Available in different sizes and shapes

Disadvantages

1. They are in limited supply as they depend upon age, gender, and medical status.
2. Expensive
3. Higher morbidity rate
4. Increased inpatient stay
5. Increase the absorption rate
6. Less revascularization
7. Required additional surgery

Various Donor sites

Extraoral: Iliac crest, Fibula, Tibia, Bone removed from osteoplasty and ostectomy, Cranium, Radius.

Intraoral: Maxillary tuberosity, Retromolar pad, Palate, Anterior Nasal spine, Ascending Ramus, Coronoid Process, Torus, Mandibular Symphysis.

In the following sections of the article various types of the bone grafts used in dentistry are discussed.

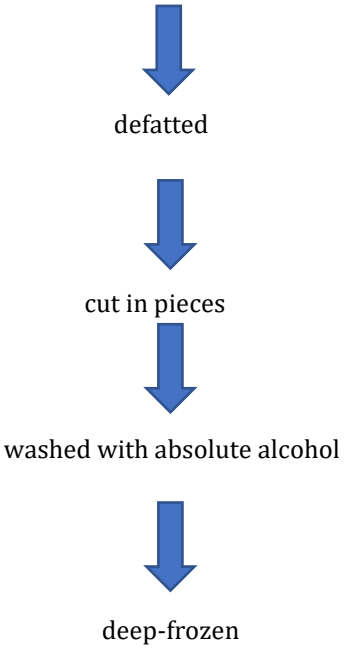
Allograft

These are the grafts transferred between genetically dissimilar members of the same species. They are available as fresh frozen, freeze-dried bone allograft (FDBA) or demineralized freeze-dried bone allograft (DFDBA). They are commonly available as tissue banks. Commercially available as- Allogro, DBX, Dynagraft, Dynablast, Grafton.[11] They are available as cortical, cancellous, or cortico-cancellous in various shapes and sizes.

Sources:

Diagram Showing Processing of Allograft:-

Cortical bone (to extract within 12 hours of the death of the donor)



The graft is then demineralized and grounded to a particle size 250-750 microns. It is later freeze-dried and vacuum-sealed in glass vials. Demineralization of graft in cold, diluted hydrochloric acid, exposes the components of bone matrix. Its antigenic potential is suppressed by various treatment such as:

Radiation treatment- 6 Mega Rads of gamma radiation

Freezing- Deep frozen in liquid nitrogen at -197degree Celsius for at least 4 weeks.

Chemical treatment- Placed in Merthiolate solution

Advantages:

1. Osteoconductive,
2. Osteoinductive
3. Relatively available
4. Does not require additional surgery required and hence reduces hospital stay.

Disadvantages:

1. Possibility of disease transmission, immunogenicity
2. Variability of properties depending on the productive method

Some important differences in FDBDA and DFDBA are given below:

S No.	Freeze-Dried Bone Allograft	Demineralized Freeze-Dried Bone Allograft
1.	More radio-opaque	More radiolucent
2.	Breakdown by way of foreign body reaction	Rapid resorption
3.	Only osteoconductive	Both osteoconductive Osteoinductive
4.	No bone morphogenetic protein expression	More bone morphogenetic protein expression
5.	Not demineralized	Demineralized
6.	Primary Indication: Bone augmentation associated with Implant treatment	Primary Indication: Periodontal disease associated with natural tooth such as attachment level gain, probing depth reduction, and osseous regeneration.
7.	Less potential for disease transfer from the cadaver.	More potential for disease transfer from the cadaver.

Xenograft

These are the bone grafts taken from a donor of another species. They are also known as an organic bone. Calf bone is denatured with 20% hydrogen peroxide followed by dried with acetone and sterilized with ethylene oxide. All cells and proteinaceous material for this graft are removed. This prevents clot stabilization and revascularization to allow the migration of osteoblasts, thus promoting osteogenesis. The remaining material is inert, absorbable bone scaffolding. Revascularization, osteoblast migration, and woven bone formation take place on this scaffold. These grafts are available as demineralized bovine bone grafts, demineralized coral bone substitutes which are similar to human cancellous bone.[12] Commercially available as- Algipore, Biocoral, Bio-Oss, Cerabone, Interporo 200.

Bio-Oss has been successfully used in bone regeneration, in Periodontal defects, in sinus grafting, and in implant surgery. Bio-Oss is anorganic, bovine-derived in origin which has osteoconductive property. It is biocompatible with no systemic immune response.

Mechanism of Action: Bio-Oss graft is covered with a resorbable membrane. This membrane prevents the migration of fibroblasts and connective tissue between the pores or granules of the graft. This helps in cementum formation and osseous regeneration. [13]

Advantages

1. Slow resorption
2. Low cost
3. Osteoconductive
4. High availability

Disadvantages

1. Immunogenicity
2. Variability of the property depending upon the productive method

Synthetic bone substitute/ Alloplastic Materials

These are synthetic material which are used for bone grafting procedure for the treatment of periodontal osseous defects. Following are some synthetic materials used for treatment of human periodontal osseous defects.

Tricalcium Phosphate (TCP)- one of the most used grafts. Calcium and phosphate are in ratio 1:1.5. These crystals are beta-whitlockite crystals. They are available in two forms as cement and ceramics. Cement is available in paste form which upon application get harden at defect sites. Ceramics grafts are porous and solid due to their heat treatment known as sintering.

Advantages

1. Biocompatible
2. Good osteoconductivity
3. Permits phagocytosis, vascularization, and bone regeneration.
4. Resistant to compressive loads

Disadvantage

1. Low mechanical stability
2. Less endurance to tensile and shear forces
3. Brittle
4. Lack of osteoinductive and osteogenic property.
5. It is least resorbable.

2. Hydroxyapatite: It is a main inorganic component of the structure of tooth, bone. They also consist of calcium and phosphate but with a ratio of 1:1.67.

Advantages

1. They possess osteoconductive properties
2. Generally, not resorbable
3. Excellent carrier for osteoinductive and osteogenic growth factors.

Disadvantages

1. Brittle
2. More prone to fracture

To overcome disadvantages and to improve their mechanical properties, both tricalcium phosphate and hydroxyapatite are mixed to form Biphasic Calcium Phosphate (BCP).[14]

3. Calcium sulphate- It is also known as Plaster of Paris or Paris gypsum. These grafts are extensively used in tooth extraction, periodontal, and dentoalveolar defect cases.[15] It is resorbed completely in 1-2 weeks.

Advantages

1. Allow fluid exchange hence prevent flap necrosis.
2. Highly Biocompatible
3. Osteoconductivity
4. Good handling property
5. Available in both cement as well as granular form
6. Good tolerating properties

Disadvantages

1. More prone to fracture when a mechanical load is applied
2. Rapid resorption
3. Minimal structural support

4. Polymers

It consists of PMMA (polymethylmethacrylate) or PHEMA (Polyhydroxyl-ethylmethacrylate beads) coated with calcium hydroxide. When introduced in the body they react to form calcium carbonate apatite. It is also known as HTR-Hard tissue Replacement. Commercially available as Bioplant.

Advantages

1. Excellent osteoconductive property
2. Good compressive strength similar to that of cortical bone
3. Non-resolvable

Disadvantages

If high temperature is used during polymerization, graft may result in thermal bone necrosis, damage membrane and blood circulation, blood circulation at bone cement interferences.

5. Bioactive Glass Ceramics

They are made up of calcium oxide, sodium oxide, Silicon dioxide, potassium oxide and are referred to as 45S5 bioactive glass. They are initially introduced as an amorphous material. Particles are used measuring 90-170 microns.

Mechanism of action: They increase bone formation by the dissolution of ions of ceramic search that layer of silica gel forms over the particles that are that encounters the body fluid. Over this silica gel another layer of calcium phosphate form which immediately get converted into hydroxy carbonate apatite layer. This hydroxy carbonate apatite layer has similar contents of mineral as that found in human bones.[16]

Advantages:

1. Better strength than other synthetic biografts.
2. Provide a surface for osteoblast cell attachment add bone deposition
3. A strong bond is formed between the glass and host bone. This phenomenon is known as bioactivity.
4. Due to continuous Ionic exchange ceramic particles undergo dissolution hence after 1-3 years the particles have shown to be replaced completely by bone.

6. Plastic material

HTR polymer has shown a positive effect in improving attachment level and defect fill. It is biocompatible, a combination of polymethylmethacrylate and polyhydroxyl-ethylmethacrylate. It is non-resorbable and microporous.

Disadvantages of Alloplastic Grafts

1. These have only osteo-conductive properties.
2. Resorption time vary greatly.
3. Not efficient as autografts and allografts.

Future Trends in bone graft

There have been various advancements in the field of bone grafting. The current use of bone grafts has a level of success but still, has limitations.

1. Clineff et. al. have introduced a bone graft that is biocompatible composed of bioactive glass, calcium phosphate, and resolvable collagen. They promote angiogenesis and osteoinductivity.
2. Lu in 2006, also developed a bone technology hey which promote bone formation with the help of various growth factors or platelet-rich plasma (**PRP**). PRP acts as an adhesive with cancellous bone particles. It is available as a capsule of protein permeable material that is calcium alginate porous beads with growth factors, PRP gel, and bone regeneration facilitating material. This material as a scaffold for the formation of bone.
3. **The introduction of polymeric bone detect filter**- it includes polymers with a plurality of particles. These particles are of various shapes and sizes to improve pore interconnectivity, material expansion, mechanical strength add handling properties[17].
4. Recent in bone grafting technology is the introduction of **tissue engineering** which has shifted the paradigm from biological graft to synthetic graft. They presented on improving the porosity of bone graft and thus they mechanical properties[18].

Conclusion

Continuous research has been conducted to improve characteristics such as mechanical strength, compatibility, degradation capacity and various other aspects of bone grafts. Despite of advancements in the field, the perfect bone reconstruction material has not yet developed. The development of various bone regenerative materials such as engineering, cells, and nanotechnology has father widen up the horizon in the field of bone regeneration. It may be concluded that a great achievement have been in bone grafting in dental field but still the wait for an ideal graft material is on.

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