Bone Repair Materials Used in Guided Tissue Regeneration - Advantages and Disadvantages

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Abstract: Depending on their origin, there are several groups of bone repair materials: autogenous, allogeneic, xenogeneic, and alloplastic bone substitutes. Autogenous, allogeneic and xenogeneic grafts are of natural origin, while alloplastic grafts are synthetic materials.

Keywords: guided tissue regeneration, autograft, allograft, xenograft, alloplastic

1. Introduction

Bone graft materials are a tissue, a biomaterial or a combination of the following, placed in a receiving lodge to assist tissue regeneration in order to maintain or restore their volume and quality. Respectively, bone repair materials are used to maintain or restore bone quality and/or volume.

Depending on their origin, there are several groups of bone repair materials: autogenous, allogeneic, xenogeneic, and alloplastic bone substitutes. Autogenous, allogeneic and xenogeneic grafts are of natural origin, while alloplastic grafts are synthetic materials [1]. An autogenous bone substitute is a bone material harvested in a situation where the donor and the recipient beds belong to the same individual. Allogeneic bone substitute is a bone material of genetically different organisms to the same species. Xenogeneic bone substitute is a material of biological origin from a different species. The alloplastic bone substitute is an inorganic synthetic material.

2. Aim

The purpose of this study is to describe and review the types of bone repair materials used in periodontology and implantology.

3. Materials and Methods

Articles related to the subject were searched in PubMed and Google Scholar databases. Articles in English only, published from 1974 to 2019, were included. The search was performed using a combination of different keywords such as: "guided tissue regeneration", "periodontal regeneration", "autograft", "allograft", "xenograft", "alloplast".

4. Results and Discussion

Tissue materials provide one or more of the following phenomena, which contribute to the repair processes in the intraosseous defects: Osteogenesis - bone growth carried out through vital cells transmitted via an autograft - autogenous bone. Osteoinduction - bone formation occurring after the differentiation of mesenchymes into osteoprogenitor cells, under the influence of one or more inducing factors, originating from the bone matrix. Osteoconduction - Bone growth through adjacent bone apposition [2, 3, 4].

Bone replacement materials must be biocompatible, they must also integrate well with the surrounding bone, have adequate mechanical properties with an ideal degree of substitution, and be predictable with a good level of acceptance from the recipient bed [5, 6, 7].

- Autogenous bone repair materials

Transplants harvested in a situation where the donor and recipient beds belong to the same individual. Autogenous bone is defined as the gold standard for regenerative procedures because it has osteogenic, osteoinductive and osteoconductive properties. There are numerous histological findings from case reports that confirm the potential of autotransplants [2, 8, 9, 10]. However, one of the most significant disadvantages of this type of transplant is the limited amount of tissue that can be taken from the donor site [1, 11]. Other disadvantages are the lack of volumetric stability due to the rapid remodeling of the autograph and the need for a second operating field [2].

Autogenous bone repair materials can be of intraoral or extraoral origin. The intraoral sites from which autogenous bone can be taken from are the area of the mentum [12], linea obliqua mandibulae, tuber maxillae, crista zygomaticoalveolaris and bone exostoses [13, 14]. The extraoral areas from which autogenous bone can be taken from are the area of the calvaria, spina iliaca, crista iliaca and others. [15, 16, 17, 18].

Autogenous bone repair materials can be cortical or spongy. Cortical grafts have very high strength, but about 6 months after transplantation, they are found to be 50% weaker than normal bone tissue [19]. Initially, the spongy graft's strength is less due to their porous structure, but over time they become stronger. Another significant feature is that spongy grafts revascularize earlier (approximately on the 5th day after transplantation) because of their structure [4].
• Allogeneic bone repair materials

Allotransplant is the transplantation of tissues to a recipient from a genetically non-identical donor of the same species. The transplant is called an allograft. The allogeneic bone restorative materials are of human origin and can be from both living and deceased donor. In 2017 Reynolds et al. summarize that allogeneic bone repair materials are the most commonly used alternative to autogenous bone in the United States. Allogeneic grafts not only have osteoconductive properties, but also have some osteoinductive potential due to the presence of proteins (e.g. bone morphogenetic proteins - BMP) [3, 20].

At this point in the literature, there is no evidence of a disease transmission during the 30-year history of the use of freeze-dried allogeneic bone repair materials in periodontal therapy [21]. Allogeneic bone repair materials are processed by a variety of methods. They may be - fresh frozen allograft, lyophilized allograft or demineralized allograft [22].

✓ Fresh-frozen bone allografts, FFB

They have the highest osteoconductive and osteoinductive potential, among all allogeneic transplants available for use [23, 24]. However, due to the risk of disease transmission, they are no longer used [3].

✓ Freeze-dried bone allografts (FDBA)

They are usually derived from living organisms. After anamnesis, explanation and serological examination (HBV, HCV, HIV, Lues), the process includes mechanical treatment, ultrasonic bath, ethanol / diethyl ether treatment, H₂O₂ treatment, lyophilization (drying at low temperature and pressure, leaving water in tissue sublimates - goes from solid to gaseous, packaging and gamma-sterilization.

The lyophilization of allogeneic grafts is intended to disrupt the 3D presentation of human leukocyte antigens located on the surface of allogeneic particles and thereby interfere with immune recognition [25, 26].

The FDBA has higher mechanical properties and a certain osteoconductive activity due mainly to the mineral component [2, 3]. It has been found that FDBAs can be combined with autogenous grafts to enhance their osteogenic potential [27, 28].

✓ Demineralized freeze-dried bone allografts, DFDBA

DFDBA treatment is identical to FDBA treatment, but allogeneic bone is also subjected to demineralization. DFDBAs are demineralized to a level of about 2% residual calcium, which results in low mechanical strength and a deficiency of osteoconductive potential (DFDBA has greater mechanical strength and osteoconductive activity). Demineralization, on the other hand, provides maximum osteoinductive potential, compared to FDBA (due to exposure to bone morphogenetic proteins and growth factors) [2, 3, 29, 30]. When DFDBA is derived from the deceased of younger individuals, it has been found that there is a higher osteogenic potential [31, 32]. The DFDBA is used alone or in combination with FDBA and auto-grafts. The DFDBA has been found to be rapidly absorbed [33, 34].

• Xenogeneic bone repair materials:

They are a transplant derived from a different species that the species of the recipient. Xenografts have osteoconductive properties and have limited resorption potential [35, 36]. There can be a deproteinized bovine bone material, a coral exoskeleton mineral, and demineralized animal bone matrix (taken from pigs and horses) [3].

✓ Deproteinized bovine bone mineral (DBBM)

It is a bone material of bovine origin that has been specially processed to produce a natural bone mineral with no organic elements [37]. After thermal and chemical treatment, the mineral component, which mainly includes hydroxylapatite, retains the structure of the bone remains [38]. Although the treatment of one of the most commercially available Bio-Oss products (Geistlich-Germany) eliminates a large amount of organic matter (nearly 97%), it does not completely eliminate the potential risk of disease transmission and graft rejection [39, 40].

✓ Demineralized animal bone matrix (pigs)

Porcine bone graft is a porous inorganic bone graft consisting predominantly of calcium phosphate (Gen-Os®). It has a granular form and is obtained by removing the organic component from porcine bones [41, 42]. The inorganic mineral component has an interconnected macro- and microscopic porous structure [43].

✓ Mineral from coral exoskeleton

These materials are manufactured by subjecting the corals to high temperature under pressure in the presence of aqueous phosphate solutions. Thus, corals are converted to calcium hydroxylapatite, preserving their porous structure [44].

These grafts have shown the potential for good filling of periodontal bone defects and are not subjected to fibrous encapsulation [45, 46, 47].

✓ Alloplastic materials:

They are biomaterials of artificial or synthetic origin. Alloplasts are biocompatible, inorganic synthetic materials. Alloplastic materials used in regenerative procedures of the periodontium are separated into two main groups - ceramics and polymers. The composition, morphology and surface topography of alloplastic materials determine their osteoconductive potential. They do not have any osteogenic or osteoinductive potential. Alloplastic materials have no risk of disease transmission. The most routinely used alloplastic materials are calcium.
phosphate ceramics for periodontal regeneration [42, 48]. They can also be used in implantology. [49]

- Biphasic calcium phosphate ceramics

Calcium phosphate ceramics are of great interest in relation to periodontal regenerative therapy as they have a similar mineral bone composition. They are osteoconductive and form a very strong bond between bone and calcium phosphate [5, 6].

- Hydroxyapatite (HA)

A biomaterial that has a composition and structure similar to the basic mineral constituent of natural bone - hydroxyapatite [50]. Hydroxyapatite grafts show a slow and limited absorption potential and therefore offer high volumetric stability [51, 52].

- Tricalcium phosphate (TCP)

In recent years, this material has been extensively researched as a bone repair material. It has two polymorphic forms α-TCP and β-TCP [53]. α-TCP is a more soluble and rapidly absorbable form and this is the reason why β-TCP is mainly used as a bone repair material in this group. This form shows good biocompatibility. β-TCP has osteoconductive properties [54]. In terms of bone regenerative potential, β-TCP grafts are similar to autogenous bone, FDBA and DFDBA [55].

- Bioactive glasses

They consist of silica, calcium oxide, sodium oxide and phosphorus pentoxide [56]. After implantation of bioactive glass on a bioactive ceramic surface, a silicone gel is formed, with the outer layer serving as a binding surface for osteogenic cells and collagen fibers [57, 58]. It was proven in a 2012 that bioactive glass nanoparticles induce cementoblasts to proliferate in vivo [59].

5. Conclusion

The study presented shows that there are many different types of bone repair materials used to accelerate the healing process of periodontal defects. According to the literature, the guided tissue regeneration has shown different long-term results depending on the type of bone repair material. The factors that favor the success of the method are still under discussion. Bone repair materials should be biocompatible, allow new bone formation and bone remodeling to occur, have adequate mechanical properties with an ideal degree of substitution, and be predictable with a good level of acceptance from the recipient bed.

References


