Chapter

Biomaterial Used in Trauma Patients

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Abstract

The development of bone tissue engineering and bone regeneration is always of interest to improve methods to reduce costs of trauma patient. Ability to use autogenous bone forming cells attached to bone morphogenetic proteins would be ideal. There are many clinical reasons to develop bone tissue engineering alternatives, for use in the reconstruction of large defects and implants. The traditional methods of bone defect management include autografting and allografting cancellous bone, vascularized grafts, and other bone transport techniques. However, these are the standard treatments. Since bone grafts are avascular and dependent on the size of the defect, the viability can limit their application. In large defects, the grafts can be resorbed by the body before osteogenesis is complete; tissue loss develops in the living organism due to infection, trauma, congenital, and physiological reasons. Placing tissue defects in the dentist and maxillofacial surgery and accelerating wound healing are an important issue. From an old Egypt, material used in treatment of different doctors with various causes. Oral surgery, periodontology, and implantology, which are surgical branches of the dentistry, need to increase bone formation in the treatment of bone defects, congenital defects, and defects around the implant. Many years of work have been done to obtain ideal biomaterials, and many materials have been used. We have prepared detailed information on biomaterials used in dentistry, oral, and maxillofacial surgeries in this book to help dentists and dental students.

Keywords: biomaterials, trauma, maxillofacial surgery

1. Introduction

Bone not only supports and protects various organs but it also facilitates mobility [1], with the help of the soft collagen protein and stiffer apatite mineral. Bone is maintained dynamically through two different processes: modeling and remodeling [2]. In bone modeling process, the new bone is formed without prior bone resorption, while in the bone remodeling process, bone formation follows bone resorption [1]. Bone remodeling is a lifelong process that begins in early fetal life and is maintaining bone function by continuously replacing damaged bone with new bone tissue [3, 4].

The use of alloplastic materials in the remodelization of traumatized lesions and fractures in the compensation of tissues lost for various reasons such as trauma first started in ancient Egypt [5]. All substances are called biomaterials, which help to

eliminate any deficiencies in the living organism and help the organism to complete this deficiency regularly and quickly [5].

Bone grafting is one of the most common surgical procedures to set up bone regeneration procedures [6]. Bone grafting procedures were the second most frequent tissue transplantation after blood transfusion [7]. Autologous bone is still gold standard in bone regeneration [8]. Bone grafting procedures vary between natural grafts to synthetic bone substitutes and biological factors [9]. Synthetic bone substitutes and biological factors, calcium phosphate (CaP)-based biomaterials (e.g., hydroxyapatite (HAp), CaP cements, and ceramics), and recombinant human bone morphological proteins (rhBMPs) are most frequently used [10].

This chapter will describe the biomaterials used in the reconstruction of defects in the head and neck region [5].

2. Structure of bone

Bone is a connective tissue that forms the skeleton of the body, acts as a support to the muscles and organs, protects them against. Bone tissue consists of two different bone structures as compact or cortical spongiosa or cancellous bone [5].

Bone tissue is examined in two separate parts: the matrix between the cells and the cells [5].

2.1 Cells

2.1.1 Osteoprogenitor cells

These cells are the result of differentiation of stromal cells arising from embryonal mesenchymal cells in periosteum and endosteum. Cells related to direct bone formation are osteoblasts, osteocytes, connective tissue, fibroblast, and fat cells.

2.1.2 Osteoblasts

They play a role in the synthesis, preparation, and mineralization of the bone matrix. They are then implanted into the tissue with calcification of the bone matrix to become osteocytes.

2.1.3 Osteocytes

They surround with osteoblasts, mineral matrix and then consequent balance of the calcium (Ca) level.

2.1.4 Bone marrow cells

They are cells similar to squamous epithelial cells found in inactive regions in the bone.

2.1.5 Osteoclasts

Osteoclasts digest the mineral matrix of the bone with acid phosphatase, which they secrete, and then resorb it by digesting collagen and other organic matrix structures with lysosomal enzymes.

2.2 The intercellular tissue (bone matrix)

Cell-to-cell tissue forms 10–29% water, 60–70% of the bone dry weight is the inorganic structure (bone salts), and 30–40% of the bone dry weight, 90–96% of the organic structure is collagen, which is also the main component of connective tissue and constitutes one-third of all body proteins [5].

3. Healing mechanism of bone defects

Bone repair can be defined in two procedures: primary bone healing and secondary bone healing. The large segmental bone loss in the defect is an extreme condition in bone healing, which can be caused by trauma, diseases, developmental deformities, revision surgery, and tumor resection or osteomyelitis [11, 12].

Primary (direct) bone healing mainly happens when the fracture gap is less than 0.1 mm, and the fracture site is rigidly stabilized. Secondary bone healing is the more common form of bone healing and occurs when the fracture edges are less than twice the diameter of the injured bone [11]. Blood clothing, inflammatory response, fibrocartilage callus formation, membranous ossifications, and bone modeling are involved in bone healing.

Bone substitutes mainly involve three important biological properties: osteogenesis osteoinduction, and osteoconduction [13].

3.1 Bone formation mechanism with bone graft materials

3.1.1 Osteogenesis

Bone graft materials in osteogenesis include organic materials that have bone formation capacity directly from osteoblast cells. Even in environments where undifferentiated mesenchymal cells are not present in the tissue, such organic materials have the ability to be osteogenic. The only graft material with osteogenic character is autogenous bone. Autogenous bone is obtained from the oral surgery, iliac bone, tuber maxilla, and mandibular symphysis [5].

3.1.2 Osteoinduction

Osteoinduction, with osteoinductive materials, has the capacity to convert undifferentiated mesenchymal cells in tissue into osteoblasts and chondroblasts. In oral surgery, bone allografts are the most commonly used osteoinductive materials. Bone allograft is derived from different human bone tissues with different genetic structure.

3.1.3 Osteoconduction

The growth of bone tissue with osteoconduction is characterized by the formation of appositional bone. That is why osteoconduction occurs in the presence of bone or undifferentiated mesenchymal cells.

As a result, although bone has a very variable metabolism, resistance depends on the amount of collagen, the arrangement of fibrils, the presence of minerals, and the presence of minerals on proteins and glucosamines.

4. Basic features of biomaterials

1. Biological suitability: the applied biomaterial should be acceptable to the tissue [5].
2. It should be bioinert and biocompatible. It should be osteoconductive and osteogenic.
3. The surface should have an immediate stabilization property and surface porosity to allow for increased stabilization.
4. It should not be toxic.
5. It must be easily sterilized.
6. It must be resistant to infection.
7. There should be no color features that can affect surrounding textures.
8. It must be easy to apply and must cause minimal trauma during application.
9. It must be resistant to bending and twisting and should be elastic; elasticity should be close to the applied texture. It must be cut and shaped during application.
10. Resorption should be resistant.
11. The application must be acceptable to the patient.
12. The application should be able to give definite results.
13. It is easy to remove or cut in case of failure.
14. Must be easy to store.
15. It must be cheap and easy to obtain.

5. Classification of biomaterials

A. Bone source biomaterials [5]

a. Autogenous bone graft (autograft)

I. Cortical and cancellous bone in or out of mouth

b. Homogeneous bone graft (allograft)

I. Isograft: fresh cancellous bone marrow

II. Fresh frozen bone

III. Frozen dried bone

c. Heterogeneous bone graft (xenograft)

I. Demineralized bone

II. Protein-extracted bone

B. Bone-free biomaterials (alloplastics)

a. Tissue sources

I. Dentin

II. Cementum

III. Cartilage

IV. Sclera

V. Dura mater, etc.

b. Metals

c. Gelatin film

d. Polymers

e. Calcium sulfate

f. Calcium carbonate

g. Calcium phosphates

h. Calcium phosphate ceramics (CaP ceramics)

i. Bioactive glass

5.1 Bone source biomaterials

In the treatment of traumatic defects, congenital deformities, tumor surgery are in used. Today, homogeneous bone grafts (allografts), heterogeneous bone grafts (xenografts), and alloplastic materials are used in oral and maxillofacial surgery [5].

An osseous graft from an anatomic site and transplanted to another site within the same individuals is called autologous bone grafting [14, 15]. With osteoconductive, osteoinductive, and osteogenic properties, an autologous bone graft can integrate into the host bone more rapidly and completely [15]; therefore, it is regarded as the gold standard bone defects [16].

Cancellous autografts are the most commonly used form. Few osteoblasts and osteocytes, but abundant mesenchymal stem cells (MSCs), survive as a result of ischemia during transplantation, which helps maintaining osteogenic potential and the ability to generate new bone from the graft [17]. Autograft-derived proteins, which are attributed to the osteoinduction of the graft, are also preserved and present when the autografts are appropriately treated [15, 18].

Cortical autografts have excellent structure and are mechanically supportive, due to osteoprogenitor cells [14]. Unlike the autologous cancellous graft, the creeping substitution of cortical autograft is mainly mediated by osteoclasts after the rapid hematoma formation and inflammatory response in early phase of bone regeneration, since the revascularization and remodeling processes are strictly hampered by the dense architecture [15].

5.1.1 Autogenous bone graft (autograft)

Autogenous grafts: the fresh autogenous graft taken from the same organism contains osteogenic cells and does not cause an immunological reaction; this group is the most advantageous graft material. However, the disadvantages of this group include the need for a second operation in the donor area, long-term postoperative pain and limitation of movement, and prolonged maintenance. Autogenous bone grafts can be obtained from crista iliaca: grafts costal grafts and cranial bones, structurally separated as cortical bone, cancellous, and corticocancellous bone [5].

Intraoral cancellous bone: Upper jaw tuber region, toothless regions, exocytoses, recovery sites ramus mandibula, interlobar alveolar bone, lower jaw semispherical region and ramus mandibula, and bone fragments arising during operation [5].

Oral cancellous bone: The iliac bone is obtained from bone, ribs, and other endochondral bones.

Corticocancellous bone: The corticocancellous bone does not have the osteogenesis-enhancing properties as cancellous bone. This type of graft is most commonly of rib or ilium origin [5].

5.1.2 Homogeneous bone graft (homograft)

An autogenous bone graft is obtained from the individual itself.

Isograft: The tissues taken from living things with the same genetic structure as the recipient are called isografts or syngenesioplastic grafts.

Allografts are tissues from the same species but from living things that are genetically identical to the recipient. Bone allografts are obtained from human beings of different genetic types and from bones extracted from humans, such as cadavers or hip fractures, and are maintained in bone banks by a series of procedures [11]. It has many advantages compared to being obtained from living people. The advantages are elimination of donor site, reduction of anesthesia and duration of operation, loss of blood loss and complications at low level. The disadvantage is that the touch is taken by another person [5].

Considering the limitation of autologous bone grafts is the best alternative to autografts and has been used effectively in clinical practice in many cases, especially for patients who have poor healing potential, established nonunion, and extensive comminution after fractures [15, 17]. The allograft may be machined and customized and is therefore available in a variety of forms, including cortical, cancellous, and highly processed bone derivatives [14]. Allografts are found to be immunogenic and have higher failure rate, which are believed to be caused by activation of major histocompatibility complex [19].

Cancellous allografts are the most common types of commercial allogeneic grafts and are supplied predominately in the form of blocks [14]. Compared to autografts, a similar but slower sequence of events happens in the incorporation process of allografts [15].

Cortical allografts confer rigid mechanical properties and are mainly applied in spinal augmentation for filling large defects [14]. In consideration of immune

responses and for safety, frozen or freeze dried products that are free of marrow and blood are commonly transplanted [15].

Demineralized bone matrix is highly processed allograft derivative with at least 40% of the mineral content of the bone matrix removed by the acid, while collagens, noncollagenous proteins, and growth factors remain [17].

Demineralized bone matrix osteoconductivity is conferred by providing a framework for cell populating and for generating new bone after the treatment [18]. Osteoinductive property of demineralized bone matrix is mainly determined by the remaining growth factors, which are directly correlated with preparation methods. Demineralized bone matrix is similar to that of the autogenous graft, with growth factors triggering an endochondral ossification cascade and culminating in new bone formation at the site of implantation [18].

Recent techniques in preparing immunoglobulin complications of allografts to remove the disease carrying potentials are freezing, freezing and drying, or exposure to radiation. The applied bone has a slower revascularization and more resorptive activity than autogenous grafts [5].

The mechanism of revascularization begins with an acute infinite response and lasts for a long time, followed by chronic infilamations. It meets cellular immunological response in frozen bone applications.

5.1.3 Heterogeneous bone graft (xenograft)

Heterogeneous bone grafts are called grafts from a different species. The heterogeneous term is used for tissues from different species. Heterogeneous bone grafts have been proposed to fill small jaw defects, and many clinicians have indicated that these grafts have any osteogenic potential but instead are matrix for bone formation. Studies done with inorganic calf bone showed successful results in graft osteotomy sites but not in posttraumatic deformity and hypoplastic area corrections [5].

5.1.3.1 Clinical use of the allogeneic bone

Allogeneic bones prepared for different frozen, dried, or frozen oral surgical procedures are available in different anatomical shapes. Cancerous iliac bone is divided into particles of about 2–10 mm in diameter for use in bone defects. Small cancellous particles are used in the periapical areas after curettage with limited alveolar edge corrections [5].

Researchers who have expected to make use of osteoconductive effects of alloplastic bone materials (hydroxylapatite, tricalcium phosphate, etc.) and bone allografts and autogenous bone grafts cause postoperative complications in the donor area have been directed to obtain bone grafts with both osseoinductive and osseoconductive allogenic, low antigenic properties. For this purpose, autolyzed, degenerated (allogenic) bone was studied. In contrast to lyophilized or other allogenic human bones, researchers indicate that the allogenic bone is osteoconductive. The use of lyophilized and sterile human allogenic bone in parts or powder forms is offered. The powder forms of this bone are suggested for filling the cyst cavity [5].

5.2 Bone-free biomaterials (alloplasts)

Allogenic grafts which lost vitality have been seen, organic, and inorganic inanimate materials and synthetic materials obtained from animals such as ceramic hydroxylapatites, tricalcium phosphates, and various "alloplastic materials."

The most important problem in the alloplastic material is the tendency of the immunological system to encapsulate and isolate foreign bodies [5].

Alloplasts have been using in bone defects due to various reasons, such as cranial, mandibular, maxillary, nasal, zygomatic, TME reconstructions, or traumatic augmentations, are metals, polymers, hydroxylapatite, and associated calcium triphosphate ceramics or combinations of these materials.

5.2.1 Tissue sources

I. Dentin: It consists of hydroxyapatite crystals with a strong structure. This crystal structure is histologically resistant and resistant to osteoblast, osteoclast, blood vessel, and nerve tissue in a strong collagen network.

II. Cement: It is a bony matter that is directly related to the collagen fibers of the jawbone through the periodontal membrane.

III. Cartilage

IV. Sclera

V. Dura mater

5.2.2 Metals

Metal biomaterials are widely used in electrosurgical surgery, orthognathic surgery, and orthopedic surgery. Metallic stiffness is a desirable feature for implants that will encounter load force, especially during functioning. The metal groups used are alloys such as gold, platinum, stainless steel, titanium, and chromium-cobalt.

Bioinorganic ions, such as silicon, magnesium, strontium, zinc, and copper, can still be regarded as essential cofactors of enzymes, coenzymes, or prosthetic groups [20].

Mechanism of magnesium ions on fracture healing is not yet fully explained; recent investigations showed that the osteogenerative effect of Mg^{2+} on undifferentiated human bone marrow stromal cells (hBMSCs) and osteogenic hBMSCs was likely attributed to connected the subsequent orchestrated [20].

Strontium to reduce bone resorption and osteoclast activity [20] were also observed under rat osteoclasts and primary mature rabbit osteoclasts, respectively. The adverse effect of strontium in cardiovascular diseases and venous thrombosis has been highlighted [20].

Silicon is a silica-based synthetic bone substitute, which is used in orthopedic; bioglass cannot be ignored when discussing the effect of silicon on bone regeneration. Bioglass has a key role because of the fact that the hydroxyapatite coating, but not the leaching silicon ions, played an active role in the processes leading to new bone formation [19]. Zinc is involved in the structural, catalytic, or regulatory action of several important metalloenzymes, and alkaline phosphatase (ALP) is among them. ALP not only generates phosphates by hydrolyzing pyrophosphates but also creates an alkaline environment, which favored the precipitation and subsequent mineralization of these phosphates in the extracellular matrix, which were produced by osteoblasts [20].

Copper has been recognized as a cofactor for several other enzymes in body, one of which is related to the musculoskeletal system [20]. Lithium has attracted attention due to its role in osteogenesis [20]. Like copper, cobalt was recently showed to stimulate angiogenesis [20].

5.2.3 Gelatin film

It can be used as resurfacing, porous, nonantigenic, and in the middle ear surgery for pleural injuries in dura mater application.

5.2.4 Polymers

Polymethylmethacrylates are self-polymerized acrylics that are identified as bone cement.

Polymethylmethacrylate (PMMA) remains a key component of modern practice and is nonbiodegradable and nonresorbable, which makes it more like grouting than cement, and thus cannot be considered a bone substitute material, which is used in clinics [19].

5.2.5 Calcium sulfate

When combined with other synthetic bone substitutes and/or growth factors [20], one of the promising approaches is to load antibiotics to this biomaterial.

5.2.6 Calcium carbonate

The outer layer of corals in the calcium carbonate structure releases a calcareous substance called aragonite. The physical structure is similar to cancellous bone and consists of trace elements such as 98% calcium carbonate, 2% fluorine, zinc, copper, iron, and strontium. It is an excellent tissue-compatible material that can completely resurface during the healing process and has an osteoconductive effect on new bone formation [5].

5.2.7 Calcium phosphate

Calcium phosphate material is similar to HA in terms of its behavior in the tissue. However, calcium phosphate has the most pronounced multiplication property, which is closely related to bone without the need for porosity.

5.2.8 Calcium phosphate ceramics (CaP ceramics)

Calcium phosphate ceramics are calcium hydroxyapatites, which is a chemical composition similar to the mineral phase of calcified tissues [17]. Hydroxyapatite (HAp) is occurring mineral form of calcium apatite with the formula of $Ca_{10}[PO_4]6[OH]_2$ and comprises about 50% of the weight of the bone, which accounts for its excellent osteoconductive and osteointegrative properties [14, 17].

5.2.9 Bioactive glass

Bioactive glass, known as bioglass, refers to a synthetic silicate-based ceramics and was originally constituted by silicon dioxide (SiO_2), sodium oxide (Na_2O), calcium oxide (CaO), and phosphorus pentoxide (P_2O_5) [20]. The optimized constitutions lead to a strong physical bonding between bioglass and host bone. If hydroxyapatite coating on the surface of bioglass takes place, it absorbs proteins and attracts osteoprogenitor cells [20].

6. Principles of biomaterial trauma applications

Correcting the deformities, the first thing to note in augmentation is the presence of the epithelium that can cover the implanted material completely and without tension. In cases where deformity is common and tissue loss is large, skin and soft tissue transplantation may be required before biomaterial is applied. If the defect in the bone tissue is too large, graft should be considered, and functional stress in the receiving area, load, and the trauma to it should be considered.

Bone defect may result in delayed union or even nonunion if the treatment is improper. Therefore, bone grafting techniques should take place in the surgical process. Even though various synthetic bone substitutes offer diversity options, the treatment outcome is still incomparable to the autologous bone graft in terms of bone healing quality and time management. Ions such as magnesium, strontium, silicon, copper, and cobalt are feasible solution for bone defect. Therapeutic effect and mechanism of ions have been understood. Bioinorganic ions can be applied with growth factors and induce new bone formation.

Every surgeon should use the technique in the direction of the prepared plan, determine the biomaterial, and apply it on the model. Atraumatic work should be performed as much as possible during the operation, the material used should conform to the defect contours, the stabilization should be esthetic of the patient, and the appropriate tools should be used in the biomaterials during surgery to manipulate the material so as not to create sharp or irregular edges. Stabilization is provided by sewing, wire, and nails. Good closure of the incision is important in the postoperative period. Careful evaluation of each phase will ultimately bring success.

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Conflict of interest

We declare that there is no conflict of interest with any financial organization regarding the material discussed in the chapter.

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References

[1] Fonseca RJ, Walker RV. Oral and Maxillofacial Trauma. Vol. II. Philadelphia, WB: Saunders Company; 1991

[2] Guyton AC. Tibbi Fizyoloji. In: Textbook of Medical Physiology. 7th ed. Philadelphia: WB Saunder Company; 1986. pp. 937-953

[3] Kikırdak GY. Kemik ve Biyokimyasl. İ.Ü.Diş.Hek.Fak. Biyokimya Bilim Dali Ders NotIan. 1988:**37**;300-391

[4] Jaffe HL. Metabolic, Degenerative and Inflammatory Diseases of Bones and Joints. Munchen, Berlin, Wien: Urban and Schwarzenberg; 1972. pp. 44-104

[5] Tuskan C, Yaltirik M. Oral ve Mksillofasiyal Cerrahide Kullanılan Biyomateryaller. İstanbul: Istanbul Universitesi Yayinlari İstanbul; 2002. pp. 1-54

[6] Amler MH, LeGeros RZ. Hard tissue replacement polymer as an implant material. Journal of Biomedical Materials Research. 1992;**24**:1079-1089

[7] Archer WH. Oral and Maxillofacial Surgery. 5th ed. Vol. II, 1975. Philadelphia: WB Saunders Company. pp. 1512-1526

[8] Aukhil I, Simpson DM, Sugss C, Petterson E. In vivo differentiation of progeniton cells of the periodontal ligament. An experimental study using physical barriers. Journal of Clinical Periodontology. 1986;**13**:862-868

[9] Bovde A, Wolfe LA, Jones SJ, Vesely P, Maly M. Microscopy of bone cells, bone tissue and bone healing around implants. Implant Dentistry. 1992;**1**:117-125

[10] Braley S. The silicones in maxillofacial surgery. Laryngoscope. 1968;**78**:549

[11] Kasaboğlu Ç. Normal ve diabetli stçanlarda kemik travmasmdan sonra kan serumunda görülen degişiklilerin incelenmesi [thesis]. Istanbul: Istanbul Universitesi; 1986

[12] Nayir E. DişhekimIiği Maddeler Bilgisi. 7th ed. İstanbul; 1999. pp. 25-39

[13] Schaffer AB. The combined use of hydroxyapatite segments and granules for alveolar ridge reconstruction. Oral and Maxillofacial Surgery. 1993;**51**:26

[14] Smith EL, Hill RL, Lehman R, Lefkowitz R J, Handler F, White A, Principles of Bio-chemistry. International student ed. 1983. pp. 15-18

[15] Soydan N. Genel Histoloji, Taş Matbaası. Istanbul: Istanbul Universitesi; 1985. pp. 100-119

[16] Wismeijer D, Vermeeren JIJH, Van Waas MAJ. Patient satisfaction with overdentures supported by one-stage TPS implants. The International Journal of Oral & Maxillofacial Implants. 1992;**7**:51-55

[17] Albrektsonn T, Zarb G, Worthington P, Ericsson A. The long term efficacy of currently used dental implants. Journal of Oral and Maxillofacial Implants. 1986;**1**:11-25

[18] Sandalll F, Karabuda C. Oral implantolojide kemik grefti materyalleri ve kullamlan. Oral Implantoloji Dergisi. 1999;**1**:9-16

[19] Bouchard P, Ouhayoun JP, Nilveus RE. Expanded polytetrafluoroethylene membranes and connective tissue grafts support bone regeneration for closing mandibular Class II furcations. Journal of Clinical Periodontology. 1993;**54**:1193-1198

[20] Wang W, Yeung KWK. Bone grafts and biomaterials substitutes for bone defect repair: A review. Bioactive Materials. 2017;**2**:224-247