UDK: 616.31-002.828

ADVANTAGES AND DISADVANTAGES OF BONE GRAFTS USED IN DENTAL IMPLANTOLOGY

ПРЕДНОСТИ И НЕДОСТАТОЦИ НА КОСКЕНИТЕ ГРАФТОВИ ВО ДЕНТАЛНАТА ИМПЛАНТОЛОГИЈА

Domlevska A.[1], Velevska-Stevkovska D.[2], Apostolova G.[3], Terzievska A.[4], Stevkovska E.[1], Bajraktarov A.[1]

[1] Intern, Faculty of Dentistry, Ss. Cyril and Methodius University-Skopje, North Macedonia, [2]Department of Implantology, Faculty of Dentistry, Ss. Cyril and Methodius University-Skopje, North Macedonia, [3]Department of Oral Surgery, Faculty of Dentistry, Ss. Ss. Cyril and Methodius, Skopje, North Macedonia, [4]Clinic of Oral Surgery, University Dental Clinics "St. Pantelejmon"-Skopje, North Macedonia

Abstract

Given the increasing popularity of dental implantology and the advancements in modern dental materials, this paper aims to present a comprehensive literature review and analysis of scientific studies. The objective is to assess whether significant differences exist among various types of bone grafts concerning the advantages and disadvantages, as well as to identify an ideal graft material that meets all success criteria. To achieve this objective, an analysis of relevant scientific and professional literature was performed using scientific databases such as PubMed, Web of Science, Google Scholar, EBSCO, and Elsevier, focusing on publications from the past decade. The keywords used for the research included: bone, bone grafts, augmentation, dental implants, and marginal bone loss. A retrospective analysis was conducted after reviewing all collected data, focusing on the significant aspects related to the application of bone graft materials in the comprehensive implant approach. In preparing this paper, the data concerning the bone graft materials used were thoroughly elaborated and processed. By investigating these electronic databases, we organized the data obtained about the advantages and disadvantages of various graft materials. From the literature review regarding the ranking of available graft materials, it can be noted that autologous grafts yield the highest levels of newly formed bone, the smallest percentage of residual graft particles, and the least amount of connective tissue development. **Key words:** bone grafts, bone augmentation, dental implantology, dental implants.

Апстракт

Со оглед на зголемената популарност на денталната имплантологија и на напредокот во современите дентални материјали, овој труд има за цел да презентира сеопфатен преглед на литературата и анализа на научни студии. Целта е да се процени дали постојат значајни разлики меѓу различните видови коскени графтови во однос на нивните предности и недостатоци, како и да се идентификува постоењето на идеален графт-материјал што ги исполнува сите критериуми за успех. За да се исполни целта, била извршена анализа на релевантна научна и стручна литература со користење на клучните бази на податоци како што се PubMed, WebofScience, GoogleScholar, EBSCO и Elsevier, фокусирајќи се на публикации од изминатата деценија. Клучни зборови употребени за пребарувањето: коска, коскени графтови, аугментација, забни импланти и маргинална загуба на коскена маса. Беше спроведена ретроспективна анализа по преглед на сите собрани податоци, фокусирајќи се на значајните аспекти поврзани со примената на материјалите за коскени графтови во сеопфатниот имплантолошки третман. При подготовката на овој труд, податоците во врска со користените материјали за коскени графтови беа темелно разработени и анализирани. Со истражување на овие електронски бази на податоци, ги организиравме добиените податоци за предностите и за недостатоците на различните графт-материјали. Од прегледот на литературата во врска со рангирањето на достапните графт-материјали, може да се заклучи дека автологните графтови даваат највисоки нивоа на ново формирана коска, најмал процент на преостанати честички од графтот и најмала количина на создадено сврзно ткиво. **Клучни зборови:** коскени графтови, зголемување на коските, дентална имплантологија, дентални импланти.

Introduction

In the field of modern dentistry, the use of dental implants is the most effective approach for treating the loss of one or more teeth. Due to the numerous advantages, especially the impressive success rates of implant procedures, dental implants have been recognized as the standard of care for replacing missing teeth and for stabilizing different types of fixed or removable prosthetic appliances in patients experiencing total or partial edentulism.

Dental implantology, recognized as a specific field within oral surgery that often requires both horizontal and vertical augmentation of the alveolar ridge during dental implants placement, raises important questions regarding currently available bone grafts, their characteristics, and their anticipated impact on the success of dental implants. This topic represents the primary focus of this paper, selected due to its critical importance, its recent evolutionary development, and the limited number of published articles addressing these issues.

As a result of alveolar bone loss, there is a significant need to develop materials for alveolar bone augmentation. These materials and techniques aim to establish a reliable foundation for successful dental implant placement. The loss of alveolar bone has led to an increased demand for the development of materials capable of supporting it. These innovations and approaches are designed to create a reliable foundation for the successful placement of dental implants.

Ultimately, it is important to note that the principal function of bone grafting is to provide mechanical support and promote bone regeneration, with the ultimate goal of producing new bone (de-novo). Apart from the well-recognized four key biological properties that enhance the performance of bone grafts: osseointegration, osteogenesis, osteoconduction, and osteoinduction, there are numerous other properties and characteristics that also influence the success of bone grafting, which are not classified under biocompatibility. This additional set includes bioresorption, structural integrity, porosity, vascular inductance, plasticity, ease of handling, resistance to compressive forces, and, of course, the cost of the bone graft material[1].

Considering the increasing acceptance of dental implantology alongside the evolution of contemporary dental materials, this paper has been designed to perform a detailed literature review and analysis of scientific articles for advantages and disadvantages of various bone grafts, and to determine whether an ideal graft material exists meeting all necessary success criteria.

A comprehensive literature review was conducted to gather data from the past decade using databases such as Web of Science, PubMed, Elsevier, Google Scholar, and EBSCO. The research applied the following keywords: bone, bone grafts, augmentation, dental implants, and marginal bone loss.

The scientific papers included in this review were predominantly written in English within the last ten years. The literature search was conducted without a specific timeframe for publication, aiming to present key theoretical principles and recent research spanning the last 15 years. Some older papers were also included to enhance the understanding of the topic or are recognized as fundamental contributions to the field.

Advantages And Disadvantages Of Bone Grafts Used In Dental Implantology

Bone tissue undergoes a continuous process of remodeling through ongoing formation and resorption. During the first year of life, nearly 100 percent of the skeleton is replaced, while in adulthood, the rate is closer to 10 percent annually. This remodeling allows bones to functionally adapt to changes in load. The remodeling of alveolar bone during the placement of alveolar bone is influenced by several factors: the population of osteoblasts, blood supply, graft stabilization, and the tension of soft tissue following suturing after the intervention[2].

Osteoblasts are the cells responsible for synthesizing new bone tissue. For the graft to be successful, the graft matrix must contain osteoblasts or stimulate their population. If there is an insufficient number of osteoblasts, the graft is typically unsuccessful[3].

During the healing process, mechanical tensions on the grafting materials can lead to a disruption in fibrin clot formation. Movement in the healing regions may result in the creation of fibrous tissue that fills the defect instead of facilitating the formation of bone tissue. The generation of fibrous tissue does not constitute true regeneration. To prevent such inadequate healing, fixation techniques and the removal of connective tissue, such as Guided Bone Regeneration (GBR), can be utilized, or collagen membranes, titanium mesh, and similar materials may be used[4].

In contemporary dentistry, numerous implant systems have been introduced, each with specific indications that can be effectively integrated. The critical factor for the successful placement of dental implants is the adequate quality and quantity of alveolar bone at the intended implant sites. Bone graft materials play a vital role in addressing this deficiency. As highlighted earlier, there is also a wide range of graft materials available, leading to the understandable divergence of opinions in professional and scientific literature regarding the advantages and disadvantages of various graft materials utilized in dental implantology[5].

Each material available for augmentation presents specific advantages and disadvantages. Human grafts can be sourced from the patient's own body, necessitating additional surgical procedures, or from cadavers, which is often deemed undesirable by the public. In addition, there are various grafts derived from non-human sources, commonly referred to as xenografts.

Xenografts consist of processed bovine bone, which serves as a supportive matrix for the augmentation of jaw bone tissues when necessary. Bovine bone has been shown to be nearly as effective as human bone in eliciting a satisfactory healing response from adjacent tissues. Following the regeneration of bone tissue, optimal conditions are established for the insertion of dental implants[6].

A significant limitation of xenografts lies in their potential to spread infectious diseases among various species. Nevertheless, it should be emphasized that there is limited available literature that points to the risk level of xenografts. As a result, bovine bone is typically the source of xenografts, and it continues to be considered one of the safest materials for their production[7].

In light of this present, although minimal risk, the need has arisen to create contemporary graft materials of synthetic origin (allograft materials).

Alloplastic graft materials consist of synthetic materials, including the mineral hydroxyapatite. The benefits of these synthetic grafts are their ready availability and potentially lower costs compared to various alternatives. Moreover, their synthetic nature helps protect individuals from the risk of infection or disease transmission from donors[8].

A disadvantage is that synthetic materials do not function identically to other alternatives, such as human or bovine bone. The key limitation is that the process may take longer. However, the additional waiting period will be beneficial primarily due to its link to the relative safety of this material for grafting[9].

Table 1. presents the advantages and disadvantages of allografts, autografts, xenografts, and alloplastic materials utilized in dental medicine.

When considering graft materials, autogenous bone has demonstrated the highest density and greatest quantity of newly formed bone. However, the application of demineralized frozen bone and an innovative demineralized allogeneic bone matrix may similarly facilitate bone regeneration in comparison to membranes after a six months recovery period[10].

In many clinical situations, it is essential to combine dental implants with bone grafts and/or bone substitutes. Following the implantation process, the silica-based bone graft particles convert into a coating that is rich in calcium and phosphate, while the inner silicon-rich core is lost. Research by Guglielmottiet al[11] reported enhanced reactive medullary bone formation when these graft particles were placed around titanium implants.

Collagen materials are applied in both medical and dental practices due to their recognized biocompatibility and their role in enhancing wound healing. An experimental study was conducted to evaluate the effects of bovine collagen granules on the alveolar wounds healing after tooth extraction in rats. The study's results demonstrated that the trabecular surface area of the bones was larger in the extraction sockets treated with collagen granules compared to the control sockets. In addition, the trabecular bone density was higher in the experimental sockets than in the control ones. Thus, it can be concluded that the research provided evidence supporting the use of bovine collagen granules as a bone grafting material, representing a therapeutic alternative for filling sockets after dental extractions[12].

One of the most effective techniques for bone augmentation is Guided Bone Regeneration (GBR). To date, procedures utilizing expanded polytetrafluoroethylene membranes (ePTFE) have proven to be the most efficient and predictable surgical method for enhancing deficient bone areas[13].

Autogenous blocks placed alongside the implants can achieve an excellent long-term implants success rate. Autogenous bone chips or deproteinized bovine bone can be used for fenestration and dehiscence defects when used in conjunction with e-PTFE membranes. In most instances, Teflon membranes are preferred due to their reliable outcomes. The use of collagen membranes, when supported by bone substitutes for space maintenance, yields favorable results, although long-term research is necessary[14].

The vertical augmentation of the alveolar bone through the use of e-PTFE membranes and particulate autografts is recognized as a secure and predictable approach. The rates of success and survival for implants placed in vertically augmented alveolar bone via the GBR technique are similar to those for implants placed in untreated bone under load. Additionally, the success and failure rates of implants in bone that has been regenerated concurrently with sinus lift and vertical augmentation techniques are found to be almost equivalent, even in cases where only vertical augmentation is necessary[15].

In addition to the benefits associated with modifications of soft and hard tissues, the necessity for further bone augmentation, the practicality of implant placement, and the implant survival and success rates may further support the implementation of ridge preservation and augmentation techniques. A recent systematic review indicates that the need for additional bone augmentation during implant placement can vary, with figures ranging from 0% to 15% for ridge preservation and from 0% to 100% for spontaneous healing[16].

It is essential to recognize that the planning of implant therapy is critical, rather than merely placing implants alongside bone graft materials; therefore, the study should emphasize the specific locations of implant placement, the diameters used, and the chosen angulation. Currently, this information is not available to provide adequate scientific evidence, which may lead to an underestimation of the impact of ridge preservation in everyday clinical practice. Overall, the literature supports the use of alveolar ridge preservation to maintain ridge volume, particularly at the hard tissue level, but does not yield additional clinical benefits regarding implant-related outcomes and is associated with an extended healing period (greater than 6 months) and a flap procedure.

Conclusion

Following the review of the literature provided data regarding the ranking of accessible graft materials and their influence on the success of dental implants and their survival rates, the following conclusions can be established: (1) autologous grafts demonstrate the highest percentage of newly formed bone compared to synthetic grafts, xenografts, and allografts: (2) autologous grafts exhibit the lowest percentage of residual graft particles compared to xenografts, synthetic grafts, and allogeneic grafts.Among the graft types, autologous grafts showed the lowest rate of connective tissue formation, succeeded by allogeneic, xenogeneic, and synthetic grafts.

Reference

1. Zhao R, Yang R, Cooper PR, Khurshid Z, Shavandi A, Ratnayake J. Bone grafts and substitutes in dentistry: a review of current trends and developments. Molecules. 2021 May 18;26(10):3007.
2. Francisco H, Marques D, Pinto C, Aiquel L, Caramês J. Is the timing of implant placement and loading influencing esthetic outcomes in single-tooth implants?—A systematic review. Clinical oral implants research. 2021 Oct;32:28-55.
3. Froum SJ, Ortiz M, Witkin RT, Thaler R, Scopp IW, Stahl SS. Osseous autografts. III. Comparison of osseous coagulum-bone blend implants with open curetage. Journal of Periodontology. 1976 May 1;47(5):287-94.
4. Elgali I, Omar O, Dahlin C, Thomsen P. Guided bone regeneration: materials and biological mechanisms revisited. European journal of oral sciences. 2017 Oct;125(5):315-37.
5. Stumbras A, Kuliesius P, Januzis G, Juodzbalys G. Alveolar ridge preservation after tooth extraction using different bone graft

Table 1. Advantages and disadvantages of different bone grafts

Type of material	Source	Advantages	Disadvantages
Autograft	From the patient himself	Osteogenic material Living cells No possibility of transmission of infectious conditions Contains cortical bone	Pain Infection Complex surgical interventions
Allograft	From another person	Osteoinductivity Osteoconductivity Effective matrix	Risk of infection transmission
Xenograft	From another species (most often bovine)	Hydroxyl apatite is similar to that in humans, which provides bulk stability. Collagen leads to accelerated bone formation.	It acts only osteoconductively.
Aloplast	Synthetic	No risk of infection transmission	It acts only osteoconductively.
	Hydroxy-apatite	Slowly resorbed which preserves bone volume	
	TCP	Contains growth factors	
	Bioglass	Rapid resorption leading to rapid replacement with new bone	

Table 2. Advantages and disadvantages of materials that are used for bone grafting in medicine and dental medicine*

Type of grafting material	Advantages	Disadvantages
Autologous bone	"Gold standard" because it is osteoconductive, osteoinductive and osteogenic	Second surgical site increases risk of infection, and there is a limitation on the amount of material available for grafting
Autologous cancellous bone	Coverslarge surface area favorable for revascularization	Poor mechanical strength
Autologous cortical bone	Structural support and mechanically stable	Takes longer to remodel than cancellous graft
Autologous vascularized cortical bone	Rapid healing time, preserved osteocytes and osteoprogenitor cells in the graft	Difficult to collect and implant
Bone marrow aspirate	Can be harvested minimally invasively	Fewer stem cells in graft than expected
PRP (platelet-rich plasma)	Available, easy to obtain, induces migration of pluripotent cells directly to the site, reduces the amount of autograft required for harvesting	Variability in preparation methods
Allogeneic graft materials	No secondary surgical site (therefore there is a reduced risk of infection and no additional pain)	Risk of disease transmission or adverse immune response
Allogeneic cancellous bone	Freeze-drying results in a graft with low residual moisture and a shelf life of 4-5 years	Low mechanical strength, difficult to implant as body encapsulates graft in fibrous tissue
Allogeneic cortical bone	Strong, can be used in load-bearing areas of the body	Slow healing due to inflammatory response
Allogeneic demineralized bone matrix	Contains growth factors that make it osteoinductive	Variable amounts of growth factors from different batches and manufacturers
Synthetic graft materials	Many options for creating graft materials (which can be 3D printed or injected)	Lack of growth factors to promote bone growth
Calcium phosphate ceramic	Similar composition to bone tissue	Poor mechanical strength, difficult to shape

Type of grafting material	Advantages	Disadvantages
Tricalcium phosphate	Synthetic graft with the most similar composition to bone tissue, "gold standard" of synthetic grafts	Degrades unpredictably, making it unsuitable for load-bearing areas
Biphasic calcium phosphate	It possesses the advantages of both tricalcium phosphate and hydroxyapatite, resorption rate and mechanical properties	Limitation of mechanical force based on graft mixture
Hydroxy apatite	Very high biocompatibility, higher compressive and tensile strength compared to tricalcium phosphate	Slow graft resorption
Calcium phosphate cement	The temperature reaction of dissolution - precipitation makes them easy to shape	Weak mechanical strength
Calcium sulfate	Cheap and easy to prepare	Resorbs faster than bone resorption, but still has a risk of serous wound drainage, lack of mechanical strength
Bioactive glasses	Forms bonds with bone and tissue, activates genes that control osteogenesis, antibacterial properties	Small range of SiO_2 content for graft bioactivity
PMMA bone cement	Secures orthopedic implants in place	No intrinsic adhesive properties, heat sensitive, cement fragmentation and foreign body reaction can lead to their resorption and loosening of the implant
Growth factors or bioactive molecules	Have both osteoinductive and osteoconductive properties	Not studied long-term, inflammatory complications, very expensive
BMP-2	Possible better results compared to autografts, good bone regeneration abilities in smokers	Can cause swelling that can close the patient's airway, risk of ectopic bone formation
OP-1 (BMP-7)	-	No longer available on the market
PDGF-BB	Less pain than when applying autografts, giving similar results	Not studied long-term, expensive
iFactor (P-15)	Similar results to autografts	Adverse effects of axial pain, postoperative radiculopathy and dysphagia after treatment

Table 3. Advantages and disadvantages of bone grafts in oral surgery*

Material Type	Product	Advantages	Disadvantages
Hydroxyapatite	Ostim™ Endobon™	Osteoconduction Macroporous structure comparable to human bone Biocompatibility Excellent hydrophilicity	Donor site morbidity Unfavorable mechanical characteristics Delayed resorption rate Limited availability
Tricalcium phosphate ceramics	Cerasorb™ OSferion™ Orthograft™	Osteoconduction Ease of handling Radiolucency allowing healing monitoring Good resorption Low immunogenicity	Poor mechanical properties, especially compressive strength
Biphasic calcium phosphate ceramics	MASTERGRAFT™	Osteoconduction Osteoinduction Resorbability Relatively better mechanical properties than TCP or HA alone	Compressive strength remains lower than that of cortical bone
Bioglass	Perioglas™ Biogran™	Osteoconduction Biocompatibility Antimicrobial activity Porous structure Completely resorbable	Brittle Low mechanical strength Poor fracture resistance
Calcium phosphate cements	Norian™ ChronOS inject™ Hydroset™ BoneSource™	Osteoconduction Self-positioning ability Molarity Biocompatibility	Low rate of cell adhesion Fragility Concern regarding extrusion of material into adjacent tissues
Calcium sulfates	OsteoSet™	Osteoconduction Low cost Readily available High moldability (plasticity) Biocompatibility Short placement time	Rapid resorption that is faster than that of human bone Relatively high risk of infection and inflammation
Polymers	Bioplant HTR Synthetic Bone™	Osteoconductive Biocompatible Adaptable shapes Low immunogenicity Porous structure Radiopacity	Concerns about acidic degradation products

Material Type	Product	Advantages	Disadvantages
Metals	OSS Builder™	Osteoconduction, acts as a membranous barrier for GBR Good mechanical strength Good biocompatibility Corrosion resistance Porous structure that improves cell adhesion	Need for second surgical visit Possibility of soft tissue dehiscence and membrane exposure
Composites Material Type Hydroxyapatite	NanoBone™	Osteoconduction Osteoinduction Resorbability Plasticity Good cell adhesion	Lack of studies investigating the use of NanoBoneTM in humans
	Fortoss Vital™ (β-TCP/calcium sulphate)	Osteoconduction Osteoinduction Completely resorbable Plasticity Porous structure Good cell adhesion	Contact with blood will delay the setting time of the paste.
	SmartBone™ (DBM/polymer/collagen)	Similar morphology to human bone Rapid adhesion and proliferation of blood cells due to high hydrophilicity Improved volumetric stability High load resistance for large bone defects	Comes in single-use packages only

* Adapted and modified from:

- Zhao R, Yang R, Cooper PR, Khurshid Z, Shavandi A, Ratnayake J. ***Bone grafts and substitutes in dentistry: a review of current trends and developments***. Molecules. 2021 May 18;26(10):3007.
- Ferraz MP. ***Bone grafts in dental medicine: an overview of autografts, allografts and synthetic materials. Materials.*** 2023 May 31;16(11):4117.

materials and autologous platelet concentrates: a systematic review. Journal of oral & maxillofacial research. 2019 Mar 31;10(1):e2.
6. Guarnieri R, Belleggia F, DeVillier P, Testarelli L. Histologic and histomorphometric analysis of bone regeneration with bovine grafting material after 24 months of healing. A case report. Journal of functional biomaterials. 2018 Aug 8;9(3):48.
7. Cascalho M, Platt JL. Challenges and potentials of xenotransplantation. Clinical Immunology. 2009 May 15:1215.
8. Cooper GM, Kennedy MJ, Jamal B, Shields DW. Autologous versus synthetic bone grafts for the surgical management of tibial plateau fractures: a systematic review and meta-analysis of randomized controlled trials. Bone & Joint Open. 2022 Mar 1;3(3):218-28.
9. Williams DF. Challenges with the development of biomaterials for sustainable tissue engineering. Frontiers in bioengineering and biotechnology. 2019 May 31;7:127.
10. Simion M, Dahlin C, Trisi P. Qualitative and quantitative comparative study on different filling materials used in bone tissue regeneration: a controlled clinical study. International Journal of Periodontics & Restorative Dentistry. 1994 Jun 1;14(3).
11. Guglielmotti MB, Olmedo DG, Cabrini RL. Research on implants and osseointegration. Periodontology 2000. 2019 Feb;79(1):178-89.

12. Ruales-Carrera E, Pauletto P, Apaza-Bedoya K, Volpato CA, Özcan M, Benfatti CA. Peri-implant tissue management after immediate implant placement using a customized healing abutment. Journal of Esthetic and Restorative Dentistry. 2019 Nov;31(6):533-41.
13. Weber HP, Fiorellini JP, Buser DA. Hard-tissue augmentation for the placement of anterior dental implants. Compendium of continuing education in dentistry (Jamesburg, NJ: 1995). 1997 Aug 1;18(8):779-84.
14. Maréchal M. Guided bone augmentation in edentulous areas. Nederlands Tijdschriftvoor Tandheelkunde. 2002 Nov 1;109(11):439-43.
15. Urban IA, Jovanovic SA, Lozada JL. Vertical ridge augmentation using guided bone regeneration (GBR) in three clinical scenarios prior to implant placement: a retrospective study of 35 patients 12 to 72 months after loading. International Journal of Oral & Maxillofacial Implants. 2009 Jun 1;24(3).
16. Ding Y, Wang L, Su K, Gao J, Li X, Cheng G. Horizontal bone augmentation and simultaneous implant placement using xenogeneic bone rings technique: a retrospective clinical study. Scientific reports. 2021 Mar 2;11(1):4947.