ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)
IJDSIR : Dental Publication Service
Available Online at: www.ijdsir.com
Volume – 5, Issue – 6, December - 2022, Page No. : 15 - 21

The various alternatives to substitute lost bone in the maxillofacial region -A brief overview

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Citation of this Article: Dr. Shivangini Nayak, Dr. Ajay Kumar Pillai, Dr. Shaji Thomas, Dr. Neha Jain, Dr. Kriti Dubey, Dr. Neha Gour, "The various alternatives to substitute lost bone in the maxillofacial region -A brief overview", IJDSIR- December - 2022, Vol. – 5, Issue - 6, P. No. 15 – 21.

Type of Publication: Review Article

Conflicts of Interest: Nil

Abstract

Bone graft is defined as a living tissue that is placed into a bony defect that will aid in regeneration of healthy bone. Bone grafts are used in various fields of health science and maxillofacial surgery is one of them. The reason of bone loss can vary from a simple periodontal defect to larger defects that are left behind following resection of a massive tumour. This review article will touch up briefly upon the history of bone grafts, the basic biology of bone graft healing in the host body, its current uses and the various types of grafts that are available including the newer bone substitutes.

Keywords: Bone graft, Maxillofacial surgery, Autograft, Allograft, Xenograft, Alloplast.

Introduction

A living tissue that can aid in bone regeneration or repair that is placed into a bony defect is referred to as a bone graft and can be used alone or in conjunction with other materials [1]. The ultimate goal of bone grafting is to substitute missing bone with healthy, well-vascularized bone that will go through normal remodelling to attain adequate bone volume and structure. Whatever the goal, whether it is to reconstruct the mandible after enucleating a cyst or augment the alveolus for prosthetic purposes, the ideal bone graft should have a histology of bone that is completely distinct from the original local tissue. Instead of repairing bone, an ideal bone graft material should be able to regenerate it [2]. Over a century has passed since the first bone graft was used for repair. Reconstructive surgery frequently utilizes this approach. It has advanced significantly over the past few decades. Bone that has been lost needs to be replaced with alloplastic materials, bone transplants, or any such alternatives.

Bone grafts throughout history

One of the earliest pieces of evidence of the use of alloplastic material to correct craniofacial deformities can be seen in the Neolithic Peruvian skulls where the frontal bone deformity was covered with hammered gold and silver plates. Van Meekren in 1632 carried out the first craniofacial repair utilizing bone graft which was harvested from a dog's calvarium. Merren reported the first successful bone implant in 1809. Macewen reported the first successful allograft in 1881. He rebuilt a child's humerus. In 1889, Seydel became the first surgeon to use autogenous bone grafts in the face region. He made use of tibia autogenous bone. Muller and Koneig harvest the first calvarial bones in 1890. In 1901, Marchand proposed that osteogenesis was caused by the host tissue at the grafted site rather than the graft. Axhausen originally described a free split calvarial graft in 1908. Pickrell employed an iliac crest graft to fix cranial deformities in 1931. 1957 saw the introduction of autogenous split rib transplants by Longacre and De Stefano to correct cranium and facial skeleton abnormalities. In 1965, Urist M. R. developed the idea of bone induction following the discovery of bone morphogenic proteins. In 1965, Ilizarov proposed distraction osteogenesis, a method for growing long bones. In 1989, McCarthy used this technique for the first time in the maxillofacial area. Later, Philips et colleagues expanded on this idea by using bone transport to fill bone deficiencies. The use of autoclaved autogenous bone for reimplantation for benign tumours of the craniofacial region was described by Lauritzen et al. [3].

Utility of bone grafts- [3,4]

- To treat congenital malformation.
- To strengthen bone in cases like hemifacial atrophy, micrognathia, nasal abnormalities, etc.
- To promote non-united fracture healing.
- Reconstruction of post-traumatic deformities. In order to restore facial prominences, vertical stress pillars, mandibular continuity, etc.
- After orthognathic surgery, to restore bone continuity at osteotomy sites.
- To fill voids left behind after cyst and tumour removal.
- To maintain bone continuity after tumour ablation.
- To strengthen alveolar bone prior to prosthetic rehabilitation.
- To enhance facial contour.

Physiology of Bone and bone graft healing

The transfer of living bone from one place to another is referred to as a bone graft. While implantation refers to the transfer of non-living cells, transplantation entails the transfer of living cells. Therefore, nonviable materials are implants rather than grafts. Despite this distinction, the exact usage of these terms is not consistently followed in the literature [5]. After placement of the bone graft in the recipient site it would heal by the following process [3,5]-

- Osteogenesis
- Osteoconduction
- Osteoinduction

Osteogenesis is the process by which new bone is formed. Viable osteoblasts and/or osteoblast precursors (stem cells) are implanted with the bone graft to kickstart this process [5].

Osteoconduction is the ability of a bone graft or implant to offer a structural foundation for the host cells to regenerate on. With the help of this scaffold, vasculature, osteoblasts, and stem cells can grow and unite with the host skeleton [5].

Osteoinduction is the process of attracting stem cells from the host bed to the site of the graft, where they undergo osteoblast differentiation [5].

Bauer and Muschler have broken down graft incorporation into five main phases [6].

- Cellular recruitment, bone-inducing factor release, and hematoma formation.
- Inflammation of the Fibrovascular tissue that connects the graft to the surrounding bone.
- Vascular invasion of the graft.
- Osteoclast recruitment results in localised graft resorption.
- New bone development, graft and surrounding bone union, and graft remodelling.

Classification of Bone grafts-

Sno.	Classification	Materials
1.	Natural Bone grafts or alternatives	• Autografts • Allografts • Xenografts • Phytogenic Materials
2.	Synthetic bone alternatives	• Hydroxyapatite • Metals • Beta Tri Calcium phosphate ceramics • Calcium sulphates • Polymers • Bioactive glass • Calcium phosphate cements
3.	Bone alternatives infused with living osteogenic cells	• Bioseed-Oral Bone • Osteotransplant DENT
4.	Bone alternatives based on growth factors	• Sticky bone • Augment • Osigraft • Infuse
5.	Composite bone substitutes	• NanoBone • Fortoss Vital • SmartBone

Table 1: Classification of bone grafts [1]

Natural alternatives of bone grafts-

- Autograft

Utilizing bone from the same person receiving the graft is termed as autologous or autogenous bone graft. These types of grafts are harvested from bones including the iliac crest, bone from rib, calvarium, mandibular

symphysis, and anterior mandibular ramus to name a few. When doing a block transplant, autogenous bone is most frequently used because there is a lower chance of graft rejection because the graft is taken from the patient itself. Along with being osteoconductive, it is osteogenic and osteoinductive in nature. Autologous grafts have the drawback of requiring a second surgical site which increases the possibility of post operative complications [7].

- Allografts

Allografts are the grafts which are harvested from other individuals of the same species. Before being prepared for use by surgeons, allografts are obtained are to be rigorously sterilised and deactivation of proteins that are encountered in a healthy bone to prevent antigenic reactions and eliminate the risk of transmission of infections [7,8]. They can be made utilising a variety of processing techniques combined. The characteristics of the allografts can vary greatly as a result of this variability in processing techniques. Broadly, they can be classified as follows-

1. Fresh or fresh-frozen bone
2. FDBA (Freeze-dried bone allograft)
3. DFDBA (Decalcified Freeze-dried bone allograft)

- Xenografts

Xenograft is obtained from other species. Hence the major disadvantage is antigenicity even though, the degree of processing is substantially higher than that of allografts. Another disadvantage is that the additional sterile processing decreases its osteoinductive qualities. However, its advantage is since there are so many donors, these grafts might be more affordable and accessible. The lengthy sterilisation procedures are another factor in the lengthy shelf life. In practice, bovine-based xenografts are most frequently employed [8].

- Phytogenic Materials

Bone substitutes made from plant sources, such as Gusuibu, coral-based bone substitutes, and marine algae, are termed as phytogenic materials. Gusuibu is a traditional Chinese herbal remedy that is frequently used to treat osteoarthritis and bone fractures in Chinese patients [9] Calcium carbonate found in coral-based bone substitutes, is either used in its naturally occurring form or processed by heat treatment with ammonium phosphate and transformed into crystalline HA (Hydroxyapatite) with very little residual carbonate ,HA is a naturally occurring calcium phosphate polymer which function as a structural scaffold making it a popular tool for promoting bone healing [10].

5.2 Synthetic bone alternatives-

Hydroxyapatite (HA) is chemically similar to the inorganic component of bone so, it's an option worth considering as a bone grafting material [11]. Because of its crystallinity and relatively high Ca/P ratio, synthetic HA has delayed resorption rate. Its comparatively poor mechanical strength prevents it from being employed at high load-bearing areas. Therefore, its use is limited as coating in implants and external fixation pins [1].

Pure phasic β-TCP (Tricalcium phosphate ceramics) is another such synthetic bone substitute. It has shown promising characteristics including ease of handling, radiopacity for monitoring healing, good osteoconductivity because of macroporosity that encourages fibrovascular ingrowth and osteogenic cell adhesion, good re-sorbability in comparison to bovine bone grafts, low immunogenicity, and low risk of disease transmission. [1,12]. Utilising the best of both worlds HA and β-TCP are frequently used together. This results in faster and higher bone regeneration rates than when using HA alone, as well as greater mechanical characteristics than when using β-TCP alone [13].

Bioactive glasses (BAG) are a class of ceramics that are made of silicates combined with other minerals like Ca, Na2O, H, and P. When the material comes in contact with body fluids silicon ions leach out and build up, generating a coating of HA on the bone surface that encourages the adhesion of osteogenic progenitor cells.

Calcium phosphate cement (CPC) is a two- or three-component system made up of an aqueous component and a powder component that frequently contains sintered CP material such α-TCP and HA. The components are combined to create a workable paste that forms HA nanocrystals at room temperature after hardening in place in a self-setting manner [1]. The main benefits of CPCs are their ability to self-set, their ability to mould the paste into the defect site, their ability to accurately replicate the structure and composition of bone, their high biocompatibility and their osteoconductive properties [1,14].

Gypsum powder that has been heated and turned into calcium sulphates finally forms an alphahemihydrate crystal structure which can be utilised to fill bony defects [15]. Its advantages include high biocompatibility and osseoconductivity, but on the downside this material also shows high resorption rate and inflammation limiting its use in practice [14].

Polymers like polylactic acid, polyglycolic acid, poly ε-caprolactone and their copolymers are adaptable morphologies, low immunogenicity, materials used as bone graft alternatives [16]. However, the osteoconductive property is limiting. Low cell adhesion capacity, and the release of acidic breakdown products alter local pH that limit their application.

Recent studies have also revealed the significance of metallic ions like strontium (Sr), zinc (Zn), and magnesium (Mg) in the preservation of bone and promotion of osteogenesis [17]. Then there are composite bone alternatives that are a combination of materials, such as bioglass and polymers, seek to enhance the mechanical properties of the resulting mixture. Through the combination of their osteoconductive qualities, composite bone They are frequently employed to enhance the osteoconductive and osteoinductive qualities of autograft products, and they are frequently mixed with bone marrow or serve as Bone Morphogenic Protein (BMP) transporters [18]. Growth factors (GFs) have also been revealed to have osteoinductive qualities, allowing for quicker bone regeneration in bony defects. Examples of these GFs include BMPs, platelet-derived growth factors (PDGFs), and insulin-like growth factors (IGFs) [19].

Conclusion

The use of allograft in bone grafting procedures often in conjunction with growth factors such platelet-rich fibrin and BMPs have increased owing to the concerns associated with autogenous grafts such as harvest site morbidity. Although risks of disease transfer and antigenic reactions with allografts are higher. Resorbable synthetic grafting materials have showed potential thanks to recent engineering developments. Resorbable membranes can be used to supplement clinically substantial volumes of bone. In order to repair the maxillofacial skeleton, autogenous bone grafts will probably continue to be the gold standard of grafting materials. But the research in this subject is ever growing and ever changing and, in the future, we can expect even better bony alternatives than what we are using at present.

References

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 Jan;26(10):3007.2.

2. Moussa NT, Dym H. Maxillofacial bone grafting materials. Dental Clinics. 2020 Apr 1;64(2):473-90.
3. Pai U, Soumya MK, Hosi RN. AUTOGENOUS BONE GRAFTS IN IMPLANTOLOGY–A REVIEW. VOLUME 1 ISSUE 2. 2017 Mar;17(23):30.
4. Clinical Periodontology And Implant Dentistry. Fifth Edition Jan Lindhe.
5. Cypher TJ, Grossman JP. Biological principles of bone graft healing. The Journal of foot and ankle surgery. 1996 Sep 1;35(5):413-7.
6. Elsalanty ME, Genecov DG. Bone grafts in craniofacial surgery. Craniomaxillofacial trauma & reconstruction. 2009 Oct;2(3-4):125-34.
7. Kumar P, Vinitha B, Fathima G. Bone grafts in dentistry. Journal of pharmacy & bioallied sciences. 2013 Jun;5(Suppl 1):S125.
8. Shibuya N, Jupiter DC. Bone graft substitute: allograft and xenograft. Clinics in podiatric medicine and surgery. 2015 Jan 1;32(1):21-34.
9. Kao, S.T.; Scott, D.D. A Review of Bone Substitutes. Oral Maxillofac. Surg. Clin. North Am. 2007, 19, 513–521.
10. McPherson, R. Bone Grafting with Coralline Hydroxyapatite. EC Dent. Sci. 2019, 18, 2413–2423.
11. Kattimani, V.S.; Kondaka, S.; Lingamaneni, K.P. Hydroxyapatite—Past, Present, and Future in Bone Regeneration. Bone Tissue Regen. Insights 2016, 7, 36138.
12. Kao, S.T.; Scott, D.D. A Review of Bone Substitutes. Oral Maxillofac. Surg. Clin. North Am. 2007, 19, 513–521.
13. Saikia, K.C.; Bhattacharya, T.D.; Bhuyan, S.K.; Talukdar, D.J.; Saikia, S.P.; Jitesh, P. Calcium phosphate ceramics as bone graft substitutes in filling bone tumor defects. Indian J. Orthop. 2008, 42, 169–172.
14. Fernandez de Grado, G.; Keller, L.; Idoux-Gillet, Y.; Wagner, Q.; Musset, A.M.; Benkirane-Jessel, N.; Bornert, F.; Offner, D. Bone substitutes: A review of their characteristics, clinical use, and perspectives for large bone defects management. J. Tissue Eng. 2018, 9, 2041731418776819.
15. Bhatt, R.A.; Rozental, T.D. Bone Graft Substitutes. Hand Clin. 2012, 28, 457–468.
16. Fuchs, J.R.; Nasseri, B.A.; Vacanti, J.P. Tissue engineering: A 21st century solution to surgical reconstruction. Ann. Thorac. Surg. 2001, 72, 577–591.
17. Wang, W.; Yeung, K.W. Bone grafts and biomaterials substitutes for bone defect repair: A review. Bioact. Mater. 2017, 2, 224–247.
18. Kolk, A.; Handschel, J.; Drescher, W.; Rothamel, D.; Kloss, F.; Blessmann, M.; Heiland, M.; Wolff, K.-D.; Smeets, R. Current trends and future perspectives of bone substitute materials—From space holders to innovative biomaterials. J. Cranio Maxillofac. Surg. 2012, 40, 706–718.
19. Oliveira, É.; Nie, L.; Podstawczyk, D.; Allahbakhsh, A.; Ratnayake, J.; Brasil, D.; Shavandi, A. Advances in Growth Factor Delivery for Bone Tissue Engineering. Int. J. Mol. Sci. 2021, 22, 903.
20. Smith, R P. The mechanism of graft rejection. Clin. Orthop. 87:15-22, 1972.
21. Cicciù, M. Growth Factor Applied to Oral and Regenerative Surgery. Int. J. Mol. Sci. 2020, 21, 7752.
22. Ahlmann E, Patzakis M, Roidis N, Shepherd L, Holtom P. Comparison of anterior and posterior iliac crest bone grafts in terms of harvest-site morbidity

and functional outcomes. J Bone Joint Surg Am 2002;84-A:716–720

23. Gu¨ven O. Rehabilitation of severely atrophied mandible using free iliac crest bone grafts and dental implants: report of two cases. J Oral Implantol 2007;33:122–126.
24. Eldibany, R.; Shokry, M. The effect of Nanobone® in combination with platelet rich fibrin on bone regeneration following enucleation of large mandibular cysts. Tanta Dent. J
25. Zhang X, Xie C, Lin AS, et al. Periosteal progenitor cell fate in segmental cortical bone graft transplantations: implications for functional tissue engineering. J Bone Miner Res 2005;20:2124–2137