

AUTOGENOUS BONE GRAFTS IN IMPLANTOLOGY – A REVIEW

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ABSTRACT:

Grafting is one of vital procedures enhancing predictability and successful outcome of dental implants. This article reviews the autogenous bone grafts that are currently used in the same.

INTRODUCTION:

Bone grafting has become one of the more frequently performed procedures in reconstructive surgery. The large number of reconstructive options brought about by advances in craniofacial surgery have created the need for large quantities of donor bone and for techniques that can reliably transfer bone material to distant and sometimes hostile tissue bed.

Autografts, both cancellous and cortical, are usually implanted fresh and are often osteogenetic, whether by providing a source of osteoprogenitor cells or by being osteoinductive. . All bone grafts are initially resorbed, but cancellous grafts are completely replaced in time by creeping substitution, while cortical grafts remain an admixture of necrotic and viable bone for a prolonged period of time.

Bone grafting in the past has been controversial and unpredictable. Strong proponents of bone grafting argue that the majority of healing studies show better success using grafting materials than open flap debridement in managing severe osseous defects. Others argue that the amount of bone regeneration possible with current techniques is too limited and unpredictable to be useful. ⁽²⁾

A wide variety of treatment modalities have been developed, all with the goal of attaining tissue/bone regeneration. Regenerative procedures frequently include the use of barrier membranes and bone grafting materials to encourage the growth of key surrounding tissues, while excluding unwanted cell types such as epithelial cells. Although regenerative therapies have great potential, they remain unpredictable in their ability to consistently produce acceptable outcomes in all situations. ⁽⁵⁾

History Of Autogenous Bone Grafts⁽⁶⁾

1. The earliest known repair of cranial and facial defects is by use of alloplast. Neolithic Peruvians used hammered gold and silver plates over frontal bone defect.
2. The first craniofacial reconstruction using a bone graft was performed by Van Meekren in 1632. He used xenograft from dog's calvarium.
3. The first successful bone implant was reported in 1809 by Merren.
4. The first successful allograft was reported by Macewen in 1881. He reconstructed humerus of a child.
5. The first surgeon to use autogenous bone graft in facial region was Seydel in 1889. He used autogenous bone from tibia.
6. The first bone harvest from calvaria is by Muller and Koneig in 1890.
7. In 1901, Marchand theorised that the host tissue at grafted site and not the graft was responsible for osteogenesis. He was one of the first to describe bone repair by creeping substitution.
8. In 1908 Axhausen described the first free split calvarial graft.
9. In 1931 Pickrell used iliac crest graft for repairing skull defects.
10. In 1957 Longacre and De Stefano used autogenous split rib grafts to repair defects of cranium and facial skeleton.
11. Schallhorn et al., (1967) in an extensive series of case reports, showed bone fill in bifurcation, dehiscence and intra osseous defects of varying sizes and shapes. Iliac grafts were used either in frozen or fresh form. They also reported successful elimination of bifurcation defects with frozen autogenous hip marrow implants.
12. The concept of bone induction was elaborated by Urist M R in 1965 with the identification of bone morphogenic proteins.
13. Codvilla in 1905 described the concept of bone lengthening in femur. Then Ilizarov in 1965 popularised the technique of bone lengthening by means of distraction osteogenesis in long bones. This principle was first applied in maxillofacial region by McCarthy in 1989. Later Philips et al extended this principle to fill bone defects by means of bone transport.
14. Lauritzen et al in 1991 reported the use of autoclaved autogenous bone for reimplantation for benign tumors of the craniofacial region. Brusati et al in 2000 reimplanted resected fronto-orbital bone after several hours of exposure in a dry sterile environment.

Classification Of Grafts⁽¹²⁾

Bone grafts can be classified

1. Based on nature of bone (Graft anatomy).
2. Based on source of donor.
3. Based on vascularity.
4. Based on donor site.
5. Based on function.

I. Based on nature of bone

- Cancellous bone graft
- Cortical bone graft
- Corticocancellous grafts

. Blocks

. Chips

. Powder

- Marrow graft

II. Depending on source of donor

- A. Autogenous bone graft – from same individual
 - i. Extra Oral
 - ii. Intra Oral
- B. Allogenic – allograft – from another individual of same species
 - i. Fresh frozen bone
 - ii. Freeze-dried bone allograft
 - iii. Demineralized Freeze-dried bone allografts
- C. Isogenic bone graft – from genetically related individual
- D. Xenografts from different species
- E. Alloplastic bone grafts

- i. Polymers
- ii. Bioceramics
 - Tricalcium phosphate
- Hydroxyapatite
- Dense, non porous, non resorbable
- Porous, non resorbable
- Resorbable hydroxyapatite derived at low temperatures
- iii. Bioactive glasses.

F. Composite grafts: Partly allograft & Autograft.

III. **Depending on the vascularity**

Autografts can be divided into:

- A. Non vascularised
- B. Vascularised bone
 - Pedicled
 - Microvascular free transfer.

IV. **Depending on donor site:**

- Iliac crest graft
- from anterior ileum
- posterior ileum
- trephine grafts
- Rib graft
 - Full thickness
 - Split rib graft
- Calvarial graft
 - Full
 - Split
- Fibula
- Others

V. Depending on function

- Bridging graft or inlay graft
- Reconstruction graft
- Contour graft – onlay graft.

Uses of grafts ⁽¹³⁾

Bone grafts have been used

1. To repair congenital defects.
2. To augment bone in congenital deformities like hemifacial atrophy, micrognathia, nasal deformities, etc.
3. To encourage healing of non united fractures.
4. To reconstruct posttraumatic deformity. Bone graft is used to restore facial projections, vertical stress pillars, continuity of mandible etc.
5. To spread union and restore continuity of bone at osteotomy sites following orthognathic surgery.
6. To fill cavities following cyst and tumour eneculeation.
7. To restore continuity of bone following tumour ablation.
8. To augment alveolar bone.
9. To improve facial contour for cosmetic purpose.

Principles of bone grafting

Mutaz B Habal⁽⁹⁾ (1994) gave certain principles based on his experience and literature review. These include.

1. Harvest bone from areas you are familiar
2. Contour bone graft to fit the defect
3. Fix the bone graft to the defect in a tension free manner
4. Ensure absolute immobilisation – static VS dynamic zones

5. Differentiate between child and adult grafts
6. Avoid contaminated sites
7. Do not have graft exposed
8. Ensure adequate blood supply to the graft
9. Assess "graft take" periodically

Biology and healing of bone and bone grafts

Healing of bone grafts has two phases.

In the first phase revascularisation of the graft takes place. This depends on the type of bone graft. In vascularised bone graft where the vascularity of the graft is maintained healing is as any normal bone. In non-vascularised bone grafts, the bone graft is surrounded by haematoma, which is organised and replaced by fibrovascular tissue. Due to lack of blood supply most of the cells in the graft perish and only bone matrix is left behind.

Further healing of the graft is by one of the three mechanism of bone regeneration after bone transplantation.

1. Osteogenesis.
2. Osteoconduction.
3. Osteoinduction.

Osteogenesis: It involves new bone formation by surviving pre-osteoblasts within the graft. Healing by this mechanism is seen in vascularised bone grafts and to some extent in cancellous bone grafts due to rapid revascularisation.

Osteoconduction: It is a prolonged process. Here the bone graft functions as a nonviable scaffold for the gradual ingrowth of blood vessels and osteo- progenitor cells from the recipient site, with gradual resorption and deposition of new bone. This is called creeping substitution. It is seen predominantly seen in cortical grafts.

Osteoinduction: It involves transformation of local mesenchymal cells into bone-forming cells in the presence of an appropriate inductive stimulus. Insoluble polypeptide moieties and specific enzymes known as 'bone morphogenic proteins" regulate it. Demineralisation of bone prior to implantation is required for osteoinduction to occur.

There are 8 factors, which induce bone formation called bone morphogenic proteins (BMP). These factors are BMP 2 (BMP 2a), BMP 3 (Osteogenin), BMP 4 (BMP2b), BMP 5, BMP 6, BMP 7 (Osteogenic protein 1), BMP 8 (Osteogenic protein 2) and Transforming growth factor.⁽¹⁴⁾

Phase I: Mesenchymal Cell Chemotaxis and Proliferation (Days 0-4)

During the first minute following DBM implantation, a blood clot forms producing a fibrin network. Aggregating platelets release multiple growth factors such as TGF and PDGF, and there is plasma fibronectin binding to the implanted matrix. During the next 18 hours, there is a chemotactic-driven arrival and accumulation of inflammatory cells such as PMNLs. Next, there is a 2-day period of fibroblast-like mesenchymal cell chemotaxis, a process largely driven by the aforementioned proteolytic peptides and growth factors. The mesenchymal cells arrive and subsequently attach to the implanted matrix. This interaction is mediated by fibronectin and other cell-adhesive proteins. As the chemotactic process nears completion, two activities are noted: 1) protein and nucleic acid synthesis is initiated to prepare for the ensuing cellular proliferation; and 2) further amplification of the bone induction cascade occurs through the release of additional growth factors.

The fibroblast-like mesenchymal cells then proliferate during the 3rd and 4th days postimplantation. A transduced signal between the matrix and cell surface appears to initiate mesenchymal cell differentiation. This step marks the transition to the second phase of bone induction, mesenchymal cell differentiation into cartilage.

Phase II: Mesenchymal Cell Differentiation Into Cartilage (Days 5-9)

Five days following bone matrix implantation, the first cells and molecular markers indicative of cartilage differentiation are seen. Histologically, chondroblasts are noted on Day 5, marking the beginning of the differentiation phase³⁵. By Day 7, chondrocytes are evident and there is further synthesis and secretion of cartilaginous matrix. By Day 9, the typical pattern of cartilage maturation described in endochondral bone formation is observed. Finally, vascular invasion of the newly formed cartilage occurs. This is seen histologically and is also accompanied by the detection of Type-IV collagen, laminin, and factor VIII (all common blood vessel components). This vascular invasion marks the transition from the cartilage differentiation phase to the final phase of bone induction, osteogenic precursor differentiation into bone .

Phase III: Mesenchymal Cell Differentiation Into Bone (Days 10-21)

Ten days after DBM implantation, the first osteoblasts are noted, and new bone formation is observed on the surface of the remaining calcified cartilage matrix . These cellular events are associated with molecular processes consistent with bone formation, including Type I collagen synthesis (the major fibrillar collagen of bone, bone-specific proteoglycan synthesis, and a peak in ⁴⁵Ca incorporation and alkaline phosphatase activity. By Days 12 through 18,

multinucleated osteoclasts are observed histologically and begin the process of bone remodeling. The osteoclasts and osteoblasts work in tandem to replace gradually early bone and remaining calcified cartilage with pure bone ossicles. By Day 21, bone marrow differentiation occurs and the appearance of erythrocytic, granulocytic, and megakaryocytic lineages is noted.

As has been noted, this DBM bone induction cascade is a growth factor-driven, highly structured step-by-step process with multiple points of amplification and regulation. Although it bears considerable similarity with natural fracture healing, bone graft incorporation, however, is considerably more complex with two processes including necrotic graft resorption and graft revascularization occurring concurrently with the bone induction cascade.

Factors influencing bone graft resorption or incorporation.

The factors can be broadly classified into graft factors, recipient factors and type of fixation.

Graft factors:

- 1. Embryological origin of the graft:** Membranous bone retains their bony mass more than endochondral bone which show fibrous replacement. Wilkes, Kernahan & Christensen 1985 showed that in onlay grafting the membranous bone survived twice as well as endochondral bone. They found no correlation on the presence or absence of the periosteum on the survival of the graft. They attributed the survival of the grafts to the presence of piezoelectric effects through the action of stress.
- 2. Nature of bone in graft:** Cancellous bone incorporation is better than cortical bone. This is due to presence of large amount of marrow spaces, which permits early revascularisation. They also retain viable osteogenic cells.
- 3. Revascularisation of the graft:** Graft incorporation is better in early vascularisation of the graft. Thus vascularised bone grafts has better chance for incorporation followed by cancellous and cortical bone grafts.
- 4. Size of the graft:** Smaller sized graft is better incorporated than larger ones.
- 5. Presence of periosteum:** Periosteum in graft reduces the resorption rate and also incorporation is better. The role of periosteum in the regeneration of calvarial defects was emphasised by Reid, McCarthy & Kolber⁽¹¹⁾ (1981), they also found a positive influence of dura on bone regeneration. Thaller, Kim & Kawamoto (1989) also emphasised periosteal layer in bone regeneration. Burstein et al 1995 found that periosteal preservation significantly enhanced bone formation in both cortical and trabecular bone.

6. Harvest of graft:

Graft to be harvested in an atraumatic fashion for better take. Excessive heat to be avoided while using rotary instruments and graft to be placed immediately at the recipient site for better take.

Recipient factors

1. **Age:** Children and younger persons have more viable osteogenic cells, so the capacity for graft take is better in the young than in the adult.
2. **Site of placement:** The graft should be in contact with bone for incorporation.
3. **Vascularity of the recipient site:** Highly vascular bed favour graft incorporation better than less vascularised areas. Thus primary grafting is more successful than secondary bone grafting. Also graft survives badly at irradiated site, scarred tissue bed due to decreased vascularity.

Fixation of the graft:

Rigid fixation of the graft aids in faster graft healing.

Perren et al 1979 and Luhr have shown that if bones were adapted perfectly and under some compression, "primary bone healing" occurred. The approximation, compression and stable fixation that are required for primary bone healing are best provided by rigid fixation, with its three-dimensional stability utilising plate and screw fixation.

Other Factors:

Other factors that influence resorption or incorporation of autogenous bone grafts include the graft position in relation to mechanical stress.

The osseous flaps may be transferred on either an endosteal or periosteal blood supply with no difference in healing. When the circulation is restored by microvascular technique, autogenous bone flaps show improved osteocyte survival and enhanced bony incorporation in comparison with conventional bone grafts. Primary osseous healing with elimination of repair by creeping substitution is possible by transferring viable bone forming cells in a microsurgically revascularised flap that is appropriately fixed. Vascularised bone flaps for mandibular reconstruction heal with similar rates of bone formation when transferred to non irradiated or irradiated beds. When mechanical strength or resistance to resorption are important, cortical bone is used.

Abbot (1947) has shown that graft containing a fatty marrow should be avoided as necrotic fat tissue is removed with difficulty and this delays the penetration of granulation tissue.

Complications of Bone Grafting:

This can be grouped into recipient site complications and donor site complication.

Recipient site complications are:

1. Infection
2. Rejection (Failure to take up)
3. Resorption
4. Alteration in dimension
5. Exposure
6. Movement or sinking of the graft
7. Defective contour
8. Resorption of graft and recipient bone

Infection is the most common complication in maxillofacial region. This is mainly due to movement of the recipient site and the graft, intraoral communication and improper fixation. With the use of rigid fixation by means of plates this has largely been reduced.

Failure of vascularisation is due to movement of graft and excessive bulk of graft tissue. Compact cortical grafts and grafts placed in irradiated areas may fail to vascularise.

Resorption and dimensional change is an inherent complication of allografts. Demineralized bone shows maximum resorption. Among autogenous graft, rib grafts show more resorption than other grafts. Due to this, use of rib for mandibular reconstruction was questioned by many authors.

Failure to contour the graft at the time of placement may lead to unacceptable appearance of grafted site. Excessive growth as in case of costochondral grafts may produce visible swelling and facial asymmetry warranting a second surgical correction. Contour defect of calvarium may be unacceptable in some cases.

Donor site complications:

These might be functional defect, sensory impairment or an aesthetic defect.

Iliac crest harvest is associated with the complication of gait problem(Tensor fascia muscle), hernia, sensory disturbance.

Rib harvest is associated with the complication of pneumothorax and persistent pain resulting in atelectasis and hypoxemia.

Elevation of pectoralis muscle can cause limitation in the movements of hand, sternocleidomastoid flap can cause difficulty in neck flexion, temporalis flap can affect jaw function, and radius forearm flap is associated with morbidity of the forearm.

Unaesthetic effects are produced while harvesting the clavicle or sternum with sternocleidomastoid muscle.⁽²²⁾

Discussion:

Attempts to correct osseous defects in the periodontium have been numerous and varied. These include reshaping the alveolar process via osteoplasty and/or osteoectomy, fracture or swaging approaches, hemisection, root amputation, and attempts to regenerate portions of the lost supporting bone. Most recently, efforts to regenerate portions of the lost supporting bone have emphasized bone implant techniques. While favorable results have been produced with various types of implants, there is growing evidence that autogenous hematopoietic marrow in cancellous bone is presently the most optimal material available for bone grafting purposes. The feasibility of utilizing marrow in cancellous bone from the ilium in the correction of osseous crater and furcation defects has been demonstrated. In addition, the feasibility of performing iliac transplant procedures in a typical dental office environment has also been reviewed in many studies.

Reconstructive technique and materials have enhanced the ability to correct the bony defects. An understanding of the physiology of bone transfer and bone healing and the knowledge of bone survival following transfer will provide the basis for achieving better results in clinical application.

Replacement of extensive local bone loss is a significant clinical challenge. There are a variety of techniques available to the surgeon to manage this problem, each with their own advantages and disadvantages. It is well known that there is morbidity associated with harvesting of autogenous bone graft and limitations in the quantity of bone available.

Summary and Conclusion:

Allografts have been reported to have a significant incidence of postoperative infection and fracture as well as the potential risk of disease transmission. During the past 30 years a variety of synthetic bone graft substitutes has been developed with the aim to minimize these complications. The benefits of synthetic grafts include availability, sterility and reduced morbidity.

The purpose of this review was to examine autogenous bone graft materials which are in used in implant dentistry and their selection principles based on their use. Presently, predictable and satisfactory bone growth occurs from the application of autogenous bone grafts that initiate and enhance the biologic process to achieve true bone regeneration to its full potential.

However, in the field of bone growth and periodontal regeneration, there are still a lot of unknown territories, which are currently being explored, or need to be investigated in future.

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