REVIEW ARTICLE

Bone Graft Banking: A Review

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Abstract

Nowadays there is an increased demand for replacement of human tissues which are lost due to variety of conditions like road traffic accident or assault. Bone grafts have been employed for repair for more than hundred years. It is a dynamic process and is extensively used in reconstructive surgery. During the last 20 years, it has undergone numerous advances, one of which is bone banking. Bone banks are necessary for providing biological tissues. The growing need for musculoskeletal tissues has been due to the development of new surgical techniques. 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. For a successful regeneration, bone graft when applied should heal, become incorporated, revascularize, and eventually assume the desired form. To increase the safety of transplanted tissues, standards for bone bank operation have been imposed by the government. This paper describes the technical considerations relating to how a bone graft taken and how they are banked for long-term usage.

Keywords: Allograft, Autogenous, Bone banks, Bone grafts.

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Introduction

The desire to repair or replace injured or diseased parts by transplantation of healthy tissues has been described in ancient medical records and depicted in works of art many centuries old. The actual clinical applications of human allografting, however, have occurred much more recently, awaiting not only improved surgical skills, methods of internal fixation, appropriate anesthesia, and satisfactory aseptic techniques but also the availability of dependable banked bone.[1]

A few sporadic attempts at bone preservation have occurred since Oilier originally discussed the concept in 1867, but the first concerted effort to store bone for elective use and a description of the clinical efficacy was provided by Inclan in 1942.[2,3] Since then, there have been numerous accounts of a wide variety of preservation techniques (refrigeration, freezing, freeze-drying, thimerosal, alcohol, demineralization, deproteinization, boiling, autoclaving, and others), banking methods, and clinical and laboratory studies in support of the biological potential of stored grafts.[4,5]

Fresh autogenous bone and cartilage are regarded as the most effective biological resource for repair or reconstruction of the skeletal system. Disadvantages, however, are related to donor-site morbidity and include the risk of wound infection, increased blood loss, prolonged anesthesia time, and additional postoperative discomfort.[5–7] Furthermore, the need to sacrifice normal structures elsewhere in the body and especially constraints related to the size, shape, and quantity of tissue available for transplantation may, on occasion, limit the applicability of osseous and osteochondral autografts.[6,8]

Allogenic rather than xenogenic tissues are generally preferred when a biological alternative to a fresh autograft is sought, and bone banks exist for the purpose of supplying the surgeon with safe and effective skeletal tissues that are suitable for their intended clinical application and are available whenever the need arises.[9]

The organization of a bone bank is based on the following facts and assumptions:

Homogeneous and autogenous bones are equally useful; in both cases the graft dies, but its presence acts on the surrounding connective tissue in such a way that it is transformed into bone by metaplasia. Thus, both act in the same way as the cell-free alcohol extract of bone with which Levander and others were able to induce bone formation in the muscles of rabbits.[10]

As the vessels accompanied by connective tissue grow into the haversian canals of the graft, bone is formed and gradually the entire graft is reconstructed to form new living bone by “creeping substitution.” Neither the blood group nor the Rh factor is of significance, and no attention needs to be paid to them.[9,10]

Bone can be stored in sterile containers in an ordinary refrigerator (+2 to +6′) for 3 weeks and at 15°F indefinitely.[10,11] The donor must be controlled. He should have no history of infection for some time before the graft is taken. His sedimentation rate should preferably be normal. Sulphonamides interfere with the calcification process.[8] The bone grafts should be stored dry.

Carrel reported before 1920 that transplanted tissues, e.g., bone, skin, or other substances stored in Ringer’s solution either do not heal or heal less well than when stored dry. In accordance with Leuander’s tests, this might be due to extraction of the ontogenetically active substance by the Ringer’s solution.[10–12]

Classification of Bone Grafts

Autograft—a graft moved from one site to another within the same individual.

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Allograft—a tissue transferred between genetically different individuals of the same species.
Xenograft—a tissue transferred from one species to another.
Isograft—tissue transferred from one twin to the other identical twin.

According to grafting technique

- Onlay grafts
- Inlay grafts
- Muscle pedicle grafts
- Dowel grafts
- Strut grafts
- Clothespin (H grafts)

Onlay Grafts

Primarily of cortical implants placed along existing bone, thus bridging the osseous defect, e.g. augmentation of alveolar ridge in instances of mandibular atrophy. It may be a single onlay or dual onlay (congenital pseudoarthrosis) placed and fixed by compression plates. Highest complication care is wound dehiscence and failure rate of grafting is high. The surgeon expects a minimum gain of 3–4 mm in height.

Inlay Graft

Originally used for treatment of fractures and nonunion. A rectangular segment of cortical bones removed and inserted into recess created across the bony defect. Modification is sliding inlay graft.

Dowel Bone Grafts

Used in the treatment of wrist fractures, depressed tibial plateau fractures, and nonunited femoral neck fractures. A rounded core of cancellous bone is inserted into a surgically created channel across a fracture/nonunion site. The cancellous bone promotes osteogenesis.

Muscle Pedicle Grafts

Used primarily in femoral neck fractures and nonunion, particularly in young patients and has largely replaced dowel grafts. The bone graft with the muscle insertion transplanted into a surgically created slot in the posterior femoral neck and transfixing the fracture site.

Strut Grafts

Commonly used in the spine to provide structural stability and to promote osteogenesis. The fibular/rib graft is inserted into the surgically prepared notches at the superior and inferior vertebral levels.

Clothespin/H Grafts

Used in cervical spine fixation. Iliac crest full thickness graft strips are slotted both proximally and distally and then placed between spinous process.

In summary, autogenous grafts can be obtained from different sites based on the need. Allografts can be obtained from the bone bank. The bone grafts used for clinical application comes in various forms, sizes, and configurations from large solid blocks to small particulate and slurry. These grafts can be cortical, cancellous, or corticocancellous.

Types of Bone Banks

In general, two types of bone banks are recognized (Elizabeth Musclow, 1919).

- Surgical: It involves collecting surgical discarded bone, processing, storing, and distributing this bone.
- Regional: These are usually expensive and involve a labor intensive proposition of supplying bone.

Procedures Involved in Bone Banking

Donor Selection

Both cadaver and living donors may be acceptable, provided there is information pertaining to the medical history and the circumstances surrounding the cause of death (in the case of cadaver) sufficient to exclude individuals with potentially serious transmissible diseases or in whom the biological properties of bone or cartilage may be compromised in terms of its intended application. Particular attention is paid to the presence of systemic infection (bacterial, viral, or fungal) or infection of those portions of the body to be collected as graft material, malignant disease, and diffuse or systemic disorders that may compromise the biological or biomechanical integrity of the skeleton, toxic substances in toxic amounts, venereal diseases, and diseases of unknown etiology.[13,14] Laboratory tests for identification of hepatitis and venereal diseases, and a complete and unrestricted autopsy following removal of tissues from cadaver donors should be routinely used to supplement the medical history.

Tissue Procurement

Although specific time constraints following death have not been established for musculoskeletal tissues, it is generally regarded as optimum to remove potential grafts and subject them to methods of preservation as rapidly as possible, preferably within 24 hours of death provided the body has been refrigerated during this period.[15]

The sterile procurement of tissues requires application of the same principles involved for any surgical procedure.[12] This approach is more time-consuming and demanding than nonsterile procurement, but it eliminates the need for further processing to achieve sterility, which may also interfere with biological or biomechanical properties of the tissues.

Nonsterile tissue procurement must be followed by a method to eliminate infectious organisms and usually involves high-dose irradiation (1–3.5 megarads has been recommended) or exposure to chemicals such as ethylene oxide.[16]

Tissue Preservation

Preservation techniques, as just mentioned, most commonly involve freezing or freeze-drying, and are applied as rapidly after tissue procurement as possible. At the present time, bone is stored in a nonviable (albeit biologically useful) state, but recently more attention has been focused on methods to provide chondrocyte viability. The percentage of functional chondrocytes required to sustain the articular matrix is unknown. To date, the best efforts at preservation for clinical application involve exposure of cartilage to glycerol (10%) for 15–30 minutes, followed by a period of refrigeration at 4°C for as long as 18 hours to allow for penetration of the cryoprotectant prior to freezing.[14,16,17]

Dimethylsulfoxide has demonstrated advantages in animal models, especially related to its ability to penetrate tissues, but because of toxicity observed in humans its safe application to banking techniques must be cautiously appraised.[18]

Tissue Storage

Frozen allografts are usually stored in sufficient plastic or cloth wraps, or both, to ensure maintenance of sterility and to retard evaporation of water that would lead to drying of tissues. Grafts remain frozen at the desired temperature until ready for use, during which time the storage environment is monitored by recording devices and appropriate alarm systems.[19]

Freeze-dried (lyophilized) grafts must be placed in sealed evacuated containers either plastic or, more commonly, glass and may then be stored at room temperature. Autolysis of the graft may be retarded by cold, and lower freezing temperatures are presumed to extend the so-called shelf life of grafts.[20] Indeed, grafts frozen to –70°C have been stored for several years and then successfully used clinically.[21]

In general, the storage conditions must be maintained until shortly before clinical application of the graft. If transit time is required between the bank and the operating room because of geographical separation, then methods to ensure storage conditions during delivery must be applied. Frozen grafts are usually thawed in the operating room in warm physiological solutions just prior to use. Freeze-dried allografts may require reconstitution with water or saline if any shaping, cutting, or fixation is to be employed.[21–23]

The period of time that is required to return the biomechanical properties of freeze-dried bone to normal depends on the size and shape of the graft. Crushed chips of bone to be used for filling cystic cavities do not require any rehydration, while massive segments of long bone may need 18–24 hours of exposure to sterile physiological solutions.[24]

Bone Distribution

Dry ice packed around the bone in well insulated Styrofoam boxes has proven effective for maintaining frozen bone during transport. In long journeys, liquid nitrogen in special constructed canisters can be used.[18] Thus, banked human bone remains a valued source for relieving suffering, for providing mechanical support and providing a better quality of life for patients.

Applications in Maxillofacial Region

Bony defects in the cranio-maxillofacial skeleton can cause severe functional and esthetic deformities. They can arise from congenital malformations, traumatic avulsions, or be the result of ablative tumor surgical resections. Surgeons have tried a variety of materials and methods to restore such defects.

In Mayan times, nacre or mother of pearl was used to try to reconstruct bony defects and as implants into the tooth bearing areas of the jaws (Lopez et al.). Since that time autogenous grafts have continued to be used, although there has been a search for substitute materials. In order to decrease the morbidity of bony reconstruction, both less invasive harvesting methods, which aim to reduce postoperative donor-site morbidity, or agents that would substitute as bone grafts and would replace the donor site all together, have been sought.[25]

Absolute indications for reconstructing the mandible with vascularized bone grafts were given by Chen et al.[26] and they are the following:

- Osteoradionecrosis of the mandible or an irradiated tissue bed.
- Hemimandibular reconstruction.
- Long-segment mandibular defect, especially across the symphysis.
- Inadquate skin or mucosal lining.
- Defects demanding sandwich reconstruction.
- Inability to obtain secure immobilization on the reconstructed unit.
- Failure of reconstruction by other methods.
- Near-total mandibular reconstruction.

Ideal qualities of the vascularized bone grafts for mandibular reconstruction have been described by Urken.[27]

- The graft should be well vascularized.
- Sufficient length width and height.
- Easily shaped without compromise to its vascular supply.
- Minimum donor-site morbidity.

Conclusion

Bone grafting is a reconstructive surgical procedure being performed over many decades. Bone grafting has continuously played an important role in the correction of craniofacial defects. The recent refinements in surgical techniques have resulted in a closer look at the use of different materials and techniques to be used for bone grafting

What is needed in the future is that when certain parts of the body are to be replaced, they can be fabricated in the same biologic autologous system as an autologous bone graft and then reapplied in the discontinuity defects.

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