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Contemporary Issue

Allogenic bone grafts in post-traumatic juxta-articular defects: Need for allogenic bone banking

Col Anil Kumar Mishra ^a, Lt Col Rohit Vikas ^{b,*}, Brig H.S. Agrawal, VSM ^c^a Senior Advisor (Orthopaedics), Military Hospital Kirkee, Pune 411003, India^b Graded Specialist (Orthopaedics), INHS Asvini, Colaba, Mumbai, India^c Commandant & Consultant (Orthopaedics), Military Hospital Kirkee, Pune 411003, India

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ABSTRACT

Allogenic bone banking provide both structural and granular bone grafts for various orthopaedic, spinal, oncological and dental surgeries. However allogenic bones, presently, are not readily available. This article discusses the clinical applications of the allogenic grafts, the screening criteria and procedure for maintenance of such a bone banking facility. This article demonstrates the effective role of allogenic bone in a case of post-traumatic bone loss situation and discusses the growing need and present situation of bone banking in our country.

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Introduction

Management of open fractures with significant bone loss is challenging. Such bone loss is commonly observed following open fractures around the knee where appropriate reconstruction of the articular surface and juxta-articular defects are essential for satisfactory functional outcome in often younger patients who sustain these unfortunate injuries.

Significant bone loss is seen in only a small minority of all fractures – those following high velocity motor vehicle accidents or missile and blast injuries. Post-traumatic articular

defects are fortunately uncommon but a large loss of joint surface presents a considerable problem in management. Depending upon the size of the subsequent defect after initial debridement and stabilization, the diaphyseal and metaphyseal bone loss can be managed with shortening, autologous bone grafting, autologous fibular strut grafting, vascularized bone grafting or by use of distraction osteogenesis. However for the reconstruction of juxta-articular defects most of the above options are not feasible. Small defects are usually ignored if there is no instability of the joint. Larger defects require reconstruction using osteochondral allograft or an arthroplasty.

* Corresponding author:.

E-mail address: drrohitvikas@yahoo.co.in (R. Vikas).

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In orthopaedics, bone grafts have been used for various purposes, from stimulating a fracture healing to structurally restore lost native anatomy. Autografts, allografts or synthetic materials can be chosen to appropriately fulfil the surgical need. Autografts, besides providing osteoconductive and structural support, also have bone morphogenetic proteins which are osteoinductive and provide osteoprogenic mesenchymal cells. These features enhance the incorporation of graft to the host bone. Although they are the 'gold standard' for enhancing bone healing and bone void filling in bone defects, autografts have limited role in juxta-articular defect reconstruction. Here we require materials with structural similarity with the lost area, so as to anatomically restore joint structure, along with articular cartilage to maximize joint motion after reconstruction. This cannot be fulfilled with autografts. For reconstruction of lost part of articular surface, allografts harvested from similar anatomical region are best, as they provide substitute for the lost anatomy, structural strength for weight bearing and articular cartilage for joint motion. Although they are deficient in osteoprogenitor cells and osteoinductive proteins which enhance incorporation, they restore the joint anatomy better. They provide sufficient osteoconductive support to the osteoprogenitor cells from the host bone to finally incorporate the graft by the process of creeping substitution. The cartilage overlying these osteoarticular allografts provide surface for joint motion.

Reconstruction of articular defects in knee with the use of osteoarticular allografts have produced good long term results in cases of major articular defects.¹ In a young patient osteochondral allograft reconstruction of the joint surface is as an alternative to arthroplasty. However in most situations, due to non-availability of allogenic osteochondral grafts in our country, many of these patients are left with long term disability.

This article demonstrates the effective role of allogenic bone in a post-traumatic bone loss situation and discusses the growing need and present situation of bone banking in our country.

Illustrative case: reconstruction of post-traumatic distal femoral bone loss with allograft femoral head

A 25-year-old patient had sustained a grade II open injury to the right knee with undisplaced fracture of lateral tibial plateau and fibular head and near total loss of the lateral femoral condyle. After initial debridement and K-wire fixation of the fracture fragments with stabilization with a knee spanning tubular fixator the patient was referred to our centre for subsequent management. He was managed with serial wound debridement and subsequent closure without the need of additional reconstructive surgery. After 6 weeks the lateral condylar defect (Fig. 1) was reconstructed using *fresh frozen femoral head allograft*. Pre-operatively, informed consent for the use of allograft was taken from the patient after explanation of its potential risks.

The allograft was retrieved from a live elderly donor who had undergone a hemi-replacement for femoral neck fracture earlier. The donor was screened for HIV and hepatitis B and C

Fig. 1 – Plain radiographs of the knee with post-traumatic bone loss of the lateral femoral condyle.

infections and intra-operative cultures and samples for histopathologic evaluation were taken from the femoral head and capsular tissue for screening for infection and pathology. After harvesting, the graft was cleaned with ringer lactate solution, and treated with povidone iodine solution for 30 min before drying and transporting in a sterile packaging to the blood bank for storage in a deep freezer maintained at -70°C for later use.

At the time of the procedure the allograft was thawed and cleaned using ringer lactate solution and previous culture negativity confirmed. The graft was carefully contoured to the articular surface of the distal femur and was fixed with screws (Figs. 2 and 3). Posterior part of the lateral femoral condyle could not be reconstructed with the available allograft. The graft provided support during $0-100^{\circ}$ of knee flexion. The lateral soft tissue was repaired over this graft. Progressive knee

Fig. 2 – Intra-operative picture showing femoral head allograft contoured to the lateral femoral condyle defect and fixed with lag screws.

Fig. 3 – 1-Year post-operative CT scan demonstrating intact structure and sclerosis of the allograft.

mobilization was started after two weeks. The graft showed progressive incorporation on follow up radiographs and CT scan. At the end of 3 years the allograft was fully incorporated and the patient had 0–90° of knee flexion and was ambulant without any support (Fig. 4). He did not have lateral instability in this range of motion. Apart from restriction of strenuous duties and sports, he was able to perform most other duties without much discomfort.

In the present case the near total loss of lateral femoral condyle was required to be reconstructed in order to prevent instability and poor function of the knee. Only femoral head allograft was available to us which were from elderly patients and hence lacked optimal cartilage tissue. We were able to restore the bony support of the lateral side of the knee in full extension and till 100° of knee flexion without lateral instability in this range. With the available resource in our setup the result with the femoral head allograft can be considered satisfactory.

Juxta-articular bone losses are best managed using appropriate osteochondral allografts of the same anatomical regions. With the non-availability of distal femoral allografts in most centres, the distal femoral condyles can be reconstructed with allograft femoral head, although the results would be suboptimal compared to reconstruction using distal femoral allograft. A distal femoral osteoarticular graft would have restored the lateral femoral condyle anatomy more completely compared to the partial restoration of anatomy using a femoral head allograft. This would have provided increased arc of motion and better stability of the joint.

The requirement of proper osteoarticular graft for a deficient anatomical region can only be met with a functional allograft bone banking system. The availability of different types of allogenic bone with such a system will make it feasible to anatomically reconstruct the large articular defects and improve the functional outcomes in patients.

Fig. 4 – 3-Year post-operative radiographs and CT scan demonstrating consolidation of allograft with trabeculations seen clearly. Clinical picture showing the available flexion is also shown.

Clinical applications of allogenic bone grafts

In 1668, Dutch surgeon Meekeren implanted a piece of skull from a dog into a bony defect in cranium of a soldier.² Macewen first described the use of allogenic human bone in 1881.³

Allogenic bone grafts are commonly used for reconstruction of bony defects during revision arthroplasties, following tumour resection and segmental bony defects in osteomyelitis or gap nonunion and post-traumatic osseous defects and arthrodesis. The advantages of allogenic bone graft include its ready availability in various shapes and sizes, avoidance of the need to sacrifice host structures, and there is no donor-site morbidity. They offer osteoconductive activity and structural support. Deep frozen allogenic bone implantation is safe with negligible immunological reactions and have been proven to be effective. Large allogenic bone grafts are utilized in complex procedures and limb salvage.

Bone banking broadens the spectrum of procedures that can be performed in an orthopaedic centre. With advancements in the field of orthopaedic surgery there is a growing need to develop resources and facilities to support such procedures, especially at centres of orthopaedic excellence. Establishing a bone bank is not expensive. Meermans et al.⁴ discussed that it is possible for a community hospital to establish a safe and cost-effective bone bank with a low administrative and financial load.

The bone bank facility will provide bone grafts for various orthopaedic, spinal, oncological and dental surgeries. The

synthetic bone graft substitutes are expensive and generally do not suffice for reconstruction of defects. The availability of allogenic bone would also reduce the cost of health care.

Bone banking procedure

Allogenic bone banking requires proper donor and cadaver selection, serological screening, microbiological cultures, histopathological examination and cadaveric autopsy to establish the safety of the allografts.

Source of allogenic bone grafts. Allogenic bone may be available following resection of bone during arthroplasty (femoral head allografts), tumour resection, amputation and cadaveric harvest. In case the bone is retrieved from a live donor following resections during joint replacements (generally hip arthroplasties), the orthopaedic surgeon should obtain permission from the donor for preservation of resected bone for therapeutic purposes. A written informed consent from the potential donor should be obtained prior to any such retrieval.

In a cadaveric bone donation generally both femurs, tibias and pelvic bones are retrieved with wooden reconstruction of donor limb. A single cadaveric donation may provide sufficient bone for up to 15 procedures.

Donor screening. Once a donor is identified (live or cadaveric) proper medical history and examination should be carried out. The donor should be in a good general health with absence of any infectious and transmittable disease. The general contraindications for bone donation are given in Table 1.

Blood grouping with Rh typing, ESR and CRP levels should be done. Rh-negative patients should be implanted with Rh compatible grafts only. Serology for viral diseases (HBsAg, HBeAg, HIV, HCV, CMV) and syphilis (VDRL) should be included. The serology for HIV and HCV should be repeated after 6 months to cover for the window period. Cadaveric autopsy and lymph node biopsy to exclude early viral infections are required in cadavers.

Swabs for aerobic and anaerobic cultures should be taken from the harvested tissue and repeated at the time of implantation. The radiological analysis of the potential grafts can be done to assess for any lesions. The allograft are considered 'safe for implantation' only if all the above tests and cultures are negative.

Table 1 – Contraindications for allograft donation.

Age < 18 years
Septicemia/systemic infection
Leprosy
History of HIV, hepatitis B&C, syphilis,
Recent live vaccine administration
History of tuberculosis
Hepatitis or unexplained jaundice
Malignancy
Autoimmune diseases
Diabetes mellitus
Metabolic bone diseases
Chronic steroid use
Use of narcotic drugs
Chronic neurological diseases
Exposure to radiation

Harvest of allografts. The bone tissue should be harvested under sterile conditions. Cadaveric retrieval of grafts are preferably done within 12 h of death of the donor, to minimize the risk of bacterial contamination. The harvested allografts should be freed from any synovial tissue or ligament attachments. Swabs from the surface of harvested tissue and synovial fluid should be sent for cultures and bacteriological analysis. A small part of harvested tissue should be sent for biopsy to exclude malignancy, autoimmune or infectious processes. The grafts should be preserved in a labelled sterile bag and sent to the bone bank within 30 min for storage. Retrieval analysis, processing, storage and sterilization are subsequent steps necessary to make the allograft suitable for clinical use.

Processing. Generally fresh frozen allografts are used in orthopaedic surgery. The harvested allografts should be washed to remove any fat and marrow elements and then stored in deep freezers.

Storage. The processed grafts should be kept in a sterile material, labelled and stored in the deep freezer at -80°C . These allografts can be generally preserved for 5 years.⁵ Freezing does not adversely affect the strength of graft and reduces immunogenicity.⁶

Sterilization. Final sterilization by gamma radiation may be done at dedicated centres like BARC, Mumbai or its authorized branches.

Documentation. Record-keeping is mandatory in bone banks for medical and legal purposes. Various guidelines for bone banking have been published by the American Association of Tissue Banks and the European Association of Tissue Banks.^{7,8}

Review of status of bone bank in India

“Orthopaedic Bone Bank” is not as popular as Blood Bank, Cornea Bank, Stem-cell Bank and Sperm Bank despite the fact that the bone is the second most commonly transplanted tissue, second only to blood. The Tata Memorial Hospital Tissue Bank was started in 1988 as part of an International Atomic Energy Agency programme to promote the use of ionizing radiation for the sterilization of biological tissues. It provides gamma-irradiated allografts retrieved from cadaveric and live donors.⁹ In 2005 bone banks were started at the Government General Hospital, Chennai and at AIIMS, New Delhi. Other facilities are at Ganga Hospital, Coimbatore and MS Ramaiah hospital, Bengaluru. Such bone banks are covered by the Transplantation Human Organs Tissues Act 1994 and have to be registered with the State health authorities. All these facilities are experiencing tremendous crisis due to shortage of donors with only one or two cadaveric donations per year. AFMC Pune and Army Hospital (R&R) also provide frozen allogenic bone in service hospitals.

Apart from allogenic bone various other allogenic tissues such as ligaments, menisci and tendons are frequently being utilized in developed countries for various orthopaedic procedures.¹⁰ However due to prevalent social issues and rituals after death in our country and lack of public awareness regarding tissue donation, the establishment of such facilities are fraught with difficulties.

Conclusion

Osteochondral allograft reconstruction of post-traumatic juxta-articular defects can restore satisfactory joint function. Besides periarticular bone loss due to blast and missile injuries seen in military service, articular bone loss due to motor vehicle accidents are not unusual. There is a need for establishment of an organized allogenic bone banking facility at centres of orthopaedic excellence to manage these cases. With the availability of such facility and public awareness on tissue donation, patients with osseous defects can be managed more effectively.

Conflicts of interest

The authors have none to declare.

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