CLINICAL ARTICLE

The use of allograft in knee surgery

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Abstract
Musculoskeletal allograft has a wide application in orthopaedic surgery. The most common applications are bone and ligament allografts, but other tissues are also available for grafting. Knee surgery has evolved in the last few years, and there has been renewed interest in the use allografts around the knee. There is a wide variety of grafts available, and these have given us alternative management options for some of the most difficult problems in knee surgery. This review will cover osteochondral, meniscal and ligament allografts.

Introduction
The use of musculoskeletal allografts has become increasingly popular, with widespread use among knee surgeons. The most common applications are bone defects and soft-tissue reconstructions. In recent literature, there has been renewed interest in the use of allograft for osteochondral allografts, meniscus transplants and ligament reconstructions. The purpose of the article is to review recent literature regarding the use of these knee allografts, including the clinical application and considerations in South Africa.

Graft acquisition and processing
The orthopaedic surgeon should have a firm understanding of the tissue-banking process and the grafts available. An understanding of these processes will enable the surgeon to choose the appropriate graft, and will assist him in reassuring the patient regarding the risks and benefits. Before grafts can be harvested, donors should be screened and serologically tested to prevent the transmission of high-risk organisms.[1]

There are two methods of graft acquisition. The first is harvesting tissue in a sterile environment (theatre) as part of an organ-donation programme.[1] The second method is employing a surgically clean harvesting technique in a non-operating-room environment.[2] The latter is the method prescribed by the National Tissue Bank, a method that does not, however, prevent contamination.

Allografts can be processed as fresh, fresh-frozen, deep-frozen, cryopreserved or freeze-dried allografts. Fresh allografts, fresh-frozen allografts and cryopreserved allografts require a prompt and sterile harvesting technique to maintain the viability of their cells for implantation. The other types of grafts can be harvested by means of either of the two techniques.

Fresh allograft carries a high risk of disease transmission and is the most immunogenic. Fresh-frozen allograft is fresh allograft preserved by means of immediate deep-freezing. Cryopreserved allografts are processed by freezing them at a controlled rate in a cryoprotectant (glycerol-containing medium).[3] Fresh allograft, fresh-frozen allograft and cryopreserved allograft are not available from the National Tissue Bank due to logistical and cost implications.

Deep-frozen and freeze-dried allografts can be harvested by applying surgically clean techniques. Deep-frozen grafts are frozen at –80 to –196 °C. This decreases the host's immune response without affecting the structural integrity of the graft.

Freeze-dried grafts are dehydrated grafts preserved by means of a special drying process. They are the least immunogenic of all the grafts, but the process has a negative effect on the structural integrity of the graft.[4] Both of these grafts require terminal sterilisation by means of ethylene oxide or gamma irradiation. Because ethylene oxide is associated with graft dissolution, gamma irradiation (2.5 Mrad) is preferred. It is also a safe and effective means of sterilising tissue.[5] High doses of radiation (greater than 3.0 Mrad) have a negative effect on the mechanical properties of grafts and the osteogenic properties of bone allografts.[6,7]

Irradiation at 2.5 Mrad might not be sufficient to inactivate HIV and other viruses completely, but serological screening should decrease the risk of HIV and hepatitis transmission. Irradiation at 3.0 to 3.6 Mrad is required to inactivate these viruses.[6] The latter two grafts are available from the National Tissue Bank.

Advantages and disadvantages

The advantages of allograft over autograft are lower donor site morbidity, shorter operative time, larger grafts, smaller surgical incisions and a lower incidence of arthrofibrosis.[8,9]

The disadvantages are disease transmission, histocompatibility rejection and a longer incorporation period.[1,10,11]

According to international literature, the risk of disease transmission is very low, with two cases of HIV (1988, 1992), three cases of hepatitis (Hep B – 1954; Hep C – 1992, 1993), and one fatal case of clostridium transmission (2002) having been reported.[8] In Africa, we are faced with the HIV epidemic, which limits the use and availability of allografts in our country. The seroprevalence of HIV in the donor population of South Africa is 2%, as demonstrated by Koch *et al*, which is not as high as the estimated incidence of HIV in the general population, but still high enough for concern.[2] There were, however, increasing numbers of seropositive donors in the latter part of the study, which might indicate higher seropositive percentages at present. Due to this problem, the National Tissue Bank does not distribute fresh allograft. Histocompatibility and immune response-triggering are two problems associated with fresh allografts that result in graft rejection and graft-incorporation problems. Immunogenicity is less of a problem with freeze-dried and deep-frozen allografts. This is the reason why fresh allograft is not used for ligament reconstructions.[12,13]

Osteochondral allografts

Introduction

Full-thickness articular-cartilage damage remains a challenging problem for the orthopaedic surgeon. The exposed bone is filled up with fibrocartilage (type I collagen), which is inferior in quality to normal hyaline cartilage (type II cartilage).[14] This leads to the development of secondary arthritis.

The following characteristics make hyaline cartilage ideal for transplantation.

- It is an avascular tissue that absorbs nutrients from the synovial fluid by means of diffusion.
- It is an aneural tissue that does not require innervation to function.
- It is immunoprivileged because it is embedded in an acellular matrix and therefore removed from the host's immune surveillance.[15]

The chondrocyte is responsible for providing nutrients and a suitable environment for hyaline cartilage to survive. Thus chondrocyte viability is important when allografts are transplanted.[16] Fresh and cryopreserved allografts are used although most authors prefer allograft. The allograft should be transplanted as soon as possible, but at least within two weeks if stored in a culture medium or within seven days if stored in Ringers lactate. Fresh allograft should be stored at 4 °C.[17]

Indications

Osteochondral allografts are ideally suited for chondral lesions larger than 3 cm in diameter and 1 cm in depth. These lesions are referred to as bulk or massive allografts. Osteochondral allografts are also indicated for smaller lesions that are 1 to 3 cm in diameter. These smaller lesions and lesions less than 1 cm in diameter can also be managed with microfracture, autologous chondrocyte transplantation, osteochondral autografts (mosaicplasty), and periosteal autografts.[14,18]

Osteochondral allografting can be used for chondral defects on the femur, tibia and patella. The procedure is reserved for posttraumatic cartilage damage. Osteochondral allografting has been used for osteochondritis dissecans and avascular necrosis with mixed results.[14]

This procedure should not be performed in patients older than 60 years due to poor results. Unipolar grafts (femur or tibia defects) have better results than bipolar grafts (femur and tibia defects) and the latter should rather not be used.

Surgical considerations

The two techniques for osteochondral allograft transplantation are the press-fit plug (Dowell) and Shell graft technique (*Figures 1a,b,c and 2a,b,c*). The latter is preferred for larger grafts and requires some form of fixation.[19]

Before surgery is performed, the weight-bearing axis of the limb should also be assessed, and if it passes through the compartment that is going to receive the allograft transplant, a realignment osteotomy should be performed. Intra-operatively the craft must be irrigated with a high-pressure lavage to remove all marrow elements and lessen the immune response.[19]

The sizing of the graft is very important and the surgeon should aim for a size difference of less than 10%. The donors should be matched for age and sex to provide a more accurate sizing. The size matching can also be done with a CT. It is important not to leave the graft more than 2 mm proud, because this leads to increased shearing forces across the graft and early failures.

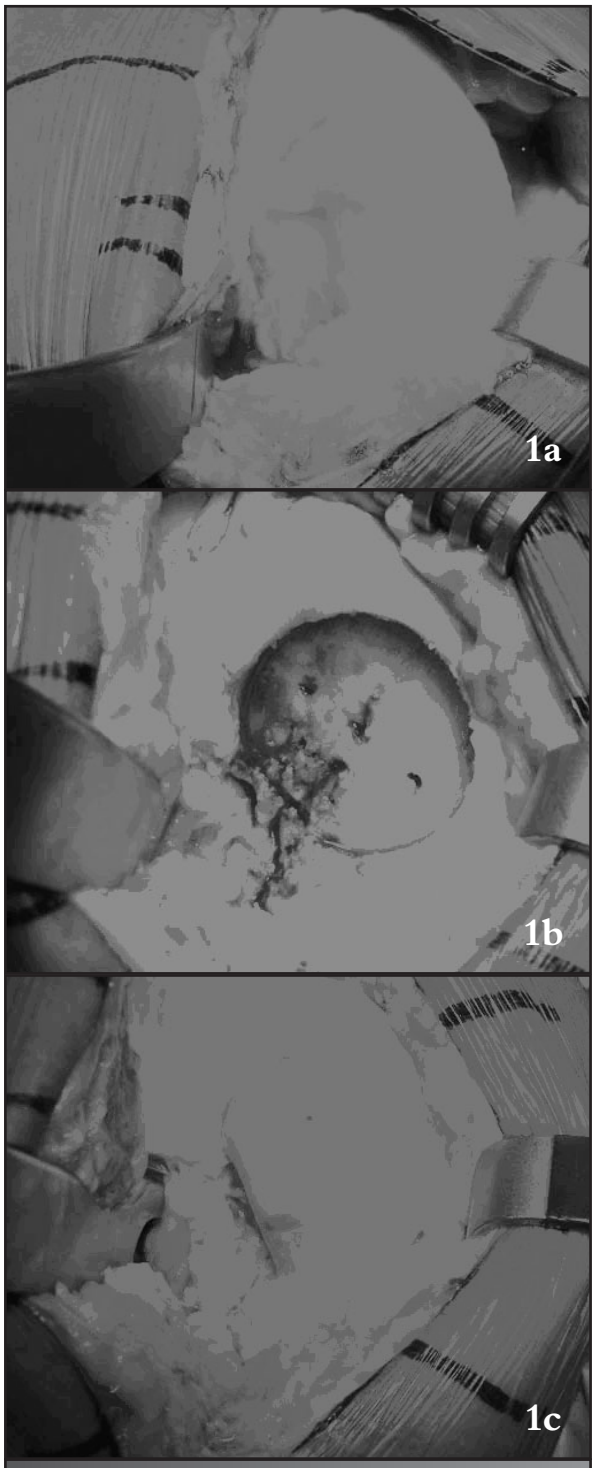

Figure 1a: Osteochondritis dissecans lesion on the medial femoral condyle

Figure 1b: Preparation of the graft bed by core reaming down to bleeding bone

Figure 1c: The osteochondral dowel plug in place fixated with absorbable pins

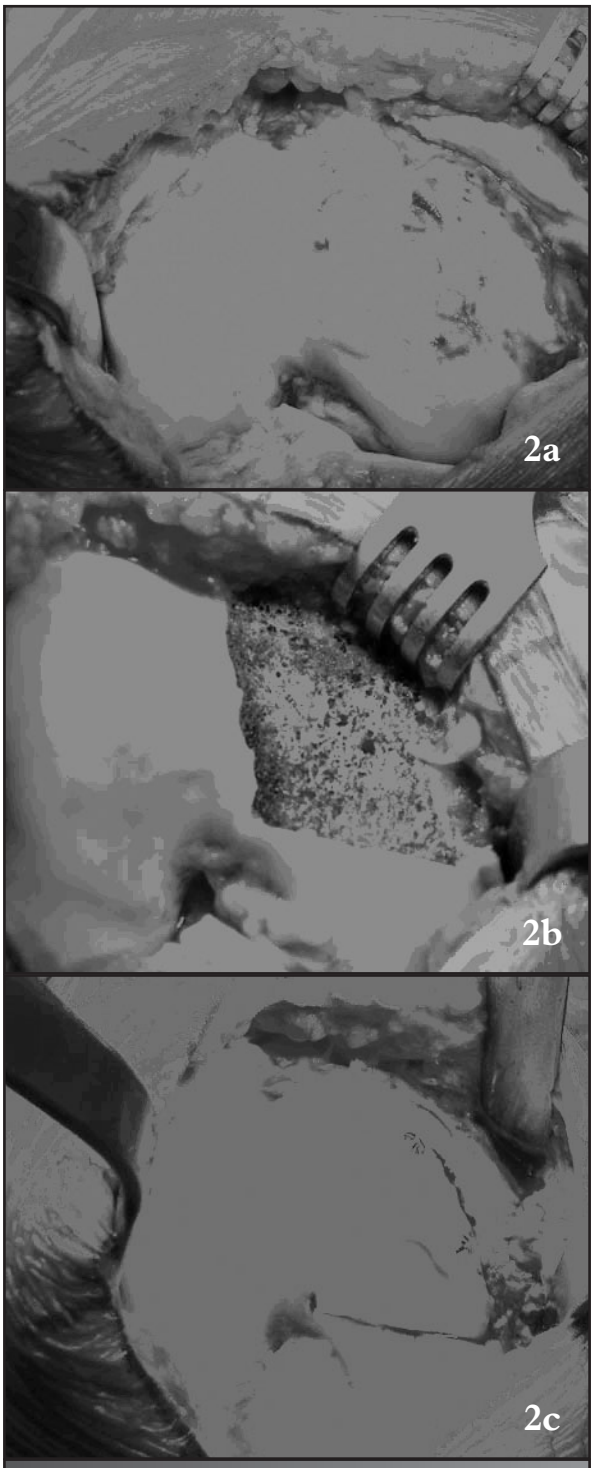

Figure 2a: Traumatic osteochondral lesion

Figure 2b: Freehand preparation of the graft bed

Figure 2c: The osteochondral shell graft in place, fixated with compression screws

Countersunk grafts serve very little mechanical function and should rather be flush with the adjacent normal cartilage.[20]

Rehabilitation involves early postoperative continuous passive movement (CPM) for three weeks and non-weight bearing for 8 to 12 weeks, depending on the size and type of the graft.[14,20]

Clinical results

Lexer performed the first procedure of this kind in 1908. He performed 34 joint allograft replacements of the whole or part of the joint and reported a 50% success rate in 1925.[14,21]

The current literature reports success rates ranging from 76 to 94%. Ghazavi *et al*[22] had an 86% success rate at a mean of 7.5 years, with 126 patients in their study. Another large series by Bugbee[23] included 122 patients who received femoral allografts. The success rate at 5 years was 91% and 76% at 10 years.

The advantages of allograft over autograft are lower donor site morbidity, shorter operative time, larger grafts, smaller surgical incisions and a lower incidence of arthrofibrosis

Future arthroplasty benefits from allograft surgery with improved bone stock and an improved range of motion. This results in a less extensive procedure with a possible improved outcome.[14,24]

Tibial allografts showed improved survivorship when they were combined with meniscal transplantation at the same sitting.[25]

Meniscus allografts

Introduction

The meniscus is a very important structure for maintaining the normal kinematics within the knee because it plays a role in load transmission and shock absorption. The menisci also act as secondary stabilisers for anterior tibial translation in the anterior cruciate ligament (ACL) deficient knee. They also contribute to varus and valgus stability.[26]

Total or partial meniscectomy has been shown to increase the peak stress across the articular surfaces from 40% to 70%. This increased stress leads to progressive deterioration of the articular cartilage and secondary arthrosis.[27] Meniscus-allograft transplantation allows for the improvement of essential knee kinematics and can delay the development of secondary arthritis.

The grafts to choose from are fresh, fresh-frozen, and cryopreserved grafts. Irradiated-meniscus transplants have been directly associated with poor outcomes, thus deep-frozen allografts are not used and fresh-frozen allografts are preferred. According to Kelly, fresh-frozen allograft is the graft of choice because it is inexpensive and has a longer shelf life.[28] Freeze-dried allograft undergoes shrinkage and is not recommended. Grafts from donors older than 45 years are not used. Patients on corticosteroids and cytotoxic medication are not eligible donors.[28]

Indications

The main indication for meniscal allografts is a patient younger than 50 years who has had a meniscectomy. The patient's tibiofemoral joint should not be painful and the X-rays should be normal. There must be more than two mm joint space left on a 45° weight-bearing postero-anterior radiograph. These indications can be extended to a non-functional meniscus, and there are authors who suggest that it should be done as soon as possible (after meniscectomy).[26,28,30]

Contraindications are the patient's age if over 60 years, Outerbridge IV articular-cartilage changes (Outerbridge III is borderline), femoral condyle flattening, the presence of osteophytes, ligamentous instability, inflammatory joint disease and significant varus or valgus of the knee.[26,28,30]

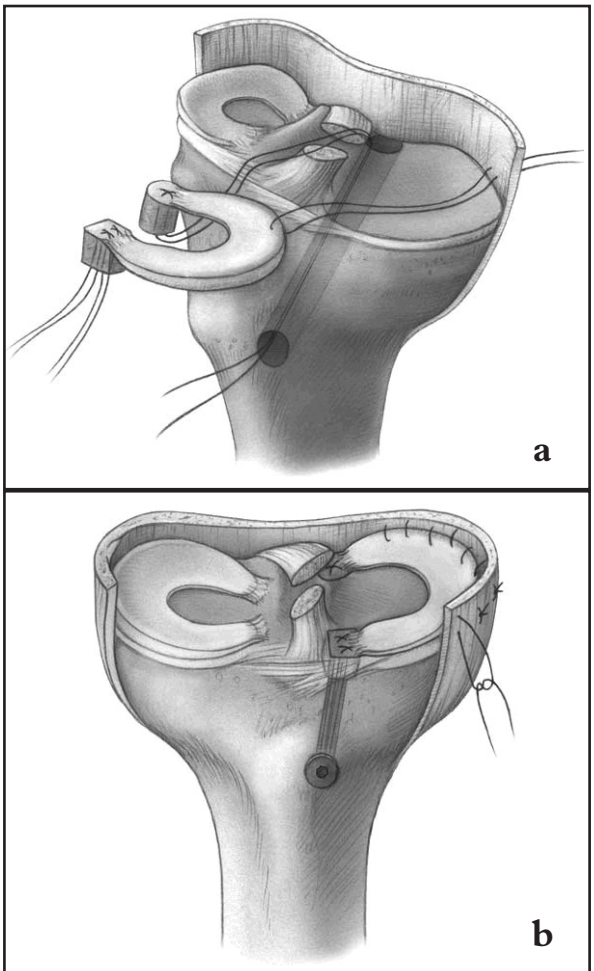

Figure 3a: The posterior bone tunnel in place for fixation of the medial meniscus

Figure 3b: Final fixation of the two bone plugs by means of a button technique

Surgical considerations

The procedure can be performed with arthroscopic or open surgery through a medial or lateral parapatellar approach. Bone plugs from the original donor attachment of the meniscus should be used to fix the meniscus to the recipient tibia. The medial meniscus is implanted by means of an anterior and posterior bone plug *(Figures 3a & 3b)*. The lateral meniscus is implanted by means of a bone bridge that connects the anterior and posterior horns of the meniscus *(Figure 4)*. Sutures should be applied between the peripheral zone of the implanted meniscus and the capsule.[28,30]

Axial misalignment has been shown to result in increased failure rates, and should be addressed at the same time as the meniscus transplantation. Anterior tibial translation due to an anterior cruciate deficiency results in increased stress of the transplanted medial meniscus and should be addressed by means of a concomitant ACL reconstruction.[31,32]

Sizing is very important and should be done by means of radiographs, computer tomography and MRI.[33,34]

Postoperative management consists of restriction of the range of movement from 0 to 90° in a hinged knee brace, with early CPM exercises. The patient should not bear weight and should mobilise toe touching for four weeks, followed by another two weeks of partial weight bearing. Full return to sporting activities is allowed six to nine months after surgery.[28]

Clinical results

Milachowski *et al* performed the first free-meniscus transplant in 1984.[35] Since then, the procedure has stimulated a lot of interest. The available studies are difficult to interpret and to compare due to a great variability in graft choice, indications and surgical techniques.

The largest study to date is that of Noyes and Barber-Westin.[36] They implanted 96 fresh-frozen irradiated grafts into 83 patients with only posterior-horn fixation, and followed them up for 5 years.

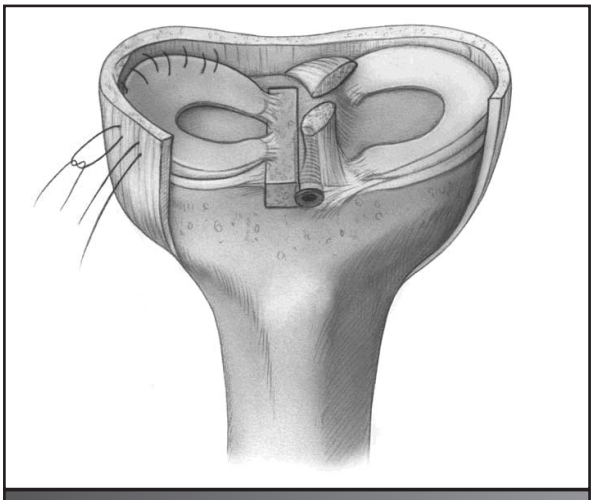

Figure 4: The bone bridge of the lateral meniscus inserted into the tibial slot

Their results were not very encouraging with complete failure in 44% and partial failure in 22%. The importance of the study lies with the conclusions, namely that surgeons should use double-horn fixation, exclude severe arthritis and should not use irradiated grafts. In a separate follow-up study, they addressed these problems by using non-irradiated cryopreserved grafts, fixed with a double-horn bone-plug technique. They implanted 40 grafts in 38 patients and addressed concomitant osteochondral defects and ACL deficiencies. Their results at 40 months were much better than in the first study, with 68% of the knees having no pain, and 75% of patients returning to light low-impact sports without problems. MRI evaluation revealed that only 28% of the grafts had failed.[30]

Verdonk *et al*[37] evaluated their first 100 transplantations using fresh allograft at a mean of 7.22 years after surgery. Their implants had a failure rate of 21%. They found a significant reduction in pain and improved knee function. This beneficial effect lasted for at least ten years in approximately 70% of the patients.

Patients with meniscal allografts who required conversion to total knee replacement underwent arthroplasty at an average of 10.6 years post-surgery compared with 7.1 years for patients without meniscal allografts.[14]

Ligament allografts

Introduction

Autograft is the preferred choice for knee ligament reconstructions. In certain circumstances, there has, however, been renewed interest in the use of allografts due to a lack of autograft availability.

As was mentioned earlier, fresh allograft is not used. Fresh-frozen allograft is the graft of choice. Other viable alternatives are deep-frozen, cryopreserved and freeze-dried grafts. Deep-frozen irradiated grafts are available at the National Tissue Bank. An irradiated graft may have less mechanical strength than a non-irradiated graft.[6]

Indications for the use of allograft

The primary indications are revision cruciate reconstructions, multiligament knee reconstructions, patellofemoral disorders, and a lack of available autograft. An ACL reconstruction in an arthritic knee that normally suffers from stiffness after autograft reconstructions is also an indication for the use of allograft. This is due to a decreased inflammatory response to the frozen allograft.[11,38]

These indications are not absolute and can be stretched in some circumstances, for example in patients who object to contralateral surgery. Athletes may benefit from allograft knee reconstructions by returning to their sporting activities earlier.[39] Some authors use allograft for all their acute and chronic ligament reconstructions.[40,41]

Surgical considerations

Allograft can be taken from the patellar tendon, Achilles tendon, tibialis anterior tendon, hamstring tendon, quadriceps tendon and fascia lata. The clinical results for the use of any of these are the same.[41] McGuire and Wolchok prefer to use patellar tendon and Achilles tendon allografts to reconstruct the ACL, and split Achilles tendon for posterior cruciate ligament (PCL) reconstructions.[11]

Revision cruciate surgery requires reaming the tunnel into which the allograft is to be implanted. This is important in ACL revision surgery, as there may be a large bony defect, which can be addressed by using an oversized bone plug for the patellar tendon allograft. This is difficult to achieve with a patellar tendon autograft.[11]

Lateral collateral-ligament reconstruction as part of a posterolateral corner injury can be reconstructed by using a patellar tendon or an Achilles tendon allograft – which is usually enough to treat the associated PCL injury.[11] Chronic valgus instability of the knee due to a medial collateral-ligament injury can be reconstructed by using an Achilles tendon allograft.[42] Chronic infrapatellar tendon tears can also be managed by means of Achilles tendon allografts.[43]

Clinical results

Allograft versus autograft cruciate ligament reconstruction reveals very little difference between the two groups. There has been a slightly increased incidence (13%) of traumatic rupture of the ACL allograft.[44] The ACL autograft reconstruction group did, however, show a greater loss of active and passive movements than allograft.[45] Another concern was late allograft stretching, but recent studies have shown that this is not a serious problem.[46]

All tendon grafts, whether autogenous or allogenic, undergo similar processes of integration accompanied by graft necrosis, revascularisation, cell repopulation and remodelling.[47] Allografts have been proven to have a delayed remodelling as compared to autografts, and this process may take up to three years or longer.[48] With graft necrosis both allograft and autograft lose a lot of their initial strength, but with remodelling they regain this strength. At 6 months, the material properties of autograft were, however, shown to be superior to allograft.[49] While these differences in biological incorporation and initial strength exist, they may not be associated with differences in patient outcome.[11]

Conclusion

In South Africa, the availability of allografts is limited due to limited resources. We do not have fresh allografts available and are restricted to the more processed types of allografts. This makes it difficult for SA surgeons to implement international advances in allograft surgery, although this situation may change in the near future due to the development of radioprotective agents shielding fresh allograft from the harmful effects of radiation, while still having a sterilising effect.[50]

With the advances in tissue harvesting and processing, the international use of musculoskeletal allograft has expanded. Its extended use has given us optional treatment modalities for previously unsalvageable problems. The orthopaedic surgeon should therefore be aware of all the applications and forms of allografts.

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