

The Mosaicplasty / OAT procedure: Technique, Pearls and Pitfalls

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Abstract

Osteochondral autologous transplantation is a surgical procedure that involves the transplant of the autologous cartilage from the non-weight bearing areas of the knee to the articular defect. It has the advantage of being a single stage procedure, repairs the subchondral bone, provides hyaline cartilage and allows a fast return to play. It is indicated for small and medium-sized defects, but the mosaicplasty technique allows treating defects up to 9 cm². A major disadvantage of this technique is the donor site morbidity associated to the graft harvesting. To overcome this drawback, we harvest the autografts from the upper tibio-fibular joint with low or none donor site morbidity. Osteochondral autologous transplantation and mosaicplasty procedures remains an excellent option for small to medium osteochondral injuries resulting in long-term good to excellent clinical and imaging outcomes.

Key-words – Knee, cartilage, osteochondral autologous transplantation, mosaicplasty.

Introduction

Articular cartilage plays a vital role in maintaining joint homeostasis by reducing friction and absorbing load impact. Cartilage lacks vascular and nervous supply. These properties make the articular cartilage a tissue with low potential to spontaneously heal and difficult to restore. Injury to the cartilage is usually seen in acute or micro trauma, malalignment, ligament injuries, or osteochondritis dissecans (OCD) in the younger population [1,2]. In patients under 40 years, the frequency of chondral defects is 63%, but only 5% of these are deep defects (grades III and IV) [1] which if not treated, there is a high risk of progressing to osteoarthritis [3,4]. Focal cartilage defects impair quality

of life in same way as severe osteoarthritis causing long term deficits in knee function [5,6].

There are several surgical methods for the treatment of focal chondral and osteochondral defects of the knee joint to obtain fibrocartilage or 'hyaline-like' cartilage [7]. Traditional resurfacing techniques (microfractures) provide reparative fibrocartilage cover with poor biomechanical properties and sub optimal outcome [8,9]. On the other hand, autologous osteochondral grafts have shown hyaline cartilage survival on the transplanted block [10,9].

Osteochondral autologous transplantation (OAT) is a single stage procedure involving the transplant of the whole osteochondral

unit (bone and hyaline cartilage) from affected or opposite knee, not requiring laboratory or cell therapy. Risk of infection is low and there is no risk of rejection. However, the technique must be carefully performed to obtain maximum coverage (>=80%) with stable and well-integrated grafts. The use of small sized multiple cylindrical grafts allows the transfer of more cartilage tissue and implanted in a mosaic fashion to progressively contour the damaged surface [11]. Harvesting of articular cartilage has an inherent risk of donor site morbidity [12] and harvesting large grafts could increase the risk of harvest-related pain and incongruity at recipient site. The most common harvest site is the periphery of the lateral trochlea above sulcus terminalis and peripheral medial trochlea. The upper tibiofibular joint was proposed as graft harvest site to reduce donor site morbidity, showing good clinical, functional and imaging outcomes at the long-term follow-up [13].

Indications and contraindications

The OAT technique is a viable option for symptomatic full thickness articular cartilage injury of knees that are stable and in neutral alignment. This procedure is usually indicated

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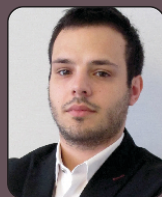
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Table 1 – Indications and contraindications of OAT procedure

Indications	Absolute contraindications	Relative contraindications
Focal chondral and osteochondral defects of weight bearing area of knee. Extended indication: talus, femoral head, capitulum of humerus	Osteochondral defect more than 9cm ² and deeper than 10mm	Bipolar or multifocal defects
Ideal diameter of defect 1-4 cm ² Extended indication: as large as 9 cm ² if mosaicplasty is used	Tumors, inflammatory arthropathy, diffuse degenerative joint disease or joint infection	Overweight patients
Age of patient <50 years. Extended up to 50-55 years	Lack of donor site availability	Severe tobacco addiction
Patient compliance is important (weight bearing, daily and sporting activities limitation)		Age more than 55 years

for young subjects (usually younger than 50) with symptomatic cartilage defects that are deep with limited local substance loss (grade III and IV). The list of indications and contraindications [14,15] is presented on Table 1. Associated injuries (meniscus, ligament) must be treated simultaneously or prior to the chondral repair. Any knee malalignment above 5° requires simultaneously or prior osteotomy. The technique is best suited for lesions between 1 and 4cm², although lesions as large as 9cm² can be resurfaced by mosaicplasty but the risk of causing donor site morbidity is higher. OCD is often a deep lesion, which may needs an osteochondral or chondral graft in case of surgical indication and the impossibility of the native osteochondral fixation.

Preoperative Evaluation

Clinical

A throughout history and physical examination is essential to decide if the patient is candidate for any cartilage restoration procedures. A detailed medical history is taken to record body mass index, associated medical conditions or other inflammatory diseases, steroid intake and smoking habits. There are no definitive signs, but the exact location, type and onset of pain, aggravating and relieving factors, mechanism of injury, expected level of occupation or sporting activity, pain at rest (degenerative disease) or on activity (mechanical), catching or locking of knee and previous treatment history are usually asked questions. Self-evaluation of the knee

pain and function by the patient is important and can be assisted by using the Knee and Osteoarthritis Outcome Score (KOOS) or the International Cartilage Repair Society (ICRS) subjective score. The physical examination starts with assessment of gait and limb alignment, knee range of motion, knee ligament integrity, and meniscal injury. The knee is checked for effusion which is an objective sign of inflammatory activity. Local tenderness on the femoral condyle is seen while excluding other causes of pain referred to knee.

Imaging

A weight-bearing anteroposterior (AP) view and flexed knee lateral x-rays are mandatory. Special views such as Merchant view for patellofemoral joint, Rosenberg view (45° flexed knee posteroanterior view) to assess posterior joint line and leg longstanding AP view to rule of axial malalignment of the lower limb is helpful. Analysis of surface and deep osteochondral substance loss can be obtained by computed tomography (CT) arthrography, magnetic resonance imaging (MRI) or arthro-MRI. Defects with more than 50% of cartilage thickness and fissures are identified with higher specificity using CT arthrography. In general, fat suppressed 3-dimensional gradient echo (3D-GRE) MRI sequences allow the analysis of the cartilage thickness and surface, whereas T2-weighted (dual) fast spin echo (FSE) with or without fat suppression outlines the inner structure of hyaline cartilage. Special sequences like the gadolinium enhanced MRI of cartilage (dGEMRIC), T1 rho, T2

mapping and diffusion weighted imaging can assess biochemical details of the cartilage. Arthro-MRI is indicated to evaluate the surface of traumatic defects, recipient cancellous bone as well as OCD [16,17].

Preoperative and intraoperative planning

General or regional anesthesia, use of tourniquet and fluid management system are recommended. Antibiotic prophylaxis, standard arthroscopy instrumentation, mosaicplasty set, reusable instruments, disposable chisel, drill bits, and bone tamps should also be available. If the patient has had prior surgery, the previous operative notes and images are useful. If performing an osteotomy on the same side as the osteochondral procedure, it is advisable to stage the procedure so that the micro vascularity of the recipient bed is not jeopardized. Only defects that remain painful at least after 3 months of observation should be treated except in specific cases. There are some salient points we need to know considering the size of the defect, harvesting technique, osteochondral graft itself, stability and viability of graft, and outcome of donor site and the transplanted graft. A threshold of 10 mm is considered as minimum for chondral repair in weight bearing area [18]. Ideally, the graft harvest site has low stress and provide cartilage with curve and thickness similar to recipient site. Contact pressure is low on the medial trochlea and at the lower lateral trochlea (above the intercondylar groove). Because

Table 2 – Pearls and pitfalls of OAT/mosaicplasty technique

Pearls	Pitfalls
The graft harvest site should provide cartilage with curve and thickness similar to recipient site	Extensive graft harvesting may cause donor site morbidity
Small grafts are harvested from lower medial trochlea and large grafts from the lower lateral trochlea (lower region is more curve)	Donor site collapse may occur if graft harvesting is adjacent to the defect. Thus, donor site should maintain 1 to 2-mm distance from the defect site and condyle edges
The upper tibio-fibular joint can be used for harvesting the grafts and decrease the risk of donor-site morbidity	Oblique harvesting and implantation results in uneven articular surface
The rim of the groove is flat and can be used to restore trochlear defects	If the graft does not match the recipient socket, the force to fix it will increase and potentially damage the chondrocyte if the plug is longer than the socket
The graft must be harvested and implanted perpendicularly	Disruptive impaction forces may affect cell viability and lead to graft failure. To prevent this complication, the donor and recipient sites depth should be carefully matched
The grafts that are wider and fixed with press-fit effect are more stable	A graft without stress will get too loose. To prevent this, surgeon should assure that the graft surface is congruent and countersunk up to 1mm to preserve the hyaline and to be hypertrophied
Carefully match the plug diameter and recipient bed to allow a good press-fit without excessive force	Implanting the graft too deep can also affect cell viability. In those cases, a crochet hook is used to lever the graft out and is stabilized with a biopin as we prepare to insert second graft.
OCD lesions extending to the subchondral bone require longer grafts or adjunctive bone grafting techniques	Fracture of the graft may occur if the graft is less than 10 mm long as it will be unstable, hence at least 15 mm graft is desirable
If multiple grafts are required, minimizing the step-off between grafts and surrounding cartilage decreases surface fibrillation and edge-loading of grafts	When the graft is unstable, use either a bio-absorbable pin or a screw to counter sunk and stabilize the graft
Hemarthrosis can be reduced by filling the donor site and applying ice packs and postoperative draining	

of different widths of the two areas, small grafts are harvested from lower medial trochlea and large grafts from the lower lateral trochlea [19]. These two locations also have the best curve for condyles as the upper section are more convex. The rim of the groove is flat and can be used to restore trochlear defects [20]. The cartilage is thicker on the sides of the trochlea compared to the intercondylar notch, especially on the lateral side [21]. Comparing the harvesting techniques, arthroscopy or arthrotomy both can be used with equal results, and incongruity was of less than 1mm in 69% and 57% of cases respectively [22]. The graft must be harvested perpendicularly, and as during arthroscopy as the patella floats laterally it is more difficult and has risk of marginal fracture. In inaccessible area of condyle (posterior condyle lesions), arthrotomy is preferred. Grafts of 11mm in diameter and 15 to 20 mm long show high resistance [23]. The grafts that are wider and fixed with press-fit effect are more stable [24]. A graft without stress gets loose, hence the surface of the graft has to be congruent, countersunk up to 1mm only to preserve the hyaline and to be hypertrophied [25]. The graft has to match the recipient socket or the force to fix it will increase and potentially damage the chondrocyte if the plug is longer than the socket [26]. Osseous integration is good, the hyaline will be viable, the 'tide mark' is continuous but a fissure might remain between the plug and the socket. The donor site is left empty and on follow-up the surface shows depression and fibrous tissue in deeper areas [27,28]. Some pearls and pitfalls of the OAT/mosaicplasty technique can be consulted on Table 2. Donor site morbidity due to harvesting autologous cartilage grafts is common and one of the main disadvantages of OAT and mosaicplasty procedure [12]. Hence, mosaicplasty using grafts from the upper tibiofibular joint is good option to overcome many of the shortcoming of OAT harvesting [29,13].

Surgical technique

OAT and Mosaicplasty

The patient is positioned supine. Flexion of the knee up to 120° should be possible, so the posterior femoral condyle can be

Table 3 - Surgical Pearls and Pitfalls of Porto-GUT technique

Pearls	Pitfalls
Preserve the safe zone to avoid damage to common peroneal nerve, anterior tibial artery, lateral collateral ligament and biceps femoris tendon	Proximity of the anatomical structures are at risk of injury
Dissect the joint capsule and move the fibula head to visualize the joint	Irrigation of the cartilage while harvesting plug is a must to avoid damage
Cut in the fibula head is made parallel to the lateral collateral ligament at an angle of 45°	
Guide pin on the tibial articular side helps not to violate tibial plateau	
Start harvesting plugs from periphery after securing the graft with K-wire	
At the center of plug K-wire is used as joy stick to manipulate and seat the graft in the recipient socket	

accessed and the graft can be placed perpendicularly. Proximal thigh tourniquet is applied. The foot is placed in a knee bar to keep it flexed for proper surgical access. Although arthroscopic procedure can be performed, arthrotomy is preferred for patellar, trochlear and posterior femoral condyle lesions. The arthroscopy portals are more central and inferior than usual on either side of patella tendon and a spinal needle can be helpful. In some cases, the harvesting and the insertion portals can be different.

The cartilage defect is evaluated according to the ICRS classification. The height and width of the defect are measured. The edges of the defect are debrided with a number 11 blade or ring curette to stabilize the borders

and measurement is performed with an arthroscopy probe or with lesional arc technique [30]. The number and diameter of the osteochondral plugs are chosen according to the size of the defect. However, few larger diameter plugs improve stability, coverage and simplify the procedure. Harvesting is limited to three large diameter plugs: 11 mm from lateral trochlea above the sulcus terminalis, 9 mm grafts from the smaller medial trochlea and 6 mm grafts from the intercondylar notch [31]. If the medial condyle is the recipient site, the graft is harvested from lateral side to allow differentiation of postoperative pain. The donor harvester is placed perpendicular to the cartilage surface and carefully advanced under vision to the desired depth making

sure the laser mark on the harvester is parallel to the surface. Donor plug of 15 mm or more is harvested (1 cm of bone loss requires 2 cm long plug) for traumatic defects and 20 mm for OCD. When desired depth is reached, the harvester is either toggled or rotated 180° to fracture the base of the plug. The donor plug is kept either in the harvester or in a saline gauze. The graft is harvested manually than power trephination to better preserve the chondrocytes [32]. Choose a recipient socket preparation device (chisel/tamp) which is sized under 1mm to allow press fit of the plug in the recipient site. Measure the depth of the socket which is the same as the plug at 12.00, 3.00, 6.00 and 9.00 o'clock position, which is created 1mm or deeper to avoid raised pressure in the socket while insertion of graft. Clear the debris from the basis of the recipient socket, measure it again. Inflow now is slowed down to avoid the graft being washed away during insertion. Place the graft in the insertion device after thorough wash with saline and insert it slowly perpendicular to the socket and stop once the desired level is reached. Use tamp or screw on the insertion device to seat the graft in the socket. When tamp is used, the size should be more than the socket size so that the graft is not inadvertently sunk, and small amount of frequent tapping is done [26]. When the graft is flush with the recipient socket, move the joint through a range of motion to assess any abnormal edge loading or shearing of graft. An ideal graft size is 4.5 mm in diameter which reduces donor site morbidity, easy to handle and reduced concern of fragmentation. Grafts <3 mm are difficult to handle and 6 mm or more will cause donor site morbidity. In some

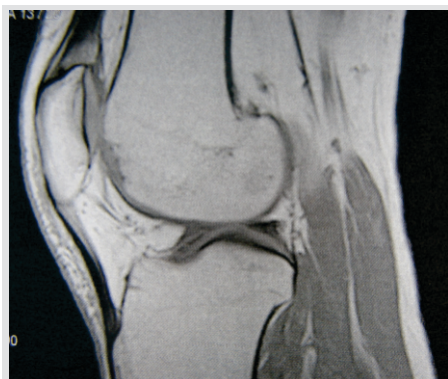


Fig 1: MRI scan of an articular cartilage defect at the femoral trochlea.

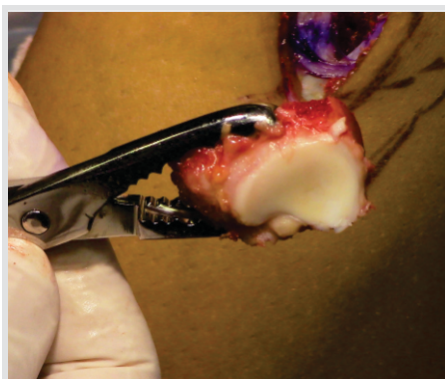


Fig 2: Removal of the fibular head bone block for autografting.

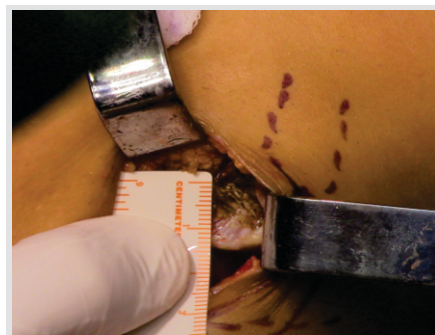


Fig 3: It is important to identify the "safe zone" to perform the vertical and horizontal cuts without violating the tibial plateau. The cuts should be made with a 1.5 cm distance from the lower cartilage end surface of the tibial side.

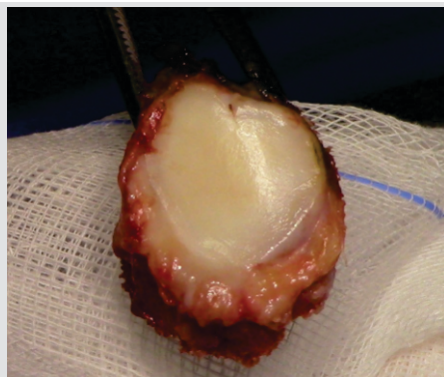


Fig 4: Tibial bone block for autografting.

situation cavitory lesions and sclerotic walled cysts resulting in collapse of donor area and possible osteoarthritic changes [33]. After implanting the plug(s), the joint is washed and closed over a drain. When the recipient site needs more than one graft (mosaicplasty), to preserve the integrity of the donor site a gap of at least 3 mm is maintained between the harvesting site. Use of different sized grafts and cutting into the adjacent graft results the higher fill rate (90-100%) [34]. To recreate the normal convex contour, most peripheral grafts are placed first followed by the central grafts in a convergent manner. The most posterior grafts are placed first. If the graft is unstable, then either a bio-absorbable pin or a screw can be counter sunk to stabilize the graft. For patella defects, arthrotomy is required. Grafts are harvested from flatter rim of intercondylar notch area to a depth of 12 mm. The recipient socket has to be convergent on the median facet and parallel on the facets. For tibial defects, in certain areas the recipient socket is done at an angle of 20-30° with special jig and the graft is harvested from femoral trochlea at the same angle.

Osteochondral graft harvesting from upper tibio-fibular joint (Porto-GUT technique)

For performing OAT/mosaicplasty, our preferred technique involves harvesting the autografts from the upper tibio-fibular joint [29]. The radiography and MRI scans are reviewed before the procedure (Figure 1). A standard supine position of the patient with proximal thigh tourniquet allowing 120° of range of movement is done. A 5-cm incision



Fig 5: The osteochondral block is held and stabilized on a hard surface to harvest the osteochondral lugs.

is made one cm anterior to the head of fibula vertically. After soft tissue dissection, the upper tibiofibular joint is located. Care must be taken to protect the common peroneal nerve, fibula collateral ligament and the anterior tibial artery. Using a micro-saw, two cuts are made at an angle of 45° on the head of fibula. One vertical leaving the attachment of biceps and fibula collateral ligament intact, and other transverse starting just above the peroneal nerve and perpendicular to the first one. With these two cuts, the head is delivered by releasing the posterior capsule with scissors and the fibular head cartilage is removed (Figure 2). With a guide pin the tibial articular surface is marked out. Two cuts of 1.5 cm are made on the tibia (Figure 3), one below the horizontal guide line and other vertically. The posterior soft tissue is released and the tibial bone block is removed (Figure 4). Care must be taken to not violate the articular surface of tibial plateau. The wound is washed, fat is interposed in the gap to reduce effusion in that area and wound is closed. The standard procedure of harvesting an autograft and seating is followed with these blocks also. While harvesting, the graft is secured on a back table to avoid it falling down (Figure 5) and a drill at slow speed with constant irrigation of saline is used to get the desired diameter of plug. A K-wire is placed into the center of the harvested graft and used as joy stick to seat into the measured recipient socket of desired size and depth. The defect should be completely covered with the plugs (Figure 6). The pearls and pitfalls for this surgical procedure are described in Table 3. This technique has the advantage of at least 6 plugs of 6 mm in

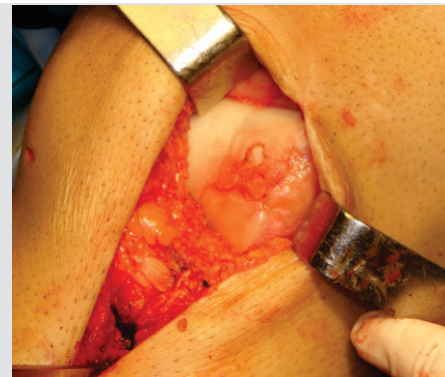


Fig 6: Final results of the Porto-GUT mosaicplasty technique at the femoral trochlea using 3 osteochondral plugs.

diameter (or a total area of 5cm² [35]) with low or no risk for donor site morbidity [13].

Post-operative management

Application of ice packs and compression bandage help to control hemarthrosis. Prophylactic antibiotics are used as desirable. Analgesics (morphine pump, crural catheter) and non-steroid anti-inflammatory drugs may be used to favor early mobilization. Passive mobilization is started as soon as the knee effusion decreases and progressed as tolerated pain. Continuous passive motion may also be implemented.

Rehabilitation

Rehabilitation following cartilage repair of knee must follow a stepwise and individualize rehabilitation program [36,37]. The progression through phases is based on objective criteria and the protocol is divided into three phases: phase 1, protection and joint activation; phase 2, progressive loading and functional joint restoration and phase 3, activity restoration [38]. Early mobilization is essential in femoral and tibial grafts to prevent potential complications. In case of multiple grafts, the weight bearing is delayed. In patellofemoral grafts, weight bearing can be started immediately, but flexion is limited to 20°-30° for 3-4 weeks

Outcomes

The goal of OAT/mosaicplasty technique is to provide host hyaline cartilage to an area of articular cartilage damage. Laszlo Hangody et al. published a series of 789 femoral condylar, 31 tibial and 147 patellofemoral defects including 815 with

an associated procedure (meniscus, ligament or osteotomy). At 15 years follow-up, 92% of patients showed good to very good result for femoral condyle, 87% for tibia and 74% for patellofemoral. Out of the 83 biopsies performed, the authors found hyaline cartilage in 83% of cases (type-II collagen glycosaminoglycans) and perfect integration of cartilage matrices [14].

In a randomized controlled trial comparing mosaicplasty and first and second generation autologous chondrocytes implantation, Horas et al. [39] reported that clinical results were better and more rapid with mosaicplasty, and histological outcomes were better with mosaicplasty despite gap in the chondral edges of the plugs. In turn, Bentley et al. [40] reported clinical improvement with both techniques, but lack of peripheral integration is a disadvantage for mosaicplasty. In recent study, comparing the OAT procedure and matrix-induced autologous chondrocyte implantation, the MRI results showed that cartilage repair techniques prevented or delayed the progression of knee to degeneration [41].

In a randomized control trial of long-term follow-up (minimum 15 years), mosaicplasty showed better clinically relevant outcomes than microfracture for articular cartilage defects (2-5 cm²) of the distal femur in patients aged 18 to 50 years [42]. Several randomized clinical studies have been published comparing microfracture and mosaicplasty/OAT in articular cartilage defects of the knee [9,43-47]. These studies concluded that mosaicplasty is superior to microfracture in the following outcomes: (1) better clinical outcome and better anatomic (arthroscopic) appearance of repair tissue in young athletes [9]; (2) better clinical outcome and MRI results in children with OCD [46]; (3) higher rate of return to and maintenance of sports at the preinjury level at 10 years [44], and (4) better

International Knee Documentation Committee (IKDC) score among patients with combined ACL reconstruction and cartilage repair [43]. Two studies found no significant difference in outcome comparing both techniques [46,47]. In the Ulstein et al study [47], the reoperation rate was higher in the microfracture group (54%) than in the mosaicplasty group (36%). The better outcome in most randomised clinical studies for mosaicplasty may be due the quality of the tissue that fills up the defect. The microfracture and other marrow stimulating procedures produce more of hyaline-like or fibrocartilage, which is less resistant to wear and tear.

In a recent study, Eirick Solheim et al [42] studied the early determinants of outcome of cartilage surgery on 205 patients and 14 years of follow-up. The patient-related predictors were more important in predicting long-term results than the type of surgery performed. Factors predicting good or excellent result included a single cartilage lesion, normal appearing cartilage surrounding the lesion, high baseline Lysholm score, short duration of symptoms, non-involvement of the patellofemoral joint, younger age at surgery and small defect size (3 cm² or smaller). On the other hand, factors predicting a poor outcome included multiple lesions, low baseline Lysholm score, (mild) degenerative cartilage surrounding the lesion, long symptom duration, previous or concomitant partial meniscectomy and large defect size. Mithoefer et al. [48] performed a systematic review of return to sports after articular cartilage repair of knee that evaluated 20 studies with 1363 patients. The overall rate of return to sports for patients who underwent ACL, microfracture or OAT was 73%. The OAT procedure with highest return to sports rate (91%) with the mean time to return to sports of 7 months. Superiority of the OAT procedure concerning return to sports rate and timing

is also seen when focusing football players [49]. However, the age of the athlete, size of the lesion and concomitant surgical procedure can influence both the time and rate of return to sports [50].

Complications

Fracture of the graft may occur if the graft is less than 10 mm long as it will be unstable, hence at least 15 mm graft is desirable. Also, a graft inserted too deep will be ineffective as loading may not occur and cells may disintegrate. In that case, a crochet hook is used to lever the graft out and is stabilized with a biopin as we prepare to insert second graft.

Hemarthrosis is rare but if it occurs has to be drained out by arthroscopy and lavage. It is common when multiple grafts are harvested or when we fail to plug the donor site with trabecular bone from recipient sockets or when anticoagulation is overused. There may be patellofemoral pain for months, but should resolve by 3 months. Autografts have to be re-evaluated either by MRI or arthroscopy to avoid having osteoarthritic episode. Necrosis of the graft or pseudo arthrosis presents with unresolved pain and is well picked up by MRI. The graft has to be revised with larger plug and debridement.

Conclusions

Modification and enhancements of the OAT and mosaicplasty techniques are continuously being investigated. Osteochondral graft fixation methods and biological augmentation for graft healing and chondrocyte survival are currently being studied. OAT/mosaicplasty remains an excellent treatment option for osteochondral injuries, with a high rate and fast return to sports.

Using the upper tibio-fibular joint to harvest the autografts, it is possible to prevent the donor site morbidity that is the main disadvantage of OAT technique.

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