CURRENT CONCEPTS REVIEW

Osteochondral Allografts for Large Osteochondral Lesions of the Knee Joint: Indications, Surgical Techniques and Results

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Abstract

The main indications for osteochondral allografts (OCA) transplantation of the knee are the following: Symptomatic full-thickness cartilage lesions greater than 3 cm^2; deep lesions with subchondral damage; and revision techniques when a previous surgical procedure has failed. Dowel and shell techniques are the two most commonly used for OCA transplantation. The dowel technique is appropriate in most cartilage lesions; however, geometrically irregular lesions may need the shell technique. Factors related to better outcomes after OCA transplantation are the following: unipolar lesions; patients younger than 30 years; traumatic lesions; and when the treatment is carried out within 12 months from the onset of symptoms. A systematic review found a survivorship rate of 89% at 5 years. Other systematic review showed a mean failure rate of 25% at 12 years with a reoperation rate of 36%. Seventy-two per cent of the failures were conversion to total knee arthroplasty (TKA) (68%) or unicompartmental knee arthroplasty (UKA) (4%). Twenty-eight per cent of failures were graft removal, graft fixation, and graft revision. In this systematic review, patellofemoral lesions (83%) had a higher reoperation rate than lesions affecting the tibial plateau or the femoral condyles. Overall, OCA transplantation showed a successful result in 75% of patients at 12 years follow-up.

Level of evidence: III

Keywords: Knee, large osteochondral lesions, osteochondral allograft transplantation, indications, surgical techniques, results

Introduction

Massive osteochondral defects in the knee pose significant challenges for the orthopaedic surgeon. Often, they occur in patients who are young, with high demands and aspirations to return to high levels of activity. Treatments include cartilage stimulation techniques such as microfracture (which has poor results in large defects), cartilage regeneration procedures such as autologous chondrocyte implantation (ACI) or mesenchymal stem cell grafting, cartilage transfer [osteochondral allograft or autograft transplantation surgery (OATS) or mosaicplasty] from non-weightbearing portions of the knee, and ultimately, arthroplasty (1,2).

Osteochondral allograft (OCA) transplantation has a number of theoretical advantages. Like OATS, it involves the transfer of mature hyaline cartilage; it does not involve donor site morbidity; the fact that the transferred fragments are osteochondral avoids problems with delamination observed in ACI (3). Many studies have been published on the role of OCA transplantation in large osteochondral lesions of the knee. The purpose of this article is to describe the surgical technique in our unit, to review and update the current knowledge about the indications, techniques, postoperative treatment and results of OCA for large osteochondral lesions of the knee.

Indications and surgical techniques

OCA transplantation is indicated in large full thickness cartilage defects which may result from primary trauma, osteochondritis dissecans, osteonecrosis or failure of previous cartilage surgery such as microfracture or ACI (4). It is contraindicated in end-stage osteoarthritis of the knee and in active infection. Indications for the surgical treatment of large osteochondral lesions of the knee by means of OCA transplantation are shown in [Table 1]. [Table 2] shows

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Table 1.   Indications   for   the   surgical   treatment   of   large osteochondral   lesions   of   the   knee   by   means   of   OCA transplantation.
Symptomatic full-thickness cartilage lesions greater than 3 cm^2
Deep lesions with subchondral damage
Revision techniques when a previous treatment has failed
OCA = osteochondral allograft.

Table 2. Different storage procedures of OCA that significantly affect cell viability, immunogenicity, and duration of the storage.
Fresh
Fresh-frozen
Cryopreserved
OCA = Osteochondral allograft

different storage procedures of OCA that significantly affect cell viability, immunogenicity, and duration of the storage.

The two most commonly utilized techniques for OCA transplantation are the dowel and shell techniques. While most cartilage lesions can be treated with the dowel technique, large and/or geometrically irregular lesions may be treated with the shell technique (4, 5).

Dowell technique
a) Approach
The Dowell technique is usually indicated for medial or lateral femoral condyle lesions. The procedure is usually performed through a small medial or lateral arthrotomy; occasionally an arthroscopy may be performed prior to arthrotomy to confirm eligibility for the procedure. One retractor must be placed in the notch to retract the extensor mechanism, and another is used to retract the medial or lateral soft tissues.

b) Preparation of the defect
The fragments of the defect must be removed and the lesion demarcated. Cannulated cylindrical sizing guides are placed over the lesion to measure the diameter of the plug. It is better to oversize the resection so that the surrounding cartilage is normal rather than leaving poor quality tissue on the perimeter. The positioning of the osteochondral graft must be planned. A guide wire is inserted perpendicular to the articular surface for preparation of the recipient site (referenced relative to the sulcus terminalis and the intercondylar notch; allograft is obtained from a similar area); then a cannulated counter-bore reamer is used to prepare the bone to fit the specific size initially measured. Reaming is performed carefully, applying cold saline to avoid thermal necrosis to the surrounding tissue, until viable subchondral bleeding bone is reached. The ideal depth is between 6-8 millimetres (multiple perforations can be made later in the bed of the cavity). The guide pin is removed and a dilator can be used in the cavity to achieve an additional dilation of 0.5 mm. On the surface of the knee, a mark is made corresponding to twelve o´clock and the depth is measured in four quadrants. Finally, the base of the cavity is cleaned using pulsatile lavage and curette.

c) Preparation of the graft
The frozen allograft is gently brought back to body temperature using temperate saline solution to avoid sudden changes in temperature that can be harmful to

the chondrocytes. The graft is secured in an allograft workstation platform and a guide wire is placed perpendicular to the donor area to correspond to the position of the defect on the recipient knee. A reamer is used, 1mm greater than the recipient size to allow for graft press-fit. A mark is made, corresponding to twelve o'clock, to match the recipient and the depth is measured in four quadrants. Once the core is extracted a microsagittal saw is used to trim the graft to the required depth; the corners of the graft are bevelled to allow the graft to fit the recipient cavity. Prior to implantation the graft should be washed with between 1-3 litres of physiological solution to decrease immunogenicity.

d) Placement of the graft
The graft is implanted in a press-fit manner into the recipient socket by aligning the markings on the donor and recipient sides. A tamp can be used to impact the graft into position; this is done gently to avoid damaging the chondrocytes. The cartilaginous surfaces of donor and graft must be contoured (step-offs of less than 1 mm may be accepted). If the graft is too shallow, bone allograft can be crushed and placed at the bottom of the socket; if the graft is too tight, the dilator can be used again. If the graft is too loose, bone graft can be performed on the periphery and the plug can be fixed with absorbable pins or biocompression screws to add stability to the system. If more than one pin is used, they should be placed in a divergent fashion. For large defects, a second plug can be used using the "Snowman Technique", one proximal to the other. The first graft is fixed with a Kirschner wire or permanently fixed with biocompression screws to prevent detachment during the preparation of the second overlapping site. Spacing between grafts and/or lack of articular congruence (i.e. cobble stoning), which can alter biomechanics and negatively affect the clinical outcome, should be avoided. Finally, joint mobility must be checked. [Figure 1] shows a drawing of the dowel technique, also called plug technique or press-fit circular plug technique.
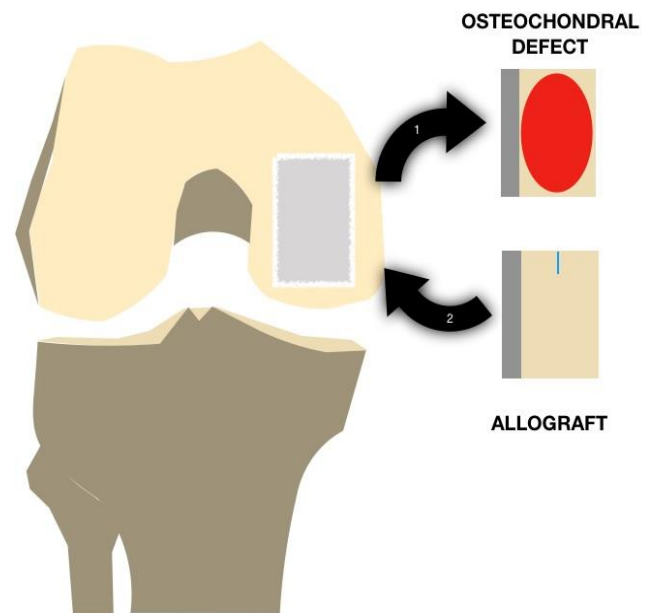
Shell technique
Non-contained or asymmetrical lesions, as well as lesions in the very posterior femoral condyles that are not accessible with the plug technique require a freehand technique to match the donor graft with the recipient's defect. The shape of the defect must be demarcated and the fragments removed with sharp curettes. A high-speed burr is then used to remove the underlying pathologic bone to expose viable subchondral bone until bleeding. In our practice, we simplify the geometry of the recipient's site defect into a rectangle or trapezoid that would resect less healthy cartilage than several plugs; this facilitates the subsequent freehand sizing of the graft [Figure 2]. Then the donor graft is similarly prepared with a microsagittal saw. Again, it is best to oversize the donor graft to obtain a press fit at the time of placing the graft.

cartilage surface using absorbable darts. Following fixation, an assessment is made as to whether a bony or soft tissue realignment procedure is necessary.
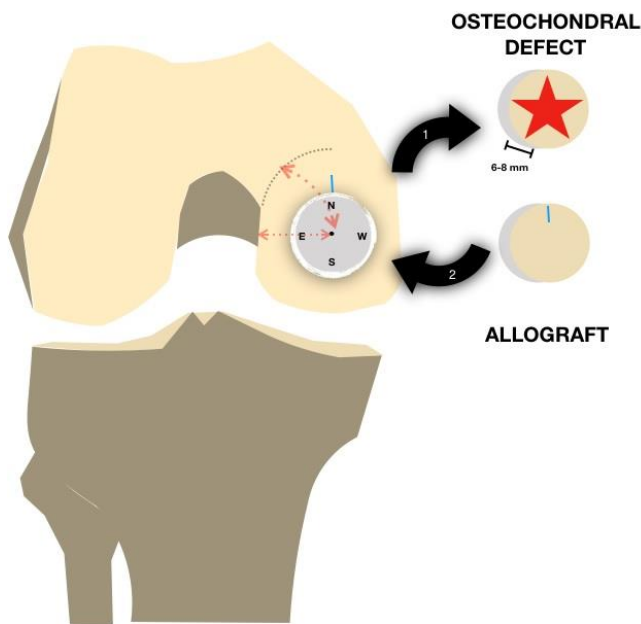
Figure 1. Osteochondral allograft procedure by the plug technique. The osteochondral defect is sized and removed with commercially available instrumentation systems. The position of the osteochondral defect is measured and referenced relative to the sulcus terminalis and the intercondylar notch in order to harvest a similar allograft. The surface of the knee is marked in what would correspond to the twelve o´clock for reference; the depth the recipient socket in the four quadrants (north, south, east and west) is measured. This way we obtain an osteochondral plug for a total depth of 6 to 8 mm. The allograft plug will be oversized by 1 mm to provide a press fit at the time of implantation. The orientation of the plug is marked at 12 o'clock in order to facilitate placement at the recipient socket. The deep surface of the allograft is measured and cut to depth precisely at all four quadrants in order to replicate the same surface contour after grafting has taken place. The recipient socket is usually dilated prior to a press fit of allograft. A tamp can be used to gently impact the graft in place to avoid damaging the chondrocytes.

Large lesions of the tibial plateau are treated with a technique similar to that used in unicompartmental knee arthroplasty (UKA). Two osteotomies are performed, either freehand, using a K- wire as a reference, or using arthroplasty jigs, one vertical and one horizontal through just beneath the subchondral bone plate. The length and width of the resected surface are measured to estimate the required dimensions of the allograft. The donor graft is then attached to allograft workstation platform, the desired dimensions are marked and the cuts are made with an oscillating saw. The graft is then fixed with two screws with interfragmentary compression, one anterior and one posterior, in submeniscal position using fluoroscopic control. Large trochlear defects require both the donor and recipient sites to be prepared using a 'v'-osteotomy using k-wires as a guide, with the graft being fixed using interfragmentary screws

Figure 2. Osteochondral allograft procedure by the shell technique. The osteochondral defect is removed with freehand technique. We simplify the geometry of the defect into a rectangle or trapezoid shape. we measure the length, width, and depth of the osteochondral defect and the allograft is similarly prepared with a microsagittal saw. The orientation of the allograft is marked in order to facilitate placement at the recipient socket.

Postoperative treatment
a) Phase I: 0 to 4 weeks
The goals are to control pain and oedema, to promote quadriceps activation and to improve range of motion (ROM) while protecting the allograft. Weight bearing status depends on the quality of the fixation and the location of the lesion. In femoral and tibial grafts weightbearing should be avoided for 6 weeks. In patellofemoral grafts we permit the patient to bear weight in extension with active flexion limited to 30-45º. Braces are not required, even in patients with patellofemoral grafts. Physical therapy will include passive- and active-assisted knee ROM, exercises include stretching and isometric strengthening of the quadriceps, hamstrings, and gluteus muscles.

b) Phase II: 4 to 12 weeks
In the second phase, the goals are to restore full ROM and to normalize gait. Physical therapy will include initiation of a stationary bike, closed-chain exercises and gait training. Full weight bearing is allowed by 6 to 8 weeks for patients with a single plug graft. Patients with large or complex grafts are restricted to partial weightbearing for 8 to 12 weeks.

c) Phase III: 12 to 18 weeks
In the final phase of rehabilitation, restrictions are discontinued and the focus is on strengthening to allow performance of activities of daily living. Recreational sports are not reintroduced until there are conclusive

signs of radiographic healing – these occur between 4 and 6 months after the operation. Patients are discouraged from returning to vigorous activities until at least 6 to 12 months after the operation.

Results of osteochondral allograft transplantation

There are now several studies of osteochondral allograft transplantation to guide our practice. Few comparative studies, and no high quality randomized studies exist.

Two large systematic reviews were published within a year of one another in the mid part of the last decade. Assenmacher et al in 2016 reported the medium to long term outcomes of OCA in the knee in five studies (291 patients) at a mean follow-up of 12 years (5). The year before, De Caro reported the outcomes of eleven clinical studies (378 knees in 358 patients) and a further 14 basic science studies (7). Only one study, Levy et al's retrospective series of 129 knees at a mean 13.5 years of follow-up, featured in both reviews (8). Both report generally good outcomes of OCA.

Of the 378 knees reported in the studies from the De Caro review, the vast majority were femoral condyle lesions (369/374, 99% of the total). Most studies had a mean age of between 25 and 35 although one study (13 knees) featured an adolescent/young adult cohort and one (25 knees) had significantly older patients (mean age 52 years). Follow-up ranged from two to 13.5 years. A range of rehabilitation protocols were used with most involving bracing or casting for up to six weeks. There were a range of clinical outcomes and the quality of reporting varied between studies and no effort is made to synthesise the clinical outcome measures. The largest included study, of Levy et al reported a 10 year graft survival rate of 82%; no formal survival analysis is reported in any other study but the proportion of patients failing in the study period ranged from 0 to 24% (with the highest failure rate reported in the study with the significantly older patient population) (8).

The smaller review of Assenmacher et al had more stringent inclusion criteria, requiring studies to have a mean follow-up of at least nine years and with outcomes assessed using a recognised outcome score [generally the Knee Society Score (KSS) or the Hospital for Special Surgery (HSS) knee score] (6). The overall mean age amongst the studies was 34.8 years and the location of the lesion varied with two thirds being in the femoral condyles, 29% being on the tibial plateau and four (1.4%) being in the patellofemoral joint. Allowing for variation in the quality of reporting, around half of cases had had previous surgery to the same knee. Overall improvements in function are reported with improvements reported in both domains of the KSS score (mean improvement in knee score, 26.4 points, 95% CI 10.4-42.4, p<0.01; mean improvement in functional score, 23.1, 95% CI 10.1-36.0, p<0.01), and the Lysholm score (mean improvement 53 points, 95% CI 27.4-78.6, p<0.01). Failure rate was 25%, as defined by conversion to UKA or total knee arthroplasty (TKA) (72% of all failures) or fixation, removal or revision of the allograft. Of the studies with a formal survival analysis, survival was given at 84% at ten years, falling to 45% at 20 (6).

Examining rates of return to sport, Nielsen et al reported a retrospective study of 149 knees (142 patients) with a mean follow-up of 6 years (9). Following OCA transplantation, around 75% of joints returned to sport or recreational activity; 71% of knees reported having very good to excellent function, and 79% were able to participate in a high level of activity. Again high rates of re-operation were reported (25.5% of cases, of whom 9% were classed as failures). Satisfaction was high, with 91% of patients declaring themselves satisfied or extremely satisfied with the results of their procedure. Separately, McCarthy et al reported the results of a small series of adolescent athletes, reporting that 7/13 returned to sport at a mean of 8 months, of which 5 returned to their pre-injury level (10). Of the eight who did not return to pre-injury levels, four reported that they would have returned had they not graduated and a further patient returned to sport in a delayed fashion after recovery from an unrelated meniscal injury: the authors report an 'adjusted return to play' level of 10/13 (77%) (10)..

Combined procedures

a) Combined osteochondral allograft and meniscal allograft transplantation

Getgood et al studied the results of 48 combined OCA transplantation and meniscal allograft transplantation (MAT) (11). None underwent concomitant realignment procedures because either they had no malalignment or had previously been corrected. The indication was a chondral defect secondary to trauma or osteochondritis dissecans in 15 cases; trauma (tibial plateau fracture) in 12 cases, and osteoarthritis in 18 cases; the remaining three cases were revisions of previous OCA. Of the 48, 11 were considered failures and required removal or revision of either one or both (10 of the 11) grafts. Most of the failures (6 cases, of which one was an isolated OCA failure with intact meniscal allograft) were in OA patients and three were in tibial plateau fracture patients. All eight of the cases where both procedures failed were converted to TKA; the single OCA failure with intact meniscal allograft underwent revision of the OCA alone. Of the two remaining failures, one had been performed for a traumatic chondral lesion and required a revision OCA and meniscal allograft and the other, which had been performed for osteochondritis dissecans, failed through infection and ultimately required arthrodesis. The mean time to failure was 3.2 years and 2.7 years for MAT and OCA, respectively. The 5-year survivorship was 78 and 73 % for MAT and OCA respectively, and 69 and 68 % at 10 years.

Frank reported the results of a study comparing isolated OCA transplantation to OCA transplantation associated with MAT in a group of 100 patients with medial or lateral femoral condyle lesions (12). The survival in the combined procedure was good, with 86% survival at 5 years. Comparing patients with MAT to a matched group of patients without, rate of reoperation, rate of failure, and patient reported outcomes [Knee Injury and Osteoarthritis Outcome

Score (KOOS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and Short-Form 12 (SF-12)] were similar.

b) Allograft plus anterior cruciate ligament (ACL) reconstruction

Wang compared patients undergoing OCA with an intact ACL (n=50) to a matched group of patients who had undergone ACL reconstruction (n=25) at two years (12). At final follow-up, 11 (22%) of the ACL-intact patients and 8 (32%) of ACL reconstructed patients had undergone a reoperation, around half of which did not include removal or revision of either graft. Failure was reported in 8 (16%) ACL intact patients and 4 (16%) ACL reconstructed patients, giving survival of 90% and 79% at two and five years for ACL intact patients, and 96% and 85% for ACL reconstructed patients at the same time points (p=0.774). There were no significant differences between any of the patient reported outcome measures collected.

Likewise, Tirico et al conducted a matched retrospective study comparing 62 ACL intact patients to 31 ACL reconstructed patients at a mean follow-up of six years (14). Again, no significant differences were noted in graft survival (94.7% and 82.3% at five and ten years for the ACL intact group; 93.4% and 79.6% at the same time points for the ACL reconstructed group, p=0.979). Whilst there was a trend to better outcome scores in the ACL intact group, this did not reach statistical significance.

c) Allograft plus tibial osteotomy

Hsu et al analysed a series of 17 patients in their institutional database in whom a combined procedure of OCA transplantation and opening wedge osteotomy was performed. The minimum follow-up was 2 years and the mean allograft size was 8.7 cm2. The indication for osteotomy was where a large osteochondral defect was present in the presence of varus malalignment (15). Of the 17 patients, two (12%) failed, at 7.4 and 11.2 years, requiring TKA or UKA. At a mean follow-up of 8.1 years, the remaining 15 patients had intact allografts; 14 were contacted for their clinical outcome and of these, 13 reported satisfaction with their result with eight being very satisfied. Five patients (29%) had to have removal of their osteotomy plate. No post-operative complications were encountered and no other reoperations were necessary.

Factors predicting outcome following osteochondral allograft
Demographic factors

Typically, the age of the recipient is associated with inferior outcomes after cartilage restoration techniques, either due to reduced regenerative potential in older patients or due to a high proportion of patients having concurrent osteoarthritic change on presentation with cartilage defects (16). The degree of heterogeneity of the existing literature makes it difficult to quantify this effect in OCA transplantation. The

systematic review of Pareek et al reported a significant correlation between age at time of surgery and both failure and reoperation (17). Likewise the retrospective study of Nuelle et al reported that the mean age of failed OCA patients was statistically significantly higher when compared to those who had had successful outcomes (18). However, two studies, of Degen et al and Frank et al report favourable results in patients aged 40 years and older, with Frank reporting no difference in the rate of failure, and only a small difference in functional outcomes between older and younger patients (19, 20). Gender does not appear to affect outcome overall (17,20), and although the bulk of evidence suggests that patients of a healthy weight fare better (18), even in overweight patients, there is some evidence that the technique can be successful (21).

Indication

Overall, patients undergoing OCA for isolated, traumatic defects report better outcomes than those undergoing the procedure for osteochondritis dissecans or osteoarthritis (4). However, two large series exist of patients treated with OCA for osteochondritis dissecans in high volume centres, and both report excellent results in terms of long term survival (22, 23).

Lesion and graft factors

Unlike other methods of cartilage restoration, increased lesion size does not appear to predict poor outcomes of OCA. Tirico et al examined the outcomes of OCA based on size of lesion (measuring absolute size and size relative to the condyle), and found no difference in the survival of the graft or the clinical outcome, with statistically non-significant differences favouring larger lesions in terms of functional outcome (24). The use of multiple grafts to fill larger defects (the 'snowman technique', described above) results in good clinical outcomes but does appear to be associated with a higher rate of failure than the use of single grafts, however (25).

As with other forms of cartilage restoration, site of the lesion appears to predict outcome, with failures more often reported in patellofemoral grafts than in tibiofemoral grafts (6). Bipolar lesions have consistently produced poorer results in terms of graft survival. Meric et al reported survival of 64.1% at two years, noting that it was inferior to series of monopolar grafts (26). The authors suggested reasons for this – it may be mechanical, with the fixation of two opposing grafts being more challenging; it may be immunological due to the burden of immune reaction to two allografts; or it may be biological – whereby the presence of a kissing lesion may suggest the presence of osteoarthritis.

The condition of the graft is important in predicting rate of failure. Nuelle et al examined the effect of graft storage duration on outcome, finding more than double the failure rate in grafts stored for longer than 28 days (18).

Previous failed cartilage surgery

OCA may be particularly indicated in cases where

previous cartilage procedures have been performed – patients in this group fare particularly badly with other forms of cartilage restoration. Overall, as would be expected, the results of OCA in the setting of previous failed cartilage surgery are inferior to those reported in the primary setting. In Frank et all's study, patients who required further surgery had had a mean of 2.97 prior procedures compared to 2.19 in those who did not (27). This is not surprising; patients who have had multiple previous operations may be further down the course of the disease, may be more likely to have osteoarthritis, and are more susceptible to complications such as infection compared to those having surgery in a previously un-operated knee.

However, OCA may be the treatment of choice in this difficult group. Lamplot et al published a systematic review on the treatment of failed articular cartilage reconstructive techniques of the knee (28). As might be expected, most were medial femoral condyle lesions, and the most common previous procedure was microfracture and other marrow stimulation techniques (MST), comprising 71% of all cases. Of the 10 included studies, three examined the use of OCA; two of these were case series with no comparator group, and one compared primary OCA to OCA performed in the setting of a previous cartilage restoration technique. One series, a cohort of patients who had undergone a range of cartilage procedures, most of which (88%) had been MST, reported good results in the medium term, with graft survival of 82% at 10 years and 75% at 15; the other, which was a series of OCAs as revisions of failed OCAs, unsurprisingly reported worse results (overall failure rate of 39%). The comparative study gave similar results for OCA in the setting of previous procedures compared to primary OCA (87.4% survival at 10 years for primary OCA compared to 86% for patients with previous cartilage surgery – p=0.84). Table 3 shows the main factors affecting results after OCA transplantation. Table 4 shows factors related to better outcomes after OCA transplantation.

Table 3. Factors affecting results after OCA transplantation.
Active patients are significantly more likely to have a successful result than low activity patients
Patients with BMI <35 are four times more likely to have a successful result
Patients with transplanted grafts stored >28 days are significantly and 2.6 times more likely to have an unsuccessful result
There are no significant differences based on donor age
OCA = Osteochondral allograft: BMI = Body mass index

Table 4. Factors related to better outcomes after OCA transplantation.
Unipolar lesions
Patients younger than 30 years
Traumatic lesions
When the treatment is carried out within 12 months from the onset of symptoms
OCA = Osteochondral allograft

Conclusion

OCA is a viable and successful procedure for patients with large osteochondral defects of the knee. Younger, lighter, more active patients can expect the best result; other factors affecting outcome include the age of the graft, the number and site of lesions and the chronicity of the lesion. Patients can be advised that upwards of 80% of grafts can be expected to survive to 5 years, although there is a not insignificant rate of reoperation.

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