# Clinical Outcomes and Failure Rates of Osteochondral Allograft Transplantation in the Knee

## A Systematic Review

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**Background:** Cartilage lesions are a significant cause of morbidity and impaired knee function; however, cartilage repair procedures have failed to reproduce native cartilage to date. Thus, osteochondral allograft (OCA) transplantation represents a 1-step procedure to repair large chondral defects without the donor site morbidity of osteochondral autograft transplantation.

**Purpose:** To perform a systematic review of clinical outcomes and failure rates after OCA transplantation in the knee at a minimum mean 2 years' follow-up.

**Study Design:** Systematic review; Level of evidence, 4.

**Methods:** A systematic review of the literature regarding the existing evidence for clinical outcomes and failure rates of OCA transplantation in the knee joint was performed using the Cochrane Database of Systematic Reviews, the Cochrane Central Register of Controlled Trials, PubMed, and MEDLINE from studies published between 1980 and 2017. Inclusion criteria were as follows: clinical outcomes and failure rates of OCAs for the treatment of chondral defects in the knee joint, English language, mean follow-up of 2 years and minimum follow-up of 18 months, minimum study size of 20 patients, and human studies. The methodological quality of each study was assessed using a modified version of the Coleman methodology score.

**Results:** The systematic search identified 19 studies with a total of 1036 patients. The mean 5-year survival rate across the studies included in this review was 86.7% (range, 64.1%-100.0%), while the mean 10-year survival rate was 78.7% (range, 39.0%-93.0%). The mean survival rate was 72.8% at 15 years (range, 55.8%-84.0%) and 67.5% at 20 years (range, 66.0%-69.0%). The weighted mean patient age was 31.5 years (range, 10-82 years), and the weighted mean follow-up was 8.7 years (range, 2-32 years). The following outcome measures showed significant improvement from preoperatively to postoperatively: d'Aubigné-Postel, International Knee Documentation Committee, Knee Society function, and Lysholm scores. The weighted mean reoperation rate was 30.2% (range, 0%-63%). The weighted mean failure rate was 18.2% (range, 0%-31%). Of note, revision cases, patellar lesions, and bipolar lesions demonstrated worse survival rates.

**Conclusion:** Improved patient-reported outcomes can be expected after OCA transplantation, with a survival rate of 78.7% at 10 years. Revision cases, patellar lesions, and bipolar lesions were associated with worse survival rates; therefore, utilization of the most appropriate index cartilage restoration procedure and proper patient selection are key to improving results.

**Keywords:** osteochondral allograft transplantation; knee; cartilage; repair

Chondral lesions constitute a common finding during knee arthroscopic surgery, with a reported prevalence of up to 63% to 66% and localized cartilage defects found in 20%.[3,14] Importantly, if these lesions are not addressed in a timely manner, they have been reported to worsen over time and may progress to more diffuse osteoarthritis.[16] The treatment of focal chondral defects remains a challenge because cartilage repair procedures have failed to reproduce native cartilage to date.[9,11] Multiple surgical options have been developed for localized articular cartilage defects, including autologous chondrocyte implantation, subchondral marrow stimulation, osteochondral autograft transplantation, and osteochondral allograft (OCA) transplantation.[20]

One of the main advantages of using OCAs is the presence of metabolically active chondrocytes without concurrent donor site morbidity.[33] Moreover, OCA transplantation presents the advantage of having both viable hyaline cartilage and structural bone.[25] OCAs are avascular and aneural; therefore, they are immunoprivileged and most appropriate

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for allogenic transplantation.[2] Furthermore, OCA transplantation allows the resurfacing of large, full-thickness osteochondral defects, and it can restore the defect to an architecturally stable articular surface with mature hyaline cartilage.[26] However, OCAs are not without limitations. First, fresh or refrigerated allografts are expensive, with costs varying by anatomic specimen and region, among other factors. In 2016, Spalding et al reported that the average cost of a fresh OCA in the United States was approximately $11,000 ("Pricing of Allografts Worldwide: An Overview." Presented at 2016 ICRS Focus Meeting: The Future of Allograft Tissue in Europe, 2016). Further, other limitations of this technique include the risk of disease transmission, despite rigorous testing before implantation; size and contour matching to donors; and limited time from graft harvest to implantation.

In recent years, there has been an increasing use of OCAs in the treatment of focal cartilage defects. Therefore, the purpose of this study was to perform a systematic review of clinical outcomes and failure rates after OCA transplantation in the knee at a minimum mean follow-up of 2 years.

## METHODS

### Article Identification and Selection

This study was conducted in accordance with the 2009 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[31] A systematic review of the literature regarding the existing evidence for clinical outcomes and failure rates of OCA transplantation in the knee joint was performed using the Cochrane Database of Systematic Reviews, the Cochrane Central Register of Controlled Trials, PubMed (1980-2017), and MEDLINE (1980-2017). The queries were performed in March 2017. The literature search strategy included the following: Search (osteochondral[All Fields] AND ("allografts"[MeSH Terms] OR "allografts"[All Fields] OR "allograft"[All Fields]) AND ("transplantation"[Subheading] OR "transplantation"[All Fields] OR "transplantation"[MeSH Terms])) AND ("knee"[MeSH Terms] OR "knee"[All Fields] OR "knee joint"[MeSH Terms] OR ("knee"[All Fields] AND "joint"[All Fields]) OR "knee joint"[All Fields])). Systematic review registration was performed in April 2017 using the PROSPERO international prospective register of systematic reviews (registration No. CRD42017062331).

Inclusion criteria were as follows: clinical outcomes and failure rates of OCAs for the treatment of chondral defects in the knee joint, English language, mean follow-up of 2 years and minimum follow-up of 18 months for all patients in the cohort, minimum of 20 patients in the study, and human studies. We excluded cadaveric studies, animal studies, biomechanical reports, basic science articles, editorial articles, case reports, literature reviews, surgical technique descriptions, instructional courses, OCAs for tumors, studies comparing different techniques in which isolated OCA subgroups were not reported independently of combined OCA groups, and OCA studies in which OCA subgroups were not reported independently of first-time OCA groups.

Three independent reviewers (F.F., M.E.C., M.L.O.) performed a review of the abstracts from all identified articles. Full-text articles were obtained for review, if necessary, to allow for a further assessment of inclusion and exclusion criteria. Additionally, all references from the included studies were reviewed and reconciled to verify that no relevant articles were missing from the systematic review.

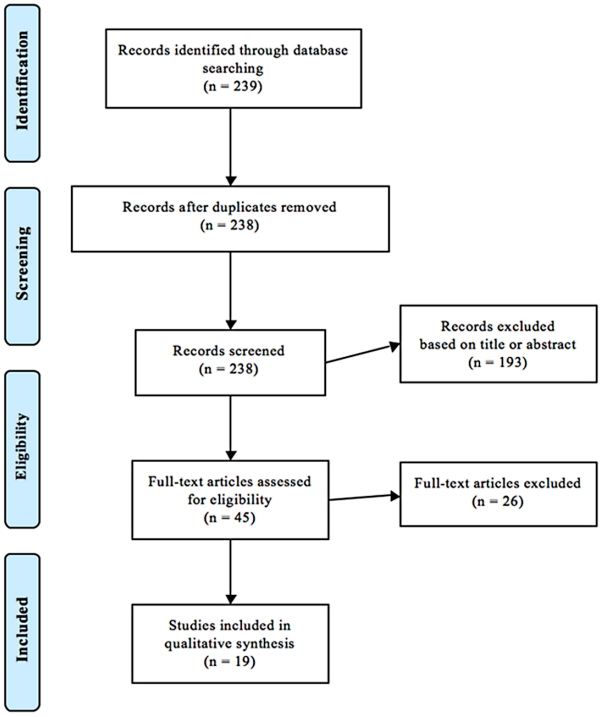


**Figure 1.** PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart of the study selection criteria.

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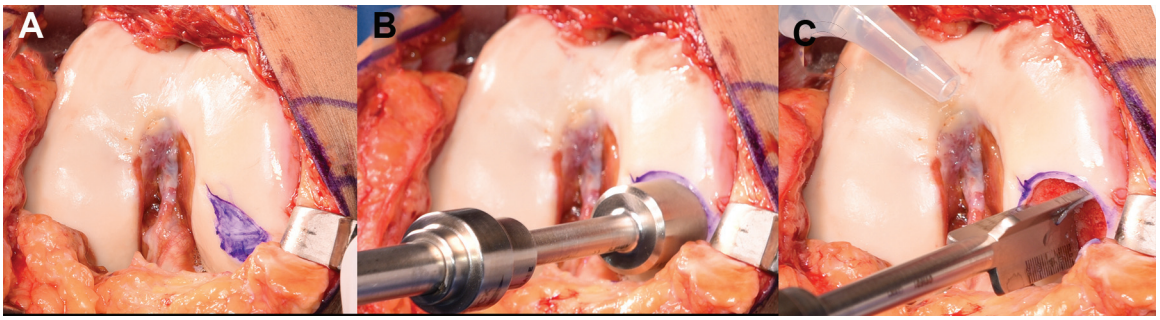


**Figure 2.** (A) The defect is identified and demarcated with a surgical pen. (B) A guide pin is placed in the center of the defect, and the edges of the defect are then scored with the recipient harvester. (C) The defect is then reamed until bleeding, healthy bone is encountered, with care not to exceed a maximum of 7 to 8 mm of overall bone depth. While reaming, copious amounts of irrigation fluid at room temperature are used to avoid heat necrosis.

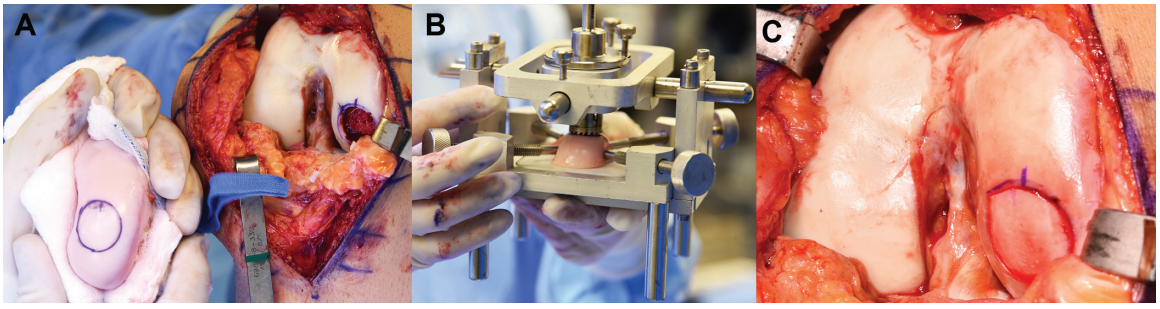


**Figure 3.** (A) The corresponding area on the allograft is outlined with methylene blue to match the dimensions of the patient's knee defect (the area to be replaced should match the area of the donor site). (B) The donor's condyle is then secured in the harvesting device to ensure precision, and a matching osteochondral plug is harvested. (C) Finally, the bone plug is then gently press-fitted into the socket to match the exact height of the surrounding articular cartilage.

### Data Collection and Processing

The level of evidence of the studies was assigned according to the classification system specified by Wright et al.[38] Data were abstracted from the full text of all eligible articles using standardized data collection forms. Abstracted and recorded data included patient demographics, the follow-up period, surgical techniques, and objective and subjective outcomes. For continuous variables (eg, age, follow-up, outcome scores), the means, SDs, interquartile ranges, and ranges were collected (if reported). Data were recorded into a custom spreadsheet using a modified information extraction table.[22]

Based on a preliminary survey of the most commonly used outcome scales, outcome scores were recorded for the following: modified d'Aubigné-Postel score, Lysholm knee score, International Knee Documentation Committee (IKDC) knee form, Knee injury and Osteoarthritis Outcome Score (KOOS), and Knee Society function (KS-F) score. If none of these scales were used, results were documented for the primary functional scale utilized in the study.

### Literature Quality Evaluation

Two reviewers (F.F., M.E.C.) used a modified version of the Coleman methodology score (mCMS) to assess the methodological quality of each study.[24] The 2-part mCMS grades cartilage-related studies based on 10 criteria. Part A includes the study size, mean follow-up, number of different surgical procedures, type of study, description of the surgical procedure, postoperative rehabilitation, participants' magnetic resonance imaging outcome, and participants' histological outcome. Part B includes the outcome criteria, procedure for assessing clinical outcomes, and description of the participant selection process. The maximum mCMS is 100, which indicates a study that largely avoids chance, biases, and confounding factors.

## RESULTS

### Study Selection

The systematic search performed using the previously mentioned keywords identified 19 studies after removing duplicates and applying exclusion criteria.** After a review of all references from the included studies, no additional studies met the inclusion criteria (Figure 1). Two independent reviewers (F.F., M.E.C.) performed a methodological quality assessment of the included articles. The mean

**References 1, 4, 6-8, 13, 17-21, 23, 26, 28-30, 32, 34, 35.

TABLE 1
Characteristics of Included Studies[a]

| Author | LOE | Type of Study | No. of Patients (Knees) | Age, Mean ± SD (Range), y | Male Sex, n (%) | Type of Graft | Location of Allograft | Cause | Follow-up, Mean ± SD (Range), y |
|---|---|---|---|---|---|---|---|---|---|
| Bayne et al[6] | IV | Retrospective | 28 (NA) | 62 (10-82) | 26 (67) | Fresh | MFC, LFC, PF, BP | Trauma, SONK, steroids, OCD | 4.9 (2-10) |
| Convery et al[13] | IV | Retrospective | 38 (NA) | 35 (15-68) | 11 (31) | Fresh | MFC, LFC, PF, BP | Trauma, OCD, AVN, OA | MFC: 3.75 (2-7); LFC: 4.75 (2.1-8.0); PF: 5 (2.1-8.0) |
| Aubin et al[4] | IV | Retrospective | 60 (NA) | 27 (15-47) | 48 (80) | Fresh | MFC, LFC | OCD, osteonecrosis, OA | 10 (4.8-21.6) |
| Gross et al[21] | II | Prospective | MFC/LFC: 60 (NA); TP: 65 (NA) | FC: 27 (15-47); TP: 43 (26-69) | FC: 48 (58); TP: 29 (45) | Fresh | MFC, LFC, TP | Trauma, OCD, AVN, OA | MFC/LFC: 10 (4.8-21.6); TP: 11.8 (2-24) |
| McCulloch et al[29] | IV | Retrospective | 25 (25) | 35 (17-49) | 18 (72) | Delayed fresh | MFC, LFC, multiple sites | Trauma, OA, OCD, AVN | 2.9 (2.0-5.6) |
| Emmerson et al[17] | IV | Retrospective | 63 (65) | 28.6 (15-54) | 45 (70.3) | Fresh | MFC, LFC | OCD | 7.7 (2-22) |
| Pearsall et al[32] | IV | Retrospective | 24 (NA) | 46 (16-71) | NA | Fresh/frozen | MFC, LFC, PF | Trauma, OCD | 3.1 (2.0-5.3) |
| LaPrade et al[26] | IV | Prospective | 23 (23) | 31 (18-47) | 13 (57) | Delayed fresh | MFC, LFC, multiple sites | OCD, idiopathic | 3 (1.9-4.0) |
| Gortz et al[18] | IV | Retrospective | 22 (28) | 24 (16-44) | 6 (27) | Delayed fresh | LFC, MFC, BP, multiple sites | Steroids | 5.6 (2.1-19.6) |
| Levy et al[28] | IV | Retrospective | 122 (129) | 32.8 (15-68) | NA (53) | Fresh | MFC, LFC, combined MFC and LFC | OCD, TCI, DCL, AVN, trauma | 13.5 (2.4-27.5) |
| Horton et al[23] | IV | Retrospective | 33 (33) | 37 (17-65) | NA (52) | Fresh | MFC, LFC, medial TP, lateral TP, patella, trochlea | OCD, TCI, OA, AVN, trauma, DCL | 10 (2.4-26.0) |
| Abrams et al[1] | IV | Retrospective | 32 (NA) | 35.0 ± 10.0 | 17 (53.1) | Cryopreserved before 2004, then fresh | MFC, LFC, combined MFC and LFC | Isolated ICRS grade 3 or 4 defect of the femoral condyle after meniscectomy | 4.4 (2-11) |
| Raz et al[34] | IV | Retrospective | 58 (NA) | 28 (11-48) | NA | Delayed fresh | MFC, LFC | Trauma, OCD | 21.8 (15-32) |
| Cameron et al[8] | IV | Retrospective | 28 (29) | 30.2 ± 10.6 (12-47) | NA (72.4) | Fresh | Trochlea | OCD, DCL, TCI, OA, trauma | 7.0 (2.1-19.9) |
| Gracitelli et al[19] | III | Retrospective | Primary OCA: NA (46); failed SMS: NA (46) | Primary OCA: 27.5 ± 11.8; failed SMS: 26.2 ± 10.4 | Primary OCA: 28 (60.9); failed SMS: 28 (60.9) | Fresh | MFC, LFC, patella, trochlea | AVN/OCD, DCL, TCI | Primary OCA: 7.8 ± 5.1; failed SMS: 11.3 ± 6.6 |
| Gracitelli et al[20] | IV | Retrospective | 27 (28) | 33.7 (14-64) | 13 (46.4) | Fresh | Patella | OCD, DCL, TCI, OA, trauma, AVN | 9.7 ± 7.5 |
| Meric et al[30] | IV | Retrospective | 46 (48) | 40 (15-66) | 21 (45.6) | Delayed fresh | BP, PF | TCI, OA, DCL, failed OCA, OCD, chronic subluxation, trauma | 7 (2.0-19.7) |
| Briggs et al[7] | IV | Retrospective | 55 (61) | 32.9 (15.7-67.8) | 30 (54.5) | Fresh | MFC, LFC, patella, trochlea, multiple sites | OCD, AVN, OA, TCI, DCL, trauma | 7.6 (1.9-22.6) |
| Sadr et al[35] | IV | Retrospective | 135 (149) | 21 (12-55) | 102 (75.8) | Delayed fresh | MFC, LFC, trochlea, multiple sites | OCD | 6.3 (1.9-16.8) |

[a]AVN, avascular necrosis; BP, bipolar; DCL, degenerative chondral lesion; FC, femoral condyle; ICRS, International Cartilage Repair Society; LFC, lateral femoral condyle; LOE, level of evidence; MFC, medial femoral condyle; NA, not available; OA, osteoarthritis; OCA, osteochondral allograft transplantation; OCD, osteochondritis dissecans; PF, patellofemoral; SMS, subchondral marrow stimulation; SONK, spontaneous osteonecrosis of the knee; TCI, traumatic chondral injury; TP, tibial plateau.

mCMS of the included studies was 35.8 (range, 19-46) of 100 points (see the Appendix, available in the online version of this article).[24]

## Study Characteristics and Demographics

There was 1 level II,[21] 1 level III,[19] and 17 level IV[††] studies that met the inclusion criteria. The methods of procurement and storage time included fresh (671 patients; 64.8%),[4,6-8,13,17,19-21,23,28] delayed fresh (309 patients; 29.8%),[18,26,29,30,34,35] cryopreserved/fresh (32 patients; 3.1%),[1] and fresh/frozen (24 patients; 2.3%) (for a general description of OCA, see Figures 2 and 3).[32] The 19 studies included in the analysis reported on a total of 1036 patients (range, 22-135 patients per study). The weighted mean patient age was 31.5 years (range, 10-82 years), and the weighted mean follow-up was 8.7 years (range, 2-32 years). The patient demographics, indications for OCA transplantation, and location of the allograft are described in detail in Table 1. Details regarding the lesion size, plug size, concomitant procedure, and prior surgical treatment are outlined in Table 2.

## Outcome Scores

Functional outcomes are listed in Table 3. Sixteen different outcome measures were recorded in the 19 studies. Twelve studies used the IKDC score.[‡‡] The aggregate mean preoperative IKDC score was 39.6, and the postoperative score was 69.7. The modified d'Aubigné-Postel score was

[††]References 1, 4, 6-8, 13, 17, 18, 20, 23, 26, 28-30, 32, 34, 35.

[‡‡]References 1, 7, 8, 18-20, 23, 26, 28-30, 32.

TABLE 2
Demographics of Patients Included in the Studies[a]

| Author | Concomitant Procedure, n (%); Most Common Procedure | Lesion Size, Mean ± SD (Range), $cm^2$ | Plug Size, Mean ± SD (Range), $cm^2$ | Prior Surgery, %; No. of Procedures per Patient, Mean (Range) |
|---|---|---|---|---|
| Bayne et al[6] | NA | NA | NA | NA |
| Convery et al[13] | NA | NA | NA | NA |
| Aubin et al[4] | 51 (85); HTO | NA | NA | NA |
| Gross et al[21] | FC: 10 (17); MAT 41 (68) and realignment; TP: 39 (60); MAT 38 (58) and realignment | NA | NA | FC: NA; TP: 83 |
| McCulloch et al[29] | 15 (63); MAT | Primary lesion: 5.2 (2.3-10.5); secondary lesion: 2.3 (0.8-4.0) | Primary lesion: 4 (1.8-7.0); secondary lesion: 2.3 (0.8-4.0) | 96; NA |
| Emmerson et al[17] | NA | NA | 7.5 | NA; 1.7 |
| Pearsall et al[32] | 42; HTO | 4.8 (0.2-22.0) | Refrigerated: 7 (NA); frozen: 8.2 (NA) | NA |
| LaPrade et al[26] | 11 (48); HTO | 4.8 (3.1-9.6) | NA | 87; 1.7 |
| Gortz et al[18] | NA | NA | 10.8 (5-19) | 50; 1.5 |
| Levy et al[28] | 10 (8.2); hardware removal | NA | 8.1 (1-27) | NA |
| Horton et al[23] | NA | NA | 9.5 (1.5-30.0) | 67; 3.8 |
| Abrams et al[1] | 32 (100); MAT | 4.7 ± 2.0 | NA | 71.9; 1.4 |
| Raz et al[34] | 36 (62); realignment osteotomy | NA | NA | NA |
| Cameron et al[8] | 11 (38); lateral release | NA | 6.1 ± 3.6 (2.3-20.0) | 89.7; 2.4[b] |
| Gracitelli et al[19] | NA | NA | Primary OCA: 8.2 ± 3.6; failed SMS: 8.0 ± 3.2 | NA |
| Gracitelli et al[20] | 10 (37); lateral release | NA | 10.1 (4-18) | 92.9; 3.2 |
| Meric et al[30] | 43 (NA); MAT | NA | 19.2 (4.2-41.0) | NA; 3.4 (1-8) |
| Briggs et al[7] | 14 (23); lateral release | NA | 9.6 (3.2-34.8) | NA |
| Sadr et al[35] | NA | NA | 7.3 (2.2-25.0) | 81; 1 (1-7) |

[a]FC, femoral condyle; HTO, high tibial osteotomy; MAT, meniscus allograft transplantation; NA, not available; OCA, osteochondral allograft transplantation; SMS, subchondral marrow stimulation; TP, tibial plateau.
[b]Some knees underwent more than 1 surgery.

utilized by 10 studies.[7,8,17-20,23,28,30,35] The aggregate mean preoperative modified d'Aubigné-Postel score was 12.4, and the postoperative score was 16.0. Nine of the 19 studies used the KS-F score,[7,8,18-20,23,28,30,35] and 3 used the Lysholm score.[1,21,29] The aggregate mean preoperative KS-F score was 66.3, and the postoperative score was 86.0. The aggregate mean preoperative Lysholm score was 42.8, and the postoperative score was 68.6.

## Imaging Analysis

Of the 19 articles reviewed, 7 investigated radiographic outcomes.[4,17,18,21,26,29,34] Of the studies that looked at radiographic union at a minimum 2 years postoperatively (mean, 5.4 years; range, 2.0-14.5 years), 83.1% (range, 71.0%-95.7%) of the patients had healing or good incorporation of the allograft to host bone.[4,17,18,26,29,34] Three studies qualified the degree of arthritis in the knee at a mean 9.3 years postoperatively (range, 3.3-14.5 years), with 47.8% (range, 41.0%-54.5%) of the patients having little to no radiographic evidence of arthritis.[4,17,21]

## Reoperation and Failure Rates

Failure rates were reported by 17 of 19 studies.[§§] The weighted mean reoperation rate was 30.2% (range, 0%-63%). Of note, several studies did not specify whether the reoperations were performed in the primary/revision group, and therefore, an analysis could not be performed. The weighted mean failure rate was 18.2% (range, 0%-31%) (Table 4). It is worth noting that different definitions of failure were used in the studies. Aubin et al[4] defined failure of the transplanted graft as when the patient required additional surgery including graft removal, unicompartmental arthroplasty, and total knee arthroplasty (TKA). Emmerson et al[17] defined failure as revision surgery for any reason (typically because of collapse and fragmentation of the osseous portion of the graft). Two studies[19,20] defined failure of the OCA as any reoperation resulting in removal of the graft, such as allograft revision and any form of arthroplasty. Gross et al[21] defined failure as allograft revision or conversion to

[§§]References 1, 4, 7, 8, 13, 17-20, 23, 26, 28-30, 32, 34, 35.

TABLE 3
Outcomes of Patients Included in the Studies[a]

| Author | Outcome Measure | Preoperative Value, Mean ± SD (Range) | Postoperative Value, Mean ± SD (Range) | *P* Value |
|---|---|---|---|---|
| Aubin et al[4] | Modified HSS | NA | 83 | NA |
| Gross et al[21] | HSS | NA | FC: 83; TP: 85.3 ± 11.0 | NA |
| | Lysholm | 47.5 ± 19.4 | 75.1 ± 18.6 | <.001 |
| | Tegner | NA | 7.3 ± 2.1 | NA |
| McCulloch et al[29] | Lysholm | 39 | 67 | <.0001 |
| | IKDC total | 29 | 58 | <.0001 |
| | KOOS symptoms | 46 | 64 | .001 |
| | KOOS pain | 43 | 73 | <.0001 |
| | KOOS ADL | 56 | 83 | <.0001 |
| | KOOS Sport/Rec | 18 | 46 | <.0001 |
| | KOOS QOL | 22 | 50 | <.0001 |
| | SF-12 | 36 | 40 | .014 |
| Emmerson et al[17] | Modified d'Aubigné-Postel | 13.0 ± 1.7 | 16.4 ± 2.0 | <.01 |
| Pearsall et al[32] | KS | 112.8 | 154.2 | NA |
| | IKDC total | 52 (NA) | 68.5 (NA) | <.03 |
| LaPrade et al[26] | IKDC total | 52 | 68.5 | <.03 |
| | Cincinnati total | 49.2 | 69 | <.02 |
| Gortz et al[18] | IKDC pain | 7.1 | 2.0 | <.001 |
| | IKDC function | 3.5 | 8.3 | .002 |
| | Modified d'Aubigné-Postel | 11.3 | 15.8 | <.001 |
| | KS-F | 60.0 | 85.7 | .005 |
| Levy et al[28] | Modified d'Aubigné-Postel | 12.2 ± 2.1 | 16.0 ± 2.2 | <.001 |
| | KS-F | 65.6 ± 15.5 | 82.5 ± 17.5 | .005 |
| | IKDC pain | 7.0 ± 1.9 | 3.8 ± 2.9 | <.001 |
| | IKDC function | 3.4 ± 1.3 | 7.2 ± 2.0 | <.001 |
| Horton et al[23] | IKDC total | NA | 70.5 (25-95) | NA |
| | KS-F | NA | 85 (60-100) | NA |
| | Modified d'Aubigné-Postel | NA | 14.8 (11-18) | NA |
| Abrams et al[1] | Lysholm | 41.9 ± 16.1 | 63.6 ± 24.1 | <.001 |
| | IKDC total | 32.9 ± 11.4 | 55.3 ± 23.6 | <.001 |
| | KOOS | 42.5 ± 11.7 | 62.7 ± 21.0 | <.001 |
| | SF-12 | 43.5 ± 5.6 | 46.6 ± 5.9 | .041 |
| Raz et al[34] | Modified HSS | NA | 87 (NA) | NA |
| Cameron et al[8] | Modified d'Aubigné-Postel | 13.0 ± 2.1 | 16.1 ± 2.2 | <.001 |
| | IKDC total | 38.5 ± 14.2 | 71.9 ± 24.6 | <.001 |
| | KS-F | 65.6 ± 19.1 | 85.2 ± 19.3 | <.001 |
| | UCLA | NA | 7.9 ± 2.2 | NA |
| Gracitelli et al[19] | Modified d'Aubigné-Postel | Primary OCA: 12.7; failed SMS: 12.9 | Primary OCA: 16.6; failed SMS: 16.2 | .46 |
| | IKDC total | Primary OCA: 36.9; failed SMS: 41.8 | Primary OCA: 78.2; failed SMS: 78.8 | .29 |
| | KS-F | Primary OCA: 68.9; failed SMS: 68.2 | Primary OCA: 89.5; failed SMS: 91.9 | .86 |
| | KOOS symptoms | Primary OCA: 57.8; failed SMS: 53.0 | Primary OCA: 87.8; failed SMS: 79.8 | .81 |
| | KOOS pain | Primary OCA: 65.6; failed SMS: 64.3 | Primary OCA: 89.9; failed SMS: 82.1 | .06 |
| | KOOS ADL | Primary OCA: 72.0; failed SMS: 70.9 | Primary OCA: 94.5; failed SMS: 87.1 | .11 |
| | KOOS Sport/Rec | Primary OCA: 37.5; failed SMS: 30.6 | Primary OCA: 92.7; failed SMS: 70.7 | .41 |
| | KOOS QOL | Primary OCA: 28.2; failed SMS: 25.0 | Primary OCA: 69.5; failed SMS: 64.6 | .92 |
| Gracitelli et al[20] | Modified d'Aubigné-Postel | 12.0 | 15.2 | .003 |
| | IKDC total | 36.5 | 66.5 | .003 |
| | KS-F | 64.6 | 80.5 | .003 |
| Meric et al[30] | IKDC pain | 7.5 ± 2.2 | 4.7 ± 3.1 | .021 |
| | IKDC function | 3.4 ± 1.5 | 7.0 ± 2.0 | .001 |
| | KS-F | 70.5 ± 16.5 | 84.1 ± 18.6 | .071 |
| | Modified d'Aubigné-Postel | 12.1 ± 2.0 | 16.1 ± 1.4 | <.001 |
| Briggs et al[7] | Modified d'Aubigné-Postel | 12.6 ± 1.9 | 16.5 ± 1.9 | <.001 |
| | IKDC total | 36.9 ± 9.7 | 80.4 ± 16.8 | <.001 |
| | KS-F | 66.5 ± 14.9 | 89.7 ± 21.4 | <.001 |
| | KOOS symptoms | 59.2 ± 17.4 | 84.9 ± 16.8 | <.001 |
| | KOOS pain | 57.9 ± 16.0 | 88.2 ± 17.5 | <.001 |
| | KOOS ADL | 63.7 ± 16.3 | 91.9 ± 16.0 | <.001 |
| | KOOS Sport/Rec | 38.3 ± 28.6 | 81.1 ± 11.1 | .001 |
| | KOOS QOL | 22.2 ± 17.0 | 65.5 ± 22.4 | <.001 |
| Sadr et al[35] | Modified d'Aubigné-Postel | 44.2 ± 17.5 | 82.3 ± 15.8 | <.001 |
| | KS-F | 72.3 ± 18.6 | 95.7 ± 9.6 | <.001 |

[a]ADL, activities of daily living; FC, femoral condyle; HSS, Hospital for Special Surgery; IKDC, International Knee Documentation Committee; KOOS, Knee injury and Osteoarthritis Outcome Score; KS, Knee Society; KS-F, Knee Society function; NA, not available; OCA, osteochondral allograft transplantation; QOL, quality of life; SF-12, Short Form–12; SMS, subchondral marrow stimulation; Sport/Rec, sport and recreation; TP, tibial plateau; UCLA, University of California, Los Angeles.

TABLE 4
Reoperations, Allograft Survivorship, and Failure Rates[a]

| Author | Reoperations | Allograft Survivorship | Failure, n (%) |
|---|---|---|---|
| Bayne et al[6] | 1 I+D | NA | NA |
| Convery et al[13] | NA | NA | MFC: UP, 3 (19); BP, 3 (100); LFC: UP, 1 (9); PF: 4 (33) |
| Aubin et al[4] | 3 OCA removal; 8 TKA; 1 OCA revision | 95% at 5 y, 85% at 10 y, 74% at 15 y | 12 (20) |
| Gross et al[21] | FC: 3 OCA removal, 9 TKA; TP: 21 TKA | NA | NA |
| McCulloch et al[29] | 1 OCA removal and then microfracture | NA | 1 (4) |
| Emmerson et al[17] | 5 OCA revision; 1 OCA; 1 TKA; 1 OCA revision and then TKA; 1 UKA; 1 OCA removal | 91% at 5 y, 76% at 10 y, 76% at 15 y | 10 (15.9) |
| Pearsall et al[32] | 9 TKA | NA | 9 (19) |
| LaPrade et al[26] | 3 HR; 1 AS and HR; 1 lateral patellotibial ligament reconstruction | NA | 0 (0) |
| Gortz et al[18] | 3 OCA revision or removal; 1 TKA; 1 DFO; 1 partial meniscectomy; 1 AS+D | 89% at NA | 5 (18) |
| Levy et al[28] | 15 OCA revision; 13 TKA; 3 UKA | 89% at 5 y, 82% at 10 y, 74% at 15 y, 66% at 20 y | 31 (24) |
| Horton et al[23] | 12 TKA; 1 UKA | 79% at 5 y, 61% at 10 y | 13 (39) |
| Abrams et al[1] | 7 MAT debridement; 6 chondroplasty; 2 loose body removal; 1 lateral release; 1 synovectomy | NA | 8 (25) |
| Raz et al[34] | 2 HR; 1 HR + partial OCA removal; 2 corrective osteotomy | 91% at 10 y, 84% at 15 y, 69% at 20 y, 59% at 25 y | 13 (22) |
| Cameron et al[8] | 1 MUA; 1 AS+D and partial meniscectomy; 1 scar tissue removal; 1 chondral flap debridement and loose body removal; 1 D, chondroplasty of patella/LFC, and synovectomy; 1 TKA | 100% at 5 y, 91.7% at 10 y | 6 (21.4) |
| Gracitelli et al[19] | Primary OCA[b]: 6 AS+D or loose body removal; 1 meniscal repair; 1 lateral release; 2 OCA revision; 3 TKA<br>Failed SMS: 15 AS+D or loose body removal; 3 meniscectomy; 3 meniscal repair; 1 extensor mechanism realignment; 2 lateral release; 1 osteotomy; 3 HR; 3 OCA revision; 4 TKA | Primary OCA: 87.4% at 10 y; failed SMS: 86% at 10 y | Primary OCA[b]: 5 (11); failed SMS: 7 (15) |
| Gracitelli et al[20] | 9 AS+D[b]; 6 HR; 6 TKA; 1 patellectomy; 1 OCA revision; 1 ACLR; 1 PF realignment; 1 manipulation; 1 loose body removal | 78.1% at 5 y, 78% at 10 y, 55.8% at 15 y | 8 (28.6) |
| Meric et al[30] | 14 TKA; 1 UKA; 1 PF arthroplasty; 6 AS+D; 1 DFO; 1 HR; 3 OCA revision; 2 arthrodesis; 1 patellectomy | 64.1% at 5 y, 39% at 10 y | 22 (45.8) |
| Briggs et al[7] | 8 TKA; 2 OCA revision; 1 patellectomy | 89.5% at 5 y, 74.7% at 10 y | 11 (18) |
| Sadr et al[35] | 12 AS+D[b]; 9 AS; 5 meniscal repair; 4 loose body removal; 3 synovectomy; 3 DFO; 2 HR; 1 ORIF; 1 osteochondral autograft transplantation | 95% at 5 y, 93% at 10 y | 12 (8) |

[a]ACLR, anterior cruciate ligament reconstruction; AS, arthroscopic surgery; BP, bipolar; D, debridement; DFO, distal femoral osteotomy; FC, femoral condyle; HR, hardware removal; I+D, incision and drainage; LFC, lateral femoral condyle; MAT, meniscus allograft transplantation; MFC, medial femoral condyle; MUA, manipulation under anesthesia; NA, not available; OCA, osteochondral allograft (transplantation); ORIF, open reduction internal fixation; PF, patellofemoral; SMS, subchondral marrow stimulation; TKA, total knee arthroplasty; TP, tibial plateau; UKA, unicompartmental knee arthroplasty; UP, unipolar.

[b]Some knees underwent more than 1 surgery.

TKA. Horton et al[23] defined failure as conversion to partial knee arthroplasty or TKA. Meric et al[30] defined failure as conversion to arthroplasty, arthrodesis, and patellectomy. Abrams et al[1] defined failure by patients' symptoms of such a degree that they chose to undergo additional arthroscopic surgery. Cameron et al[8] defined failure as revision of the graft or conversion to arthroplasty. Briggs et al[7] defined failure as revision of the OCA or conversion to arthroplasty. Sadr et al[35] defined failure of the allograft as any procedure that included removal of the allograft, such as revision of the allograft, unicompartmental knee arthroplasty, or TKA.

### Kaplan-Meier Survival Curve

Twelve studies performed Kaplan-Meier survival analysis for fresh OCAs (Table 4).[||||] The mean 5-year survival rate across the studies included in the analysis was 86.7% (range, 64.1%-100.0%),[4,7,8,17,20,23,28,30,35] while the mean 10-year survival rate was 78.7% (range, 39.0%-93.0%).[¶¶] The mean survival rate at 15 years was 72.8% (range, 55.8%-84.0%)[4,17,20,28,34] and, subsequently, 67.5% at 20 years (range, 66.0%-69.0%).[28,34]

## DISCUSSION

The main findings of this study were that OCA transplantation of the knee yielded fair to good functional outcomes and good survival rates at short- to medium-term follow-up. The mean 5-year survival rate across the studies included in this review was 86.7%, while the mean 10-year survival rate was 78.7%. Meanwhile, the survival rates were 72.8% at 15 years and, subsequently, 67.5% at 20 years.

While the reported outcome measures were heterogeneous, all studies that utilized preoperative and postoperative modified d'Aubigné-Postel, KS-F, IKDC, and Lysholm scores for patients' outcome evaluations reported a significant improvement at final follow-up.[##] It has been widely reported that a large number of variables affect the outcomes after fresh OCA transplantation. One of the important factors is the location of the OCAs (ie, femoral condyle vs tibial plateau, trochlea, and patella).[6,12] Other variables include patient age, the length of follow-up, the size of the lesion treated, the use of concomitant procedures, and the number of previous procedures. Furthermore, some of the included studies involved concomitant injuries and/or procedures (such as high tibial osteotomy, meniscal transplant, or lateral retinacular release), which may have influenced outcomes. Alignment is an important factor when dealing with cartilage problems in the knee. Varus or valgus malalignment increases joint loading in the medial and lateral compartment, respectively, and a concurrent osteotomy procedure should be considered in patients with focal cartilage defects requiring an OCA procedure. Few of the studies focused on osteochondral procedures in patients with malalignment, and therefore, this was not able to be analyzed further.

Good survival rates at short to medium term (5-10 years) were reported in the included studies. However, OCA transplantation was associated with considerable reoperation (30.2%) and failure (18.2%) rates at final follow-up. Levy et al[28] and Emmerson et al[17] reported 5- and 10-year survival rates for OCAs to the femoral condyle to be 89% and 82%, respectively. Certain factors were associated with inferior survival rates in the included studies. Meric et al[30] reported lower survivorship for bipolar osteochondral defects (64.1% at 5 years and 39% at 10 years), while Gracitelli et al[20] reported worse survivorship for patellar OCAs (78.1% at 5 years, 78% at 10 years, and 55.8% at 15 years). The majority of failures (42.6%) were converted to arthroplasty, while the remainder necessitated subsequent interventions to treat graft failure. These results demonstrated higher failure and reoperation rates than for alternative cartilage restoration methods.[27] Reoperation and failure rates were higher for patellofemoral OCAs (28.6%) and bipolar chondral defects (45.8%).[20,30]

OCA transplantation was initially performed within 7 days after the death of the donor to optimize chondrocyte viability. However, increasing safety concerns about disease transmission led to a minimum of 14 days required for microbiological and serological testing of donor specimens. In addition, allografts are now hypothermically stored in culture medium at 4°C as opposed to frozen or cryopreserved grafts. Interestingly, it has been reported that allografts generally should be implanted by 28 days after harvest because studies have demonstrated a substantial decrease in chondrocyte viability after this period of time.[5,37] Therefore, there is a small window of time (15-28 days) for implantation of the allograft. In our review, fresh grafts were used in 64.8% of the cases, delayed fresh grafts in 29.8%, cryopreserved/fresh grafts in 3.1%, and fresh/frozen in 2.3%. In this regard, 2 different groups reported that there was no correlation between graft storage time and functional scores when the allograft was stored at –4°C for 4 to 6 weeks.[15,36] Current recommendations based on previous basic science and clinical studies advise 42 days as the maximum storage period for a fresh allograft, and ideally, implantation should be performed by 24 to 28 days.[10] Unfortunately, because of the lack of randomized clinical controlled trials, a comparison of outcomes of different storage protocols could not be performed.

The authors acknowledge some limitations to the present study. First, there was heterogeneity in the reporting of subjective and objective outcomes. Furthermore, some of the included studies involved concomitant injuries and/or procedures, which may have influenced outcomes. As with all systematic reviews, it is possible that relevant articles or patient populations were not identified with our search criteria. In addition, the quality of the included research was a limitation. We identified only 1 level II study and 1 level III study, while 17 level IV case series were used in the analysis. The use of varying scoring systems also limited our ability to compare studies.

## CONCLUSION

Improved patient-reported outcomes can be expected after OCA transplantation, with a survival rate of 78.7% at 10 years. However, this procedure is associated with considerable reoperation (30.2%) and failure (18.2%) rates over time. Revision cases, patellar lesions, and bipolar lesions were associated with worse survival rates; therefore, proper patient selection is key to improving results.

[||||]References 4, 7, 8, 17-20, 23, 28, 30, 34, 35.
[¶¶]References 4, 7, 8, 17, 19, 20, 23, 28, 30, 34, 35.
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