Loose Body Versus Trochlear Biopsy Matrix-Induced Autologous Chondrocyte Implantation (MACI) MOCART Scores and IKDC Reported Outcomes in Pediatric Patients

Zachary Hill, MD,* Connor Delman, MD,* Trevor Shelton, MD,† Wyatt Vander Voort, MD,* and Brian Haus, MD‡

Background: Matrix-induced autologous chondrocyte implantation (MACI) has shown promising results in the treatment of osteochondral lesions of the knee. A recent study showed similar viability comparing chondrocytes harvested from the intercondylar notch compared to those harvested from osteochondral loose bodies. However, there is limited evidence assessing how these different biopsies perform clinically. The goal of this study was to compare both radiographic and patient-reported outcomes in patients with patellar and femoral osteochondral lesions treated with MACI using either a standard intercondylar notch biopsy or an osteochondral loose body biopsy.

Methods: A retrospective study was performed on all pediatric autologous chondrocyte implantation procedures performed from 2014 to 2017 at a single institution. Patients were divided into 2 groups: one group had cartilage derived from a standard intercondylar notch biopsy (n = 9) and the other group had cartilage derived from an osteochondral loose body found within the ipsilateral knee (n = 10). At a minimum of 1-year post-implantation, magnetic resonance imagings of the operative knee were performed and the Magnetic Resonance Observation of Cartilage Repair Tissue Knee Score (MOCART 2.0) knee score was used to assess the integrity and quality of the cartilage repair tissue. Interclass correlation coefficients were calculated between the 2 groups. International Knee Documentation Committee (IKDC) outcome scores were determined at a minimum 2 years post-implantation.

Results: The interclass correlation coefficient between three independent examiners for the MOCART scoring was excellent at 0.94. With regards to the MOCART score, the loose body group had an insignificant 17-point lower median score at 63 [interquartile range (IQR): 58 to 89] compared to the intercondylar group at 80 (IQR: 65 to 90) (P = 0.15). There was no difference in IKDC scores with the loose body group having a median score of 82 (IQR: 65 to 95) and the intercondylar group having a median score of 84 (IQR: 53 to 99) (P = 0.90).

Conclusion: These results demonstrate that osteochondral loose bodies can be used as viable harvest site in MACI procedures with no difference in functional and radiographic outcomes at 2 years postimplantation. This may limit both short and long-term donor site morbidity.

Level of Evidence: Level III—retrospective comparative study.

Key Words: sports medicine, knee, arthroscopy, autologous chondrocyte implantation, cartilage, osteochondritis dissecans (J Pediatr Orthop 2023;43:e25–e29)

Autologous chondrocyte implantation (ACI) has evolved since being introduced in a rabbit model in 1968.1 ACI was first trialed in humans using periosteal patches to deliver chondrocytes to osteochondral defects with the periosteum serving as a biological frame for chondrocyte implantation. Problems with this technique included extensive exposure to perform periosteum retrieval, tedious suturing of the periosteal patch into the defect, and periosteal patch hypertrophy/overgrowth phenomenon.2

Second and third generation ACI procedures, including matrix-induced autologous chondrocyte implantation (MACI), have gained popularity by addressing the shortcomings of prior ACI techniques. In second generation ACI, a synthetic membrane is used with chondrocytes implanted evenly throughout a matrix to improve contact with the irregular subchondral bed formed by preparation of the defect.3 Third generation ACI consists of biodegradable scaffolds that provide 3-dimensional structural support for chondrocytes implanted into the defect.4,5 These advancements improved cell distribution, minimized operative time, and obviated the need to suture the graft with the use of fibrin glue.6

The intercondylar notch and trochlea of the femur are known viable sources of donor tissue and have remained the preferred site for harvesting chondrocytes.
McCarthy and colleagues recently reported minimal joint morbidity associated with biopsies taken from the intercondylar notch and trochlea 5 years postoperatively. However, long-term Lysholm knee scores were significantly better in the trochlear biopsy group. Despite the common use of standard biopsy sites within the knee, limited studies have evaluated donor site morbidity in the context of ACL. Given the potential for functional deficits associated with these biopsy sites, studies have evaluated the functionality and viability of alternative donor sites.

Several studies have assessed the viability of osteochondral loose bodies associated with acute osteochondral lesions (OCLs). Osteochondral loose bodies result from traumatic OCLs and are comprised of both cartilage and subchondral bone. Pascual-Garrido et al evaluated the viability of chondrocytes harvested from loose osteochondral fragments of injured talar articular cartilage and subchondral bone. This patient cohort was the same used by Robinson et al for evaluation of the viability of osteochondral loose bodies. Of the 20 patients in the traditional intercondylar group, 4 patients were excluded due to having talar OCLs, 1 patient was excluded for a congenital osseous abnormality, 3 patients were excluded as they did not have postoperative imaging, and 3 patients were unable to be contacted for 2-year outcome scores. In total, 9 patients were included in the standard intercondylar biopsy group. Of the 12 patients in the osteochondral loose body group, 2 patients did not have postoperative imaging. In total, 10 patients were included in the osteochondral loose body group.

An MRI was scheduled for patients at 6, 12, and 18 months postoperatively. Only imaging obtained after 1 year was used for determining the Magnetic Resonance Observation of Cartilage Repair Tissue Knee Score (MOCART 2.0). Three independent observers who were blinded to patient treatment evaluated each patient’s MRI and determined the MOCART 2.0 scores on a scale of 0 to 100. The observers included 2 senior orthopaedic surgery residents and an attending orthopaedic surgeon who were also contributing authors in the study. The International Knee Documentation Committee (IKDC) Subjective Knee Forms were collected at 12, 18, 24, and 36 months postoperatively. Only IKDC forms collected after 24 months were included in the study.

Basic demographic data was also collected including patient sex, age, laterality, location of the defect (medial condyle, lateral condyle, patella), date of biopsy, date of implantation, concomitant injuries, and additional procedures.

**METHODS**

This study was approved by an Institutional Review Board (IRB# 1079773-6) and looked at all pediatric patients with knee OCLs who underwent MACI by a single surgeon at a single institution from 2014 to 2017. The diagnosis of an OCL was identified on MRI and subsequently evaluated with a standard diagnostic arthroscopy. The inclusion criteria were patients below 18 years of age at the time of biopsy with full-thickness, well circumscribed grade 4 cartilage lesions involving >2 cm² of the articular surface who also had an MRI at a minimum of 1-year postoperatively and patient-reported outcome scores at a minimum of 1-year postoperatively. Only lesions that were identified within the knee were included in the study. Patients included in the study had either isolated osteochondritis dissecans lesions or traumatic osteochondral defects associated with free floating osteochondral loose bodies. Patients with congenital cartilage defects or other osseous abnormalities were excluded from the study. The patients were divided into 2 cohorts: (1) the control group which consisted of patients without loose bodies identified during arthroscopy who underwent a standard biopsy from the intercondylar notch and (2) the osteochondral loose body group who underwent chondrocyte harvesting from the loose osteochondral fragment. In the standard intercondylar group, biopsies were obtained with subchondral bone attached. All biopsies were sent to the same institution for inoculation and growth prior to second stage implantation (Vericel, Cambridge, MA).

In total, 20 patients with traditional intercondylar notch biopsies and 12 patients with osteochondral loose body biopsies were identified. This patient cohort was the same used by Robinson et al for evaluation of the viability of osteochondral loose bodies. Of the 20 patients in the traditional intercondylar group, 4 patients were excluded due to having talar OCLs, 1 patient was excluded for a congenital osseous abnormality, 3 patients were excluded as they did not have postoperative imaging, and 3 patients were unable to be contacted for 2-year outcome scores. In total, 9 patients were included in the standard intercondylar biopsy group. Of the 12 patients in the osteochondral loose body group, 2 patients did not have postoperative imaging. In total, 10 patients were included in the osteochondral loose body group.

Statistics

Data were recorded and analyzed using statistical software (JMP Pro 15.0.0, http://www.jmp.com; SAS, Cary, NC). Differences in MOCART and IKDC scores between groups were determined using the Wilcoxon rank-sums test and the data reported using the median and interquartile range. A χ² test was used to determine differences between categorical data (i.e. sex, laterality, etc.). Categorical data were reported using n (%). Significance was set at a P-value < 0.05.
An intraclass correlation coefficient (ICC) analysis was performed to determine the reproducibility (i.e., interobserver) of the MOCART measurements using a 2-factor analysis of variance. Three observers independently performed the MOCART measurements on all patients in the study. As previously described, an ICC value > 0.9 indicated excellent agreement while a value from 0.75 to 0.90 indicated good agreement.16

RESULTS

Of the 9 patients identified in the control group (biopsies harvested from the intercondylar notch), 4 were male and 5 were female. The intercondylar biopsy group included 7 osteochondritis dissecans lesions and 2 traumatic OCLs. Of the 10 patients with biopsies harvested from osteochondral loose bodies, 7 were male and 3 were female. The age in years at the time of biopsy was 14 ± 2 for the loose body group and 13.6 ± 4 for the intercondylar group with the time from biopsy to surgery (in months) averaging 5.4 ± 5 and 3 ± 3, respectively (Table 1). There was no difference in laterality, location, or concomitant injuries between the 2 groups. The intercondylar notch consisted of 6 lesions on the lateral femoral condyle, 1 lesion on the medial femoral condyle, and 2 lesions on the patella. A concomitant medial patellofemoral ligament reconstruction was performed in 3 patients and an ACL reconstruction in an additional 3 patients which were performed at the time of MACI implantation. The loose body group consisted of 7 lesions on the lateral femoral condyle and 3 lesions on the medial femoral condyle. A concomitant medial patellofemoral ligament reconstruction was performed in 6 patients and an ACL reconstruction in 1 patient.

The MOCART scoring ICC was 0.94 for 3 independent observers indicating good to excellent agreement. MOCART scores between the 2 groups were not significantly different (P = 0.151) with a median of 80 [interquartile range (IQR) = 65 to 90] in the intercondylar biopsy group and a median of 63 (IQR: 58 to 89) in the osteochondral loose body group. There was also no significant difference (P = 0.902) in IKDC scores with a median score of 84 (IQR: 53 to 99) in the intercondylar biopsy group and a median score of 82 (IQR: 65 to 95) in the osteochondral loose body group and Table 2.

DISCUSSION

The treatment of femoral and patellar OCLs has challenged orthopaedic surgeons for many years given their inherent impaired healing potential. In 1743, William Hunter highlighted that “ulcerated cartilage is a troublesome thing, once destroyed it is not repaired.”17 Although many years later it remains true that there is limited biological regenerative capacity to restore articular cartilage, ACI has shown promise in the treatment of full-thickness cartilage defects larger than 2 cm² in younger patients.18–21 ACI has demonstrated successful graft incorporation with histology closely matching native hyaline cartilage.22,23 Young patients have comparable, if not improved, knee functional outcome scores and 10-year survivorship approaching 90% when comparing ACI to other surgical techniques.20,24–28 Although studies corroborate the success of ACI, donor site morbidity remains a concern. Harvesting chondrocytes from the osteochondral loose body aims to circumvent donor site morbidity while maintaining chondrocyte viability, identity, and yield.11 However, there is a paucity of data evaluating radiographic and functional outcomes to support the use of osteochondral loose bodies as biopsy sites for ACI procedures. The most important findings of this study are as follows: (1) there is no significant difference in radiographic outcomes using MOCART 2.0 scores at 1-year postoperatively and (2) no significant difference in patient-reported outcomes using IKDC scores at 2 years postoperatively in patients with knee OCDs treated with the MACI technique using chondrocytes harvested from loose osteochondral bodies compared to the intercondylar notch. Articular cartilage is a complex entity with poor regenerative capacity. Its nutrition is intimately balanced with underlying subchondral bone and synovial fluid.29,30 This relationship explains why intra-articular osteochondral loose bodies retain their viability when separated

### TABLE 1. Basic Demographics

| Location                          | Intercondylar Biopsy (N = 9), n (%) | Osteochondral Loose Body (N = 10), n (%) | P      |
|----------------------------------|------------------------------------|-----------------------------------------|--------|
| Age [mean (SD)]                  | 13.6 ± 4                           | 14 ± 2                                  | 1.000  |
| Sex                              |                                    |                                         |        |
| Males                            | 4 (44)                             | 7 (70)                                  | 0.258  |
| Females                          | 5 (56)                             | 3 (30)                                  |        |
| Laterality                       |                                    |                                         |        |
| Right                            | 5 (56)                             | 4 (40)                                  | 0.497  |
| Left                             | 4 (44)                             | 6 (60)                                  |        |
| Lateral femoral condyle          | 6 (67)                             | 7 (70)                                  | 0.146  |
| Medial femoral condyle           | 1 (11)                             | 3 (30)                                  |        |
| Patella                          | 2 (22)                             | 0                                       |        |
| Time from biopsy to surgery      | 3 ± 3 (1-15)                       | 5.4 ± 5 (1.5-15)                        | 0.240  |
| with SD (range) (mo)             |                                    |                                         |        |
| Concomitant MPFL reconstruction  | 3 (33)                             | 6 (60)                                  | 0.242  |
| Concomitant ACL reconstruction   | 3 (33)                             | 1 (10)                                  | 0.206  |

Significance set to P < 0.05.
Percentages in parenthesis unless otherwise noted.
ACL indicates anterior cruciate ligament; MPFL, medial patellofemoral ligament.

### TABLE 2. Results

|                      | Intercondylar Biopsy (N = 9) | Osteochondral Loose Body (N = 10) | P       |
|----------------------|------------------------------|-----------------------------------|---------|
| MOCART score (IQR)   | 80 (65-90)                   | 63 (58-89)                        | 0.151   |
| IKDC (IQR)           | 84 (53-99)                   | 82 (65-95)                        | 0.902   |

Significance set to P < 0.05.
IKDC indicates International Knee Documentation Committee Subjective Knee Form; IQR, interquartile range; MOCART, Magnetic Resonance Observation of Cartilage Repair Tissue Knee Score and Atlas.
The assessment of OCD lesions. Utilizing osteochondral studies where the MOCART 2.0 scoring system was used in obviating the need for a postimplantation arthroscopy or between harvest sites. The MOCART scoring system serves as outcomes as prior studies showed comparable viability between the intercondylar notch group. Likewise, Reddy and colleagues looked at 11 patients with previous asymptomatic knees who underwent autologous biopsies from non-weightbearing portions of the femur for OATS procedures to the ipsilateral talus. Four of the 11 patients had poor Lysholm outcome scores at a mean follow-up of 47 months further suggesting the potential morbidity of intercondylar harvesting procedures.

Although previous studies confirm the viability of osteochondral loose bodies as a harvest site for MACI procedures. McCarthy et al reported on 23 patients who underwent ACI for chondral defects in the ankle and hip using chondral biopsies from the intercondylar notch or trochlea. The biopsies were performed in native knees without a history of prior injury or surgical treatment. They found a significant decrease in Lysholm scores, particularly from the intercondylar notch group. Likewise, Reddy and colleagues looked at 11 patients with previous asymptomatic knees who underwent autologous biopsies from non-weightbearing portions of the femur for OATS procedures to the ipsilateral talus. Four of the 11 patients had poor Lysholm outcome scores at a mean follow-up of 47 months further suggesting the potential morbidity of intercondylar harvesting procedures.

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