Cartilage Restoration of the Patella Using ProChondrix® Osteochondral Allograft: A Case Report

Evan D. Boyd, MD[1]; Michael S. Barnum, BS[2]; James R. Slauterbeck, MD[1]

[1]Department of Orthopaedics and Rehabilitation, University of Vermont, Burlington, Vermont

[2]College of Medicine, University of Vermont, Burlington, Vermont

Corresponding Author Evan Boyd, MD. Department of Orthopaedics and Rehabilitation, University of Vermont, Stafford Hall, Room 436, 95 Carrigan Drive, Burlington, VT 05405-0084 (email: evan.boyd@uvmhealth.org).

Funding The authors received no financial support for the research, authorship, and publication of this article.

Conflict of Interest James R. Slauterbeck, MD, is a research consultant for the ProChondrix® Osteochondral Allograft through Allosource®. All other authors declare no conflict of interest.

Acknowledgements We would like to acknowledge Matthew G. Geeslin, MD, for his assistance in interpretation of radiographic studies.

Informed Consent The patient was informed that the data concerning their case would be submitted for publication, and they provided verbal consent.

ABSTRACT

Articular cartilage injuries are challenging to treat because of the limited healing potential of articular cartilage. Various cartilage restoration procedures have been developed to restore the protective role of articular cartilage and to delay or prevent additional damage to the articular surface. ProChondrix® Cartilage Restoration Matrix is a cryopreserved hyaline cartilage allograft with viable chondrocytes and growth factors necessary to promote its incorporation and viability. We describe a 19-year-old man with a well-contained, full-thickness cartilage defect on his patella. He subsequently underwent cartilage restoration with a ProChondrix® osteochondral allograft. At 1-year postoperatively, the patient had both clinical and radiographic evidence of an excellent outcome and had returned to sport.

Keywords: Fractures, Cartilage, Articular

INTRODUCTION

For patients sustaining articular cartilage injuries within the knee joint, various cartilage repair techniques are available to prevent or prolong the need for a total joint replacement. Traditional treatment strategies include microfracture, osteochondral autograft (OATS), osteochondral allograft (OCA), and autologous chondrocyte implantation (ACI).[1] Selecting the appropriate treatment strategy for each patient relies on the patient's age, activity level, willingness or hesitancy to undergo multiple procedures; size and location of the defect; and whether this is the initial procedure or a procedure following a failed operation.

Microfracture is considered first-line treatment for small cartilage lesions less than 2 cm because of its technical ease, low cost, minimally invasive nature, and low morbidity.[2] However, microfracture biopsies have shown that the new filling cartilage is predominately fibrocartilage and only 10.0% hyaline cartilage.[3] OATS type procedures fill cartilage defects with mature, hyaline articular cartilage immediately. This procedure is not recommended in defects greater than 4 cm, and donor site morbidity can be problematic.[4] OCA has emerged as a successful treatment option, with graft survivorship approaching 80.0% at 10 years.[5] OCA remains limited by cadaver availability, shelf life, and disease transmission.[6] ACI has shown promising results, with survivorship up to 71.0% at 10 years and 75.0% of patients showing improvement in function.[7] The major limitations of ACI include the high cost and the need for a two-stage operation.

Despite the favorable results observed with these traditional treatment options, cartilage restoration techniques continue to evolve. One of the recently developed technologies includes the ProChondrix® Cartilage Restoration Matrix (AlloSource; Centennial, CO). This matrix is a cryopreserved hyaline cartilage allograft prepared on a thin, semi-flexible platform of bone, with viable chondrocytes and growth factors necessary to promote its incorporation and viability. ProChondrix® has been shown to have 87.5% chondrocyte viability at 35 days when utilizing conventional cryopreservation techniques.[8] When using a proprietary cryopreservation method designed by AlloSource® (Centennial, CO), ProChondrix® was found to have a viability of 95.0% at 2 years.[9] This is longer than the current shelf life for conventional osteochondral allografts, which is 28 days postmortem when stored at 4˚C.[10] To our knowledge, no studies have been published on the use and outcomes of this implant in human patients.

Figure 1. *Sagittal A) and axial B) magnetic resonance images of the right knee obtained after initial injury showing an approximately 1-cm articular defect of the patella and an articular loose body that can be seen posterior to the posterior cruciate ligament.*

CASE REPORT

A 19-year-old man presented after sustaining a traumatic patella dislocation of his right knee when playing soccer. He had a history of contralateral patella dislocation. Findings during patellofemoral examination showed mild tenderness over the medial patellofemoral ligament, a medial and lateral patellar glide of 30.0%, 5° of negative patellar tilt, and a seated Q angle of 25°. He was very apprehensive during examination maneuvers. Significant radiographic findings consisted of a small effusion and an Insall-Salvati ratio of 1.4. Magnetic resonance imaging (MRI) revealed bone contusions on the medial patella and lateral femoral condyle, with a large intra-articular loose body and a significant patellar defect measuring 1 cm in diameter with adjacent delamination (Figures 1A and 1B).

At this time, the patient elected to proceed with arthroscopic debridement of the patellar defect and loose body removal because of his desire for a short rehabilitation period and quick return to sport. During arthroscopy, a well-shouldered, 1-cm diameter, full-thickness cartilage defect was identified on the medial facet of the patella. The defect was minimally debrided, and a sizable and delaminated area extending beyond the injured patellar cartilage surface was recorded.

Over the next year, the patient sustained various right patellar dislocations with subsequent development and progression of patellofemoral pain. An MRI and computed tomography (CT) Fulkerson series were obtained. Findings showed a large loose body measuring at least 20 mm in diameter, a large well-circumscribed patella defect (Figures 2A and 2B), a dysplastic patellofemoral joint with significant lateral patella tilt, slight patella subluxation, and the tibia tubercle-trochlear groove distance (TTTG) of 25 mm (Figure 3).

At this point, conservative management had been maximized and was unlikely to prevent further dislocations. Therefore, 15 months after the initial injury, the patient underwent operative intervention to address his multiple patella dislocations, excessive TTTG, lateral tilt, lateral subluxation, and large patellar cartilage defect. The operation included a Fulkerson procedure with an anteromedial tibia tubercle osteotomy to address the excessive lateral position of the tibia tubercle and the patella alta. It also included a lateral retinaculum release to decrease the negative patellar tilt and a medial retinacular reefing to decrease the patella subluxation proximally. To address the cartilage

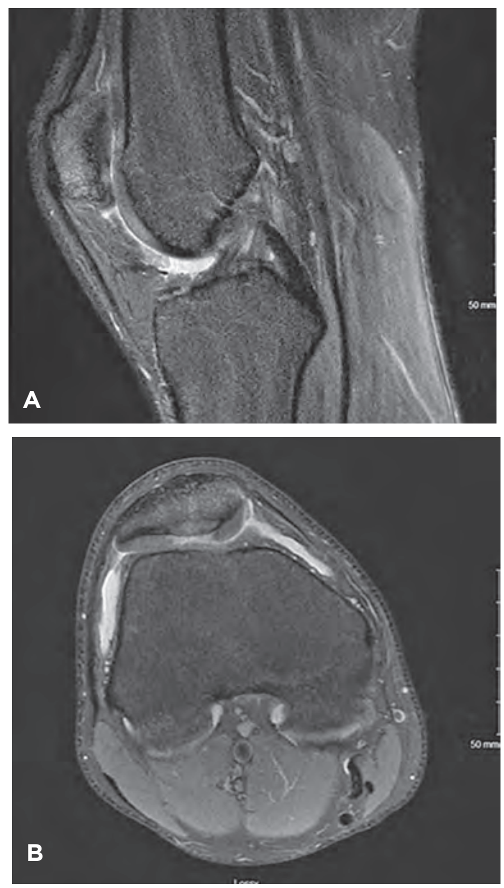

Figure 2. *Sagittal A) and axial B) magnetic resonance images showing enlarged articular defect of the patella 1 year after initial patellar instability.*

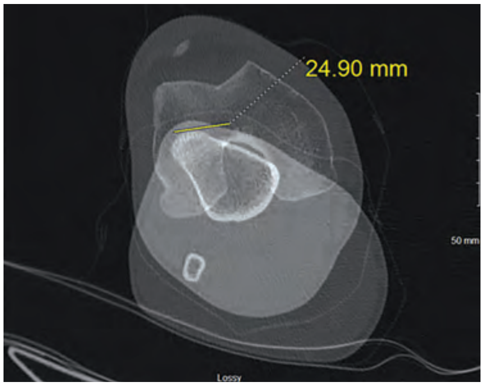

__Figure 3.__ Computed tomography scan of the right knee following the Fulkerson procedure showing a tibial tubercle to trochlear groove distance of 25 mm.

defect on the patella, which measured approximately 20 mm with a healthy bone base, microfracture was performed and the defect was repaired using a 20-mm ProChondrix® graft placed within a fibrin clot to hold the graft in place.

The postoperative rehab protocol consisted of bracing with the knee locked in extension for 48 hours. Once the brace was removed, a continuous passive motion (CPM) machine was used with a range of motion of 0° to 90° for 10 hours per day for 4 weeks.[11] Immediate weight bearing of 50.0% in full extension was allowed because of the robust fixation of the tibial tubercle osteotomy.

At 6 weeks, the patient's range of motion was 0° to 130°. X-rays confirmed good healing at the osteotomy site, and he was progressed to full weight bearing and full range of motion. At 5 months postoperatively, the patient had returned to running, jogging, and weight training, including light squats without limits. His range of motion was full and equal to the uninjured side. At his 1-year postoperative visit, he had no pain with activities of daily living, work, or any casual life activity. The patient was able to walk, jog, and play Frisbee without any difficulties. After several consecutive days of skiing, he would get a small effusion that would go away within 24 hours with ice, rest, and activity modification. An MRI was obtained to investigate the source of effusion. The Magnetic Resonance Observation of Cartilage Repair Tissue (MOCART), MOCART [2], and the Osteochondral Allograft MRI Scoring System (OCAMRISS) scoring systems were used to analyze and evaluate the MRI findings (Tables 1 through 3 and Figures 4A and 4B). This patient had a

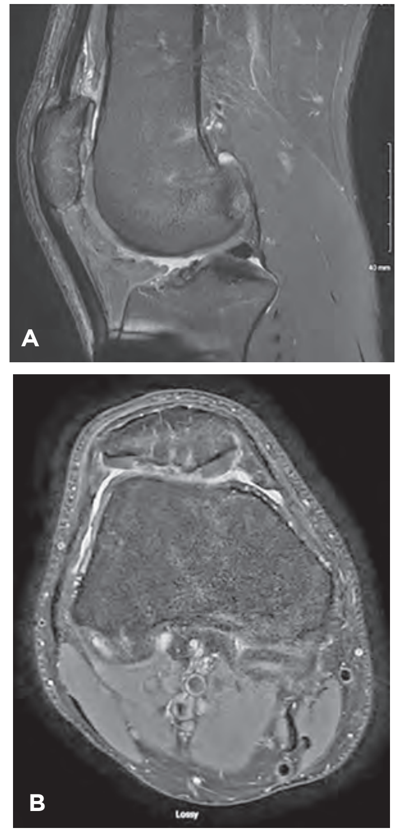

__Figure 4.__ Sagittal A) and axial B) magnetic resonance images of the right knee at 1-year postoperatively showing filling of the articular defect with the ProChondrix® allograft and the incorporation of the graft into the surrounding native tissue. Filing is at a similar level compared to the adjacent articular cartilage.

Table 1. *MOCART Scoring*

Variable	Score
Degree of defect repair and filling of the defect	Incomplete with greater than 50.0% of the adjacent cartilage
Integration to border zone	Defect visible with less than 50.0% of the length of the repair tissue
Surface of the repair tissue	Surface damaged (fibrillation, fissures, and ulcerations) with less than 50.0% of the repair tissue depth
Structure of the repair	Inhomogenous or cleft formation
Signal intensity of the repair tissue	Moderately hyperintense
Subchondral lamina	Intact
Subchondral bone	Intact
Adhesions	No
Effusion	No

MOCART, Magnetic Resonance Observation of Cartilage Repair Tissue

Table 2. *MOCART 2.0 Scoring*

Variable	Score	
Volume of cartilage defect filling compared to native cartilage	Underfilling 50.0% to 74.0%	10 points
Integration into adjacent cartilage	Defect greater than 2 mm, but less than 50.0%	5 points
Surface of the repair tissue	Irregularities less than 50%	5 points
Structure of the repair tissue	Inhomogenous	0 points
Signal intensity of the repair tissue	Minor hyperintense	10 points
Bony defect or bony overgrowth	No defect or overgrowth	10 points
Subchondral changes	Edema-like	15 points

MOCART, Magnetic Resonance Observation of Cartilage Repair Tissue

Table 3. *OCAMRISS Scoring*

Variable	Score	
Cartilage signal of graft	Altered intensity (either hypointense or hyperintense, but not fluid)	1 point
Cartilage "fill" of graft	51.0%-75.0%	1 point
Cartilage edge integration at host-graft junction	Discernable boundary	1 point
Cartilage surface congruity of graft and host-graft junction	Flush	0 points
Calcified cartilage integrity of the graft	Intact, thin, and smooth	0 points
Subchondral bone plate congruity of graft and host-graft junction	Intact and flush	0 points
Subchondral bone marrow signal intensity of graft relative to epiphyseal bone	Normal	0 points
Osseous integration at host-graft junction	Crossing trabeculae	0 points
Presence of cystic changes of the graft and host-graft junction	Absent	0 points
Opposing cartilage	Abnormal	1 point

OCAMRISS, Osteochondral Allograft MRI Scoring System

MOCART 2.0 score of 50 out of 90 (90 being the best possible score) and an OCAMRISS score of 4 out of 14 (0 being the best possible score).

DISCUSSION

ProChondrix® is a fresh cartilage matrix with living chondrocytes designed to maintain the natural signaling factors vital to the repair and regeneration of hyaline cartilage. ProChondrix® has been shown to express bFGF, PRG4, TGF-β, IGF-1, BMP-2, BMP-7, and PDGF. The growth factors present in ProChondrix® encourage chondrogenesis and promote bone marrow-derived cell (BMDC) migration into the surgical site after being liberated via microfracture. The goal is that the combination of a live cell-signaling matrix and migration of BMDCs will lead to the incorporation of the allograft and form healthy hyaline cartilage.[12] ProChondrix® presents a unique option for contained cartilage defects as it is readily available, can reconstitute complex articular surface geometry, restore adequate cartilage depth, and perform in a single-stage procedure. ProChondrix® serves as an option for both a primary repair and as a salvage procedure for chondral defects.

Indications for the use of ProChondrix® include chondral defects without bone involvement and within the dimensions of the available implants (11-20 mm). Contraindications are chondral injuries with bone involvement.

To our knowledge, there are no current studies evaluating outcomes following chondral repair with ProChondrix® allograft in humans. At 1-year postoperatively, the patient displayed excellent clinical results. He had returned to running and skiing and had no pain with activities of daily living, work, or causal life. An MRI was obtained due to intermittent joint effusions. It showed the graft had become incorporated with the surrounding native tissue, and there was filling of the defect to a similar level compared to the adjacent cartilage. However, given this patient had multiple, simultaneous operations with his chondral repair using ProChondrix®, it is impossible to quantify how much of his outcome is attributable to the chondral repair alone.

We used the MOCART,13 MOCART 2.0,[14] and OCAMRISS[15] grading systems to analyze the MRI and grade graft incorporation. Previous studies have compared MRI findings of the individual components of both the MOCART to clinical outcomes[6] and OCAMRISS to histologic findings[8] to validate these scoring systems. There is currently a lack of strong evidence to suggest MRI scoring systems reliably correlate with clinical outcomes.[16] Therefore, we felt it was pertinent to explore this correlation in the case reported here. This patient had a MOCART 2.0 score of 50 out of 90 (90 being the best possible score) and an OCAMRISS score of 4 out of 14 (0 being the best possible score) in the setting of an excellent clinical outcome. Again, we cannot attribute this outcome entirely to the ProChondrix® chondral repair because of the other operations performed.

REFERENCES

1. Bedi A, Feeley BT, Williams RJ 3rd. Management of articular cartilage defects of the knee. J Bone Joint Surg Am. 2010;92(4):994-1009. doi: 10.2106/JBJS.I.00895.
2. Steadman JR, Rodkey WG, Rodrigo JJ. Microfracture: surgical technique and rehabilitation to treat chondral defects. Clin Orthop Relat Res. 2001;(391 Suppl):S362-S369. doi: 10.1097/00003086-200110001-00033.
3. Knutsen G, Engebretsen L, Ludvigsen TC, et al. Autologous chondrocyte implantation compared with microfracture in the knee: a randomized trial. J Bone Joint Surg Am. 2004;86(3):455-464. doi: 10.2106/00004623-200403000-00001.
4. Hangody L, Füles P. Autologous osteochondral mosaicplasty for the treatment of full-thickness defects of weight-bearing joints: ten years of experimental and clinical experience. J Bone Joint Surg Am. 2003;85-A(Suppl 2):25-32. doi: 10.2106/00004623-200300002-00004.
5. Familiari F, Cinque ME, Chahla J, et al. Clinical outcomes and failure rates of osteochondral allograft transplantation in the knee: a systematic review. Am J Sports Med. 2018;46(14):3541-3549. doi: 10.1177/0363546517732531.
6. Liu YW, Tran MD, Skalski MR, et al. MR imaging of cartilage repair surgery of the knee. Clin Imaging. 2019;58:129-139. doi: 10.1016/j.clinimag.2019.07.004.
7. Minas T, Von Keudell A, Bryant T, et al. The John Insall Award: a minimum 10-year outcome study of autologous chondrocyte implantation. Clin Orthop Relat Res. 2014;472(1):41-51. doi: 10.1007/s11999-013-3146-9.
8. Delaney R, Barrett C, Stevens P. High chondrocyte viability of ProChondrix® at the maximum shelf life of 35 days: potential for good clinical outcome and consistency of cartilage allograft. Centennial: AlloSource®;2016:1-8. Available at https://www.allosource.org/wp-content/uploads/2019/10/Vol-3_Basic-Science_ProC-Cell-Viability_121216-M8S0117-001.pdf.
9. Rorick C, Mitchell J, Ramasamy S. Laser-etched cryopreserved osteochondral allograft, ProChondrix® CR maintains metabolically active and viable cells after two year storage. Centennial: AlloSource®;2019:1-8. Available at https://www.allosource.org/wp-content/uploads/2019/10/Vol-6_Basic-Science-ProC-CR-2-Year-Cell-Viability.pdf.
10. Capeci CM, Turchiano M, Strauss EJ, et al. Osteochondral allografts: applications in treating articular cartilage defects in the knee. Bull Hosp Jt Dis (2013). 2013;71(1):60-67.
11. Reinold MM, Wilk KE, Macrina LC, et al. Current concepts in the rehabilitation following articular cartilage repair procedures in the knee. J Orthop Sports Phys Ther. 2006;36(10):774-794. doi: 10.2519/jospt.2006.2228.
12. Delaney R, Barrett C, Stevens P. ProChondrix® cartilage restoration matrix contains growth factors necessary for hyaline cartilage regeneration. Centennial: AlloSource®;2016:1-8. Avaiable at https://www.allosource.org/wp-content/uploads/2019/10/Vol-1_Basic-Science-ProC-Growth-Factor_111616_M8S0106-001.pdf.
13. Marlovits S, Singer P, Zeller P, et al. Magnetic resonance observation of cartilage repair tissue (MOCART) for the evaluation of autologous chondrocyte transplantation: determination of interobserver variability and correlation to clinical outcome after 2 years. Eur J Radiol. 2006;57(1):16-23. doi: 10.1016/j.ejrad.2005.08.007.
14. Schreiner MM, Raudner M, Marlovits S, et al. The MOCART (Magnetic Resonance Observation of Cartilage Repair Tissue) 2.0 Knee Score and Atlas. Cartilage. 2019:1947603519865308. doi: 10.1177/1947603519865308.
15. Chang EY, Pallante-Kichura AL, Bae WC, et al. Development of a comprehensive osteochondral allograft MRI scoring system (OCAMRISS) with histopathologic, micro-computed tomography, and biomechanical validation. Cartilage. 2014;5(1):16-27. doi: 10.1177/1947603513514436.
16. de Windt TS, Welsch GH, Brittberg M, et al. Is magnetic resonance imaging reliable in predicting clinical outcome after articular cartilage repair of the knee: a systematic review and meta-analysis. Am J Sports Med. 2013;41(7):1695-1702. doi: 10.1177/0363546512473258.