

Fresh Osteochondral Allograft Transplantation of the Capitellum for the Treatment of Osteochondritis Dissecans

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Background: Osteochondritis dissecans (OCD) of the humeral capitellum is a rare and challenging condition to treat. Several surgical options exist, but in the last few years, the pendulum has swung from debridement and microfracture to restoration of the articular surface. Osteochondral autografts from the rib and knee have been described, but donor-site morbidity is a concern.

Purpose: To expand the results of fresh osteochondral allograft transplantation (FOCAT) in a previously published report with inclusion of additional patients and a longer follow-up period.

Study Design: Case series; Level of evidence, 4.

Methods: After institutional review board approval, the charts of patients who underwent FOCAT for OCD of the capitellum between 2006 and 2022 by a single surgeon were reviewed. The majority of cases (94%) had unstable lesions (Minami grades 2 and 3). A trial of nonoperative treatment had failed in all. All patients underwent diagnostic arthroscopy, followed by a mini-open, ligament-sparing approach with grafting using commercially available guides and instruments.

Results: A total of 35 patients were identified, of whom 25 were male. The mean age was 16 ± 3.9 years (range, 11-32 years). There were 24 baseball players (19 pitchers and 5 position players), 5 gymnasts, 3 cheerleaders/tumblers, 1 tennis player, 1 student (who did not participate in athletics), and 1 patient with avascular necrosis from chemotherapy. Eighteen patients had a mean flexion contracture of $14.1^\circ \pm 11.9^\circ$. A single osteochondral allograft plug was used in 23 patients (mean diameter, 11.3 ± 2.8 mm), and 12 patients required 2 plugs (Mastercard technique). The mean follow-up was 92.6 ± 54.5 months (range, 24-204 months). There was significant improvement in Oxford (from 25.5 ± 4.9 to 46.7 ± 3.5 ; $P < .00001$) and visual analog scale for pain (from 7.5 ± 2 to 0.3 ± 1.0 ; $P < .0001$) scores. The mean Single Assessment Numeric Evaluation score at the time of follow-up was 90.6 ± 10.8 (range, 60-100). In overhead athletes, there was significant improvement in the Kerlan-Jobe Orthopaedic Clinic score (from 40.8 ± 11.8 to 90.6 ± 10.8 ; $P < .00001$). A postoperative magnetic resonance imaging scan was obtained in 16 (46%) patients at a mean of 32.6 months. In all cases, the graft was incorporated. All overhead athletes were able to return to their sport and perform at the same level or higher for >2 years. Two elbows required a subsequent arthroscopy for loose-body removal; otherwise, there were no other complications.

Conclusion: FOCAT is an excellent option for treating OCD lesions of the humeral capitellum. Excellent outcomes and high return-to-sport rates were observed, with midterm follow-up showing no graft failures. FOCAT eliminates donor-site morbidity.

Keywords: elbow; baseball; allografts; capitellum; fresh osteochondral allograft; osteochondritis dissecans

Osteochondritis dissecans (OCD) of the capitellum typically occurs in adolescent athletes such as throwing athletes, gymnasts, and weightlifters^{2,51,52} and is increasingly being recognized.^{2,19,37} The treatment of capitellar OCD remains controversial, and a variety of procedures exist based on the stability of the lesion, quality of the articular surface, and size. Nonoperative management is recommended for stable lesions,^{29,45} and surgical treat-

ment is recommended for unstable lesions or those for whom nonoperative management has failed. Surgical options include open or arthroscopic debridement,²⁵ microfracture,^{7,9,24,50,54} fragment fixation,^{16,21} osteochondral autograft transfer,^{3,4,27,28,34} and osteochondral allograft (OCA) transplantation.^{14,33} Autograft transfers restore the elbow joint with hyaline articular cartilage at the expense of donor-site morbidity, which has been reported to be between 7.8%⁶ and 10.6%.⁴² For these reasons, the senior author (R.M.) began using fresh OCA transplantation (FOCAT) for the reconstruction of unstable OCD lesions of the capitellum.⁴³ FOCAT offers several advantages, including an abundance of graft material (more than could be harvested from the patient's knee), which

is crucial in larger or uncontained lesions, without the complication of donor-site morbidity. The disadvantage is the cost of the graft, but with precut fresh grafts being commercially available,¹⁴ this has been minimized. The authors chose either a knee medial or lateral hemicondyle, as these are more readily available from tissue banks. The purpose of this study was to report the midterm outcomes of patients who had undergone OCA transplantation for capitellar OCD lesions by a single surgeon (R.M.). This paper is an expansion of a previously published paper,³³ with inclusion of additional patients and a longer follow-up period. Our hypothesis was that this treatment would provide great results with high activity levels and a low complication profile at midterm follow-up.

METHODS

After obtaining approval from the Southern California Kaiser Permanente Institutional Review Board, we performed a retrospective chart review on prospectively collected data. Inclusion criteria included (1) all patients who had undergone FOCAT for OCD of the capitellum by a single surgeon (R.M.), (2) surgeries performed between 2006 and 2022, (3) unstable OCD lesions (as defined below), and (4) stable lesions for which nonoperative management had failed. Exclusion criteria included (1) post-traumatic articular injuries of the capitellum, (2) neoplastic lesions of the capitellum, (3) infections, (4) and previous surgeries of the capitellum.

Preoperative and postoperative visual analog scale scores, the Oxford Elbow Score, the Kerlan-Jobe Orthopaedic Clinic (KJOC) Shoulder and Elbow score, and the postoperative Single Assessment Numeric Evaluation score were used to clinically evaluate the patients. The KJOC score is a validated scoring system that has been shown to be more sensitive in detecting subtle performance changes in high-performance overhead throwing athletes, as it avoids a ceiling effect.^{1,15} When this series was started, the KJOC evaluation form had not been published. However, at the time of follow-up, patients were asked to fill out the KJOC questionnaire based on their best recollection of preoperative symptoms. The postoperative scores were obtained in person or via telephone. A paired *t* test was used to compare the pre- and postoperative scores across all patients with a *P* value of <.05 set as significant. All analyses were done with SAS/STAT version 15.1 (Cary).

Classification

The lesions were classified by the senior author based on plain radiographs, magnetic resonance imaging (MRI),

and intraoperative findings. Using plain radiographs and the Minami classification, we separated the lesions into 3 grades, with grades 2 and 3 being considered unstable.³² The Itsubo classification¹⁷ is an MRI-based classification in which stages 3 to 5 are considered unstable. The International Cartilage Regeneration & Joint Preservation Society grading system¹¹ is used to classify lesions based on arthroscopic findings, and grades 3 and 4 are considered unstable. In addition, we categorized lesions to be “contained” (located in the central part of the capitellum, surrounded by intact cartilage) or “uncontained” (at the edge of the capitellum, extending beyond the lateral cartilaginous margin), as described by Shi et al.³⁹

Lesion location was also described based on the work of Kolmodin and Saluan.²⁰ Type 2 lesions are medial to the radial head centerline, and type 3 lesions are lateral to it. Type 3b lesions are lateral to the radial head centerline, including the lateral cartilage margin, and have lateral column involvement.

In all patients, the lateral physis was closed; however, 5 patients had open olecranon and 1 patient had an open medial apophysis.

Surgical Technique

We chose either a knee medial or lateral hemicondyle allograft, as these are more readily available from tissue banks. Upper extremity (shoulder and elbow) fresh allografts are “specialty order” and not routinely procured given the high contamination rate. Hemicondyles are routinely procured for the placement of knee defects but oftentimes have to be discarded because of expiration dates if they have not been placed. Because the condyle does not have to be size matched with the elbow recipient, even the smallest condyle that may not be suitable to treat a knee defect can be used for elbow cases. All fresh OCAs were obtained from the Joint Restoration Foundation. The grafts were kept at 4°C and in a proprietary nutrient medium until immediately before implantation.

From 2006 to 2018, the senior author used a ligament-sparing approach through a Kocher interval with an accessory incision perpendicular to the capitellum.⁴³ From 2018 to the present, the author adopted the Takahara approach, which utilizes a single incision over the anconeus muscle, splits it, and incises the capsule for exposure to the capitellum without taking down the collateral ligaments.⁴³ All elbows were evaluated arthroscopically, with the patient in the prone position, at the same time as the FOCAT. The lesion was identified from the posterior compartment and through the soft spot portal. Loose bodies were

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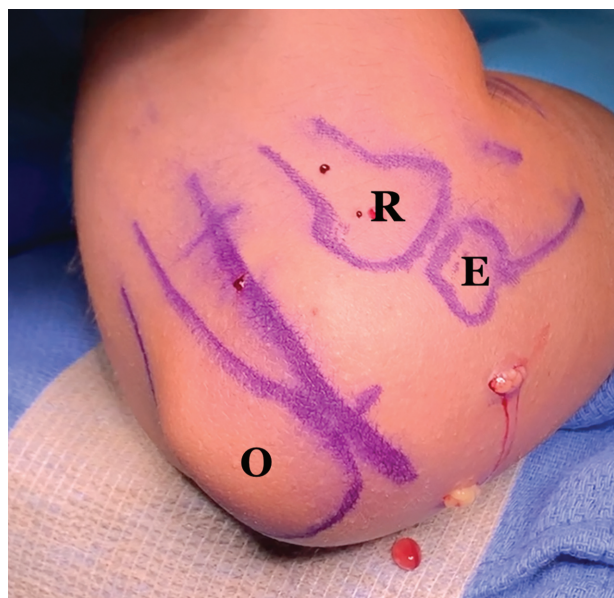


Figure 1. Posterior view of a left elbow where the incision is marked. E, lateral epicondyle; O, olecranon; R, radial head.

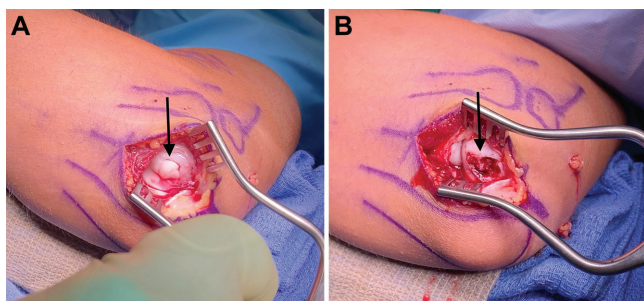


Figure 2. The anconeus is split and the capsule incised, exposing the lesion (arrows). (A) The lesion is desiccated and partially detached. (B) The flap is removed, showing the full extent of the lesion.

removed when present. An arthroscopic anterior capsular release and/or osteophyte resection was performed in those who had $>15^\circ$ of flexion contracture.

A 3-cm incision was used between the radiocapitellar joint and the olecranon over the anconeus muscle (Figure 1). The fascia over the anconeus was incised, the anconeus muscle was split, and the capsule was incised (Figure 2). Occasionally, for larger lesions, the annular ligament was incised and later repaired. The lesion was then sized using cannulated sizing guides from the Small OATS Tray (Arthrex) (Figure 3A) and reamed (Figure 3B) to a depth of approximately 8 mm or as deep as necessary to remove the depth of the lesion. The fresh medial or lateral femoral hemicondyle was brought close to the incision, and the location that most closely matched the curvature radius of the capitellum was identified (Figure 4). A coring reamer was used to harvest a cylindrical plug from the hemicondyle

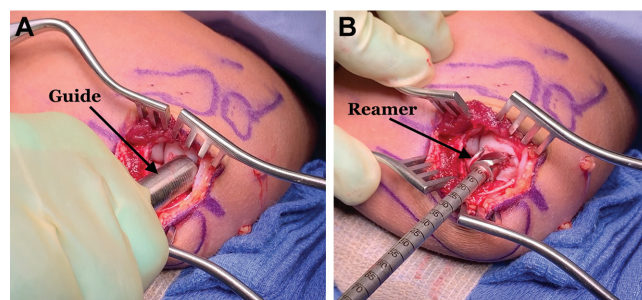


Figure 3. (A) A sizing guide (arrow) is used to cover the entire lesion. (B) The corresponding reamer (arrow) is used to ream to a depth of 8 mm.

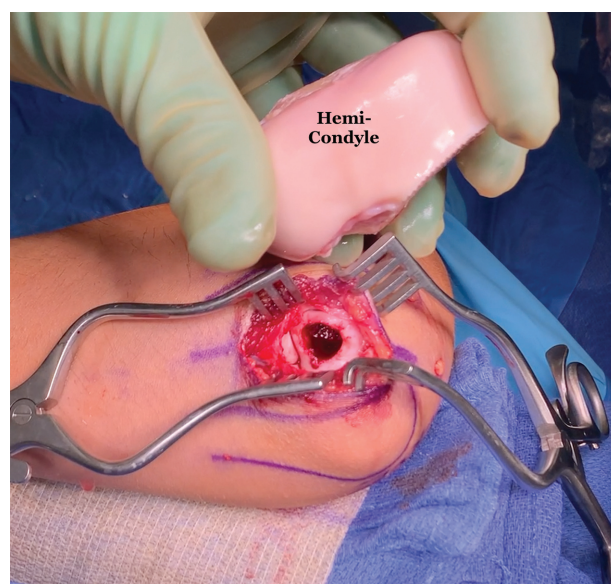


Figure 4. A femoral hemicondyle is held close to the capitellum, and the graft location is assessed based on the best match of the curvature radius.

and measured to a length of 7 mm (1 mm shorter than the socket) (Figure 5). The cylindrical plug was inserted into the reamed-out socket in the capitellum (Figure 6).

Postoperative Protocol

Patients were placed in a long-arm posterior molded splint for 7 to 10 days postoperatively. Additional bracing was not applied after splint removal. Physical therapy was initiated at 7 to 10 days, with the goal of regaining a pain-free full range of motion within 4 weeks. A gentle strengthening program was initiated at 4 weeks, but patients were restricted from activities that would significantly load the graft, such as throwing or push-ups, for a minimum period of 3 months. Throwing athletes were placed on a 3 month-long throwing program, beginning at 3 to 4 months after surgery, and were released to throwing without

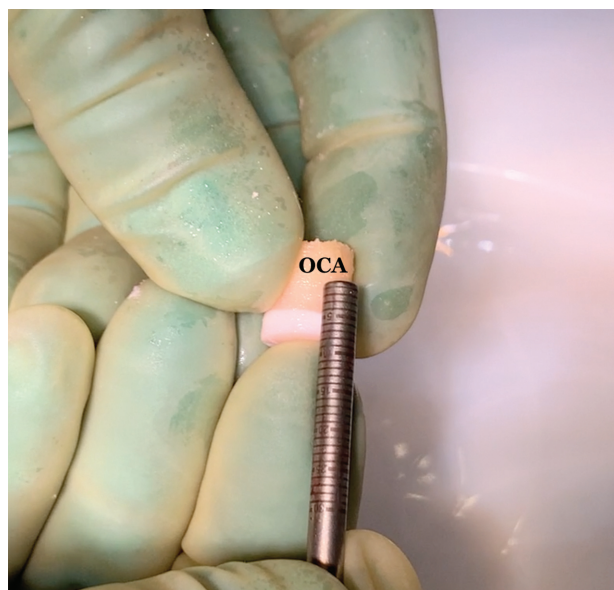


Figure 5. A cylindrical osteochondral allograft (OCA) plug is harvested from the hemicondyle, and a depth of 7 mm is measured to cut the excess bone.

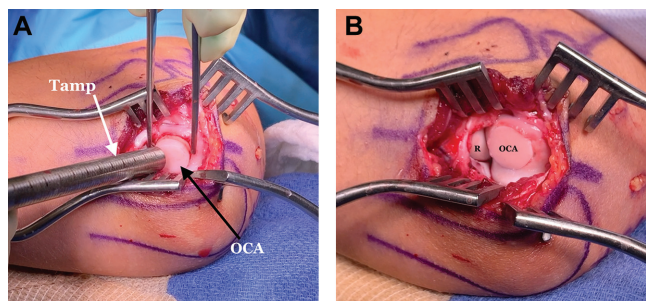


Figure 6. (A) The osteochondral allograft (OCA) plug is held in place, and a tamp is used to gently advance the graft into the socket, achieving circumferential press-fit fixation. (B) Photograph of the graft (OCA) flush with the surrounding cartilage. R, radial head.

restrictions at approximately 6 months after surgery. Non-throwing athletes were released at 4 to 5 months.

RESULTS

Patient Information

Of the 38 patients identified, 35 (92%) were able to be evaluated. An in-person assessment was made in 8 (23%) patients and a telephone assessment in 27 (77%) patients. The mean age at time of surgery was 16 ± 3.9 years (range, 11-32 years). There were 25 male patients. Of the 35 patients, there were 24 baseball players (19 pitchers and 5 position players), 5 gymnasts, 3 cheerleaders/tumblers, 1 tennis player, 1 student, and 1 patient with avascular

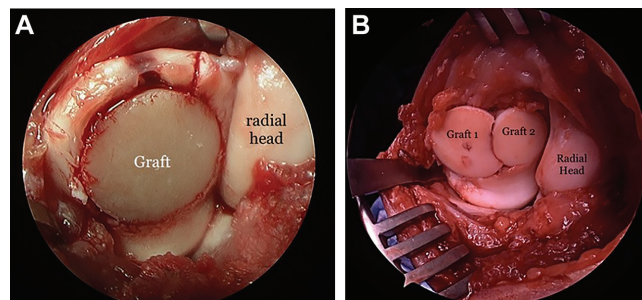


Figure 7. (A) Single osteochondral allograft (OCA) plug. (B) Two OCA plugs in a Mastercard configuration.

necrosis from chemotherapy. The mean follow-up was 92.6 ± 54.5 months (range, 24-204 months). Using the Minami classification,³² we found that 30 patients had grade 3 lesions, 3 had grade 2, and 2 had grade 1. According to the Itsubo classification,¹⁷ 28 patients had stage 5 lesions, 3 had stage 4, 1 had stage 3, 2 had stage 2, and 1 had a lesion that was unable to be classified. Using the International Cartilage Regeneration & Joint Preservation Society classification,¹¹ we found that 31 patients had stage 4 lesions, 2 had stage 3, and 2 had stage 2. Using the Shi classification,³⁹ we observed that 24 lesions were contained and 11 were uncontained. According to the Kol-modin classification,²⁰ there were 3 type 2, 21 type 3a, and 11 type 3b lesions.

Surgical Procedures

A single OCA plug was used in 23 patients (mean diameter, 11.3 ± 2.8 mm; range, 6-18 mm) (Figure 7A), and 12 patients required 2 plugs (Mastercard technique), with the second plug averaging a mean diameter of 10 ± 2.9 mm (range, 6-12 mm) (Figure 7B). A lateral hemicondyle was used in 14 patients, a medial hemicondyle was used in 12 patients, and in 9 patients the hemicondyle was not specified. All patients underwent arthroscopy before FOCAT. An ulnar collateral ligament reconstruction was performed in 2 patients. FOCAT was also performed to the radial head in 2 patients (bipolar grafting) (Figure 8). Eighteen patients had a mean contracture of $14.1^\circ \pm 11.9^\circ$ (range, 5° - 45°). A contracture release was performed in 5 patients who had contractures of $\geq 15^\circ$. The mean contracture in those undergoing a release was $27.8^\circ \pm 9.6^\circ$ (range, 20° - 45°).

Clinical Outcomes

There was significant improvement in the Oxford (from 25.5 ± 4.9 to 46.7 ± 3.5 ; $P < .00001$) and visual analog scale for pain (from 7.5 ± 2 to 0.3 ± 1.0 ; $P < .0001$) scores. The mean Single Assessment Numeric Evaluation score at the time of follow-up was 90.6 ± 10.8 (range, 60-100). In overhead athletes (24 baseball players and 1 tennis player), there was significant improvement in the KJOC score (from 40.8 ± 11.8 to 90.6 ± 10.8 ; $P < .00001$). All

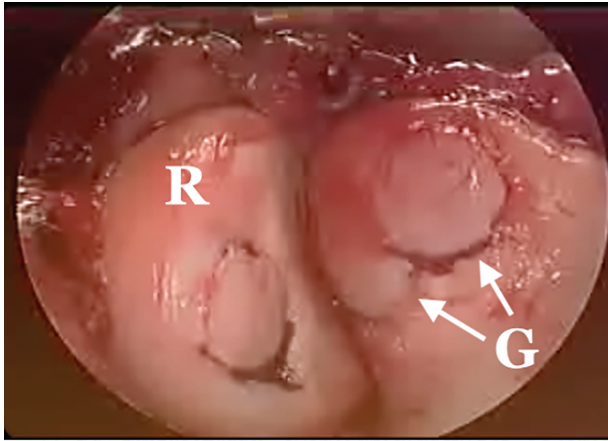


Figure 8. Two osteochondral plugs (G; arrows) placed using the Mastercard technique with a concomitant osteochondral allograft plug in the radial head (R).

overhead athletes were able to return to their sport and perform at same level or higher for >2 years. In baseball players specifically, all were able to return to play at the same or higher level for at least 2 years. Most baseball players stopped pursuing baseball after high school for reasons completely unrelated to the elbow, with the exception of 2 players who returned to pitching at top speeds of 94 and 96 mph and both played professional baseball and while another topped at 88 MPH and obtained a college scholarship for NCAA Division I baseball. One tennis player received a NCAA Division I scholarship. Of the 2 patients who underwent a concomitant ulnar collateral ligament reconstruction, both returned to sport and played for >2 years, and one of those athletes turned professional and could pitch at a speed of 96 mph. The 2 athletes who had concomitant bipolar grafting of the radial head both returned to play for >2 years, and one of them turned professional.

In 2 elbows, a subsequent arthroscopy was performed for loose-body removal. In both cases, the articular cartilage overlying the graft was in pristine condition. There were no other complications and no graft rejections. Postoperative MRI was routinely offered to patients to assess graft healing (not due to having symptoms) and was obtained in 16 (46%) patients at a mean of 32.6 months. In all cases, MRI scans showed the graft was incorporated (Figure 9).

DISCUSSION

This paper is an expansion of a previously published paper,³³ with the inclusion of additional patients and a longer period of follow-up. Our findings demonstrated excellent midterm outcomes of FOCAT for the treatment of OCD of the humeral capitellum. Patients had significant clinical improvement and reduction in pain scores. All (100%) of overhead athletes were able to return to sport and perform at preinjury levels, with two patients making it into professional baseball. There were no major complications or graft rejection. Based on our findings, FOCAT is an outstanding option for restoring the articular surface of the capitellum without the concern of donor-site morbidity. We did not see any deterioration in outcomes with longer follow-up. In addition, since the mean graft diameter was 11 mm, with one as large as 18 mm, and over one third of patients required two cylindrical grafts, a fresh allograft source may be a better option than an autologous transfer from a patient's knee which can limit the diameter and number of donor grafts.

OCD of the humeral capitellum is a rare and debilitating condition seen in young adolescent athletes who are involved in baseball or gymnastics.^{2,51,52} The initial management for stable lesions is nonoperative. Open capitellar growth plates and lack of contracture increase the likelihood for successful return to activity with nonoperative

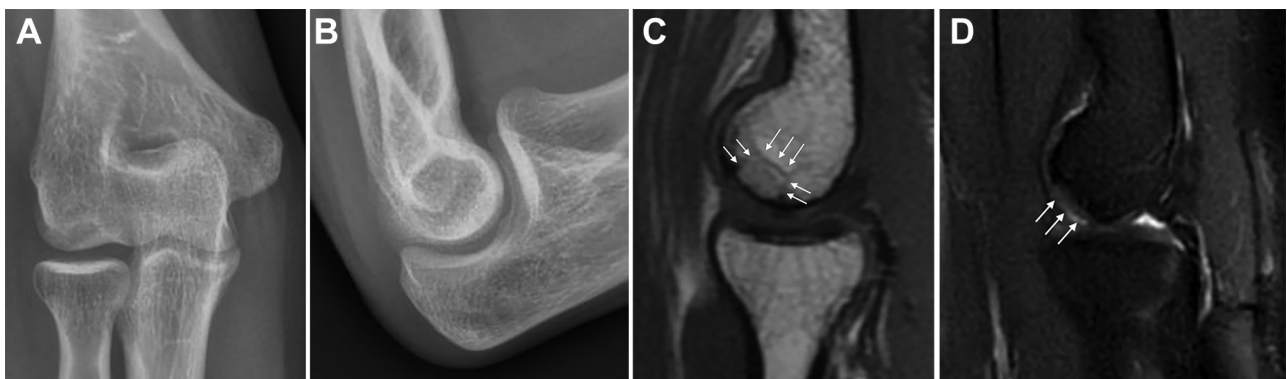


Figure 9. (A) Anteroposterior and (B) lateral radiographs at 47 months postoperatively showing complete incorporation of the graft without lucency or sclerosis around the graft. (C) T1-weighted sagittal MRI scan obtained in the same patient at 47 months postoperatively, demonstrating incorporation of the graft and a faint "scar" (white arrows) outlining the graft. (D) T2-weighted MRI scan of the same elbow demonstrating fully incorporated graft, no stress reaction, and preservation of the cartilage on the graft (white arrows). MRI, magnetic resonance imaging.

management.^{31,46} Nonoperative management of unstable lesions has been shown to have poor outcomes.^{5,10,12,47,48}

Arthroscopic debridement with chondroplasty and loose-body removal has been shown to improve outcomes,⁸ but 54%⁴⁶ to 60%¹³ of patients are unable to return to their previous level of athletic activity. In a recent large cohort of 53 elbows treated with debridement, 56% of the athletes were able to return at their preinjury level.² Microfracture is inexpensive and can be performed with technical ease to stimulate a marrow response. However, microfracture has been shown to create a fibrocartilage tissue, rather than hyaline articular cartilage, and may not be able to withstand loading forces.^{44,49} This is demonstrated by not all of patients being able to return to the same level of sporting activity. Bojanic et al⁸ reported on 9 adolescents treated with microfracture, and only 2 (22%) were able to return to same level of sport activity. Wulf et al⁵⁴ reported on 10 patients, and only 6 of 8 (75%) patients involved in competitive athletics returned to the same level of participation. Lewine et al²⁴ reported that only 14 of 21 (66.7%) adolescents treated with drilling/microfracture returned to their primary sport. Michelin et al³⁰ reported similar results: 12 of 18 (66.7%) athletes returned to their primary sport at the same level or higher. In a recent systematic review and meta-analysis of 24 studies including 492 patients, Westermann et al⁵³ reported return-to-sport rates of 64% for fragment fixation, 71% for microfracture, and 94% for OCA transfer.

Restoration of the hyaline articular surface with autologous osteochondral transfers has been shown to be superior to debridement or microfracture.^{41,46,55} Takahara et al⁴⁶ reported that patients who had restoration of the joint surface with autograft or fragment fixation had significantly better results compared with those who underwent debridement alone, suggesting that the goal of treatment is to obtain a normal capitellum articular surface. This finding is supported by multiple series with autograft from the knee and costal rib. Lyons et al²⁶ published results of 11 patients who underwent an autologous osteochondral transfer harvested from the ipsilateral knee. They concluded that treatment of large, unstable OCD lesions of the capitellum via autologous transfer from the knee in adolescent athletes is safe, allows reliable return to play, and has good clinical outcomes at a short-term follow-up. In 3 reports^{18,26,36} of autograft transfers from the knee to treat unstable OCD lesions of the knee, the authors reported that there was no donor-site morbidity. In contrast, several authors have reported on the morbidity associated with femoral osteochondral autograft harvesting.^{22,38} Shimada et al⁴⁰ used a lateral costal chondral autograft as an alternative source of autograft for larger lesions (>15 mm) and for laterally based lesions that are more difficult to address using standard mosaicplasty techniques. However, in their series, 1 patient sustained a pneumothorax resulting in chest tube placement. In a systematic review and meta-analysis of 11 studies including 190 patients, Bexkens et al⁶ found donor-site morbidity in 10 of 128 (7.8%) knees, including knee pain during activity (7.0%) and locking sensations

(0.8%). In a meta-analysis with best-case and worst-case analysis, Shimozono et al⁴² found the rate of knee donor-site morbidity to be as high as 10.6%. Donor-site morbidity can oftentimes be debilitating, with pain and mechanical symptoms that can prevent young athletes from returning to sport even though their elbow issue is resolved. In some cases, the knee may require revision with FOCAT itself.

Although autograft is an option to restore the articular surface, some surgeons, parents, and patients may be reluctant to have a surgical procedure that violates an asymptomatic knee. FOCAT represents another alternative to restore hyaline articular cartilage without the disadvantage of donor-site morbidity. OCA in the knee has an 80% to 90% graft survival at 10 years in both adolescent and adult populations with good clinical results.^{23,35} One other advantage is a relatively larger supply of plugs from a hemicondyle graft without limiting the size of the graft diameter or if multiple plugs are needed, which was the case in 34% of our series. It is also useful in treating laterally based capitellar OCD lesions, which have been previously described as difficult areas to treat because of the lack of supportive circumferential subchondral bone around the lesion and difficulty in restoring a concurrent articular surface using current mosaicplasty techniques.^{13,40}

We previously published on 9 male baseball players who underwent FOCAT at a mean of 48 months of follow-up.³³ All 9 players were able to return to their previous level of play for at least 2 years. In our current series, which was expanded to include 24 baseball players with longer follow-up, all (100%) were able to return to their previous level of performance. Two went on to play professional baseball, and 1 obtained NCAA Division I scholarship. We did not see any deterioration in outcomes in the 9 patients previously reported on.

The disadvantage of the allograft is cost and the minute risk of disease transmission. There are currently commercially available fresh precut core grafts with substantial cost savings over a hemicondyle,¹⁴ if only a single cylindrical plug is needed.

There are some limitations to our study, which was a retrospective chart review of a series of patients with no control group. A portion of our patients' preoperative KJOC scores were obtained based on the athletes' recollection of preoperative symptoms at the time of follow-up, which could lead to recall bias. Furthermore, the cost versus benefit of an allograft should be considered, as the cost of allograft is significant when compared with autograft, with the only benefit being reduced donor-site morbidity, but as stated above, with precut core grafts now being commercially available, the cost can be very reasonable.

CONCLUSION

FOCAT for the treatment of OCD of the humeral capitellum is safe with great midterm results, including returning to sport at high levels, minimal complications, and graft incorporation.

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