Original Article

Adolescent Athletes Achieve High Levels of Athletic and Daily Function After Arthroscopic Marrow Stimulation for Elbow Capitellar Osteochondritis Dissecans

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Purpose: To determine the functional outcomes of adolescent athletes treated with arthroscopic marrow stimulation/microfracture for elbow capitellar osteochondritis dissecans (OCD). **Methods:** The medical records for all patients younger than 18 years of age with capitellar OCD who underwent arthroscopic treatment at a single institution were retrospectively reviewed. The variables examined included patient characteristics, bone age, pre- and postoperative lesion grade/size and range of motion (ROM), intraoperative lesion grade/size, time to postoperative return to sport, and validated outcome scores. **Results:** Twenty patients with 21 treated elbows met the study's inclusion criteria. Three patients were not available for follow-up, leaving 18 of 21 (85.7%) elbows in the final cohort. Mean age and follow-up was 14.1 and 4.4 years, respectively. All 18 elbows were treated with diagnostic arthroscopy, arthroscopic debridement with loose body removal as indicated, and marrow stimulation. Sixteen of 18 (88.9%) elbows returned to sports postoperatively, with 12 of 18 (66.7%) elbows returning to their primary sport at the same level or higher. Overall, there were significant improvements in elbow ROM (132.8°, range 120°-140° postoperatively, compared with 122.1°, range 80°-140° preoperatively) ($P = .002$) and excellent Quick Disabilities of the Arm, Shoulder and Hand scores (mean 2.3 ± 5.1), as well as Kerlan-Jobe Orthopaedic Clinic Overhead Athlete Shoulder and Elbow scores (mean 94.1 ± 8.7) in those who returned to sports. There was no correlation with outcome or return to sport for preoperative lesion grade/size, bone age, physeal status or open versus arthroscopic treatment. **Conclusions:** Arthroscopic debridement and marrow stimulation for capitellar OCD in adolescent athletes leads to improvements in ROM, as well as a high rate of return to sport, and high levels of athletic and daily functional activity during follow-up, regardless of bone age and lesion grade/size at time of surgery. **Level of Evidence:** Level IV, therapeutic case series.

Osteochondrosis of the capitellum was described in 1929 by Panner as an incidental finding in young children that typically resolves spontaneously.[1] Capitellar osteochondritis dissecans (OCD) was later described as a separate entity seen in adolescents, defined as the separation of a portion of articular cartilage commonly seen in overhead athletes.[2-8] The etiology is not fully understood, but pathogenesis is thought to be a stress reaction from repetitive trauma and/or ischemia.[3,5,7] Even in overhead athletes, the incidence of elbow OCD remains low, making the prospective evaluation of treatment challenging and creating concerns for long-term recovery due to the increased predisposition for osteoarthritis (OA).[9]

Treatment options consist of both nonoperative and operative care, typically dictated by skeletal maturity and stage of disease. Early studies focused on conservative care consisting of immobilization and/or rest

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demonstrated high rates of long-term dysfunction and OA in up to 50% of patients.[10,11] It is this work done by Takahara et al.[11,12] that has helped us to more effectively stage this disease and define indications for treatment. Children presenting with an open capitellar physis and mild disease have good results with conservative care due to high remodeling potential, whereas children with a closed capitellar physis are less likely to experience such remodeling and may be better suited for operative management.[10,12-14] It should be noted, however, that compliance with conservative care can be an issue in the young athlete population, and duration to full recovery has been reported to range from 12 to 15 months.[14]

Surgical options consist of open and arthroscopic debridement, fragment excision, fragment fixation, abrasion chondroplasty, marrow stimulation via microfracture/drilling, and, more recently, osteochondral autograft transplantation, or mosaicplasty, for larger high-grade lesions. Mosaicplasty has shown good short- to mid-term results[12,15-18] but requires an open arthrotomy, which can lead to elbow stiffness[19] and potentially lengthy recoveries.[15,16,18] Arthroscopic treatment is therefore preferable when possible. While early arthroscopic studies focused on debridement and abrasion chondroplasty,[19-25] with mixed outcomes and varying return to sport rates (25%-86%), some studies have suggested increased risk for early OA with arthroscopic debridement alone.[20,22,24] In response, more recent studies have focused on marrow stimulation/microfracture,[26-30] with good-to-excellent results commonly reported. However, most of these studies had small sample sizes, a short duration of follow-up, no comment on bone age, and vague characterization of the return to sport (e.g., level of play). The purpose of this study was to determine the functional outcomes of adolescent athletes treated with arthroscopic marrow stimulation/microfracture for elbow capitellar OCD. We hypothesized that arthroscopic marrow stimulation of capitellar OCD in the adolescent athlete would result in improved symptoms, high return to sport rates, and good functional outcomes in a majority of those treated.

Methods

After approval by our institutional review board, a retrospective review was performed of the medical records for all children and adolescents younger than 18 years who underwent arthroscopic treatment with marrow stimulation for elbow OCD between January 2010 and December 2019 at a single institution by a single surgeon. All patients who had undergone previous surgery of their elbow were excluded. The characteristics and details of injury were collected from the patient's charts. Preoperative information such as primary sport played and level at of play at the onset of symptoms, history of previous trauma, arm dominance,

months symptomatic before surgery, length of rest before surgery, reported mechanical and/or loss of motion, and clinical range of motion (ROM) was recorded. All patients and their parents were encouraged to attempt conservative treatment (i.e., rest from all sports) before considering surgery, unless they demonstrated a significant loss of motion and/or loose bodies were identified on imaging at the initial presentation. Preoperative radiographs and magnetic resonance imaging (MRI) were reviewed for all patients. Bone age, capitellar physeal status, lesion grade, and size were recorded. The Sauvegrain method was used for determining skeletal age based on preoperative radiographs.[31] Lesions were classified as either stable or unstable (Table 1), and lesion size was measured and classified as either small, moderate, or large using the classification systems proposed by Takahara et al.[11,12] Defect percentage was calculated as a percent width of the defect size in relation to the capitellum on anteroposterior radiographs. Defect angle was calculated as the angle created from the center of the capitellum to the upper and lower ends of the defect on lateral radiographs. Defect percentages <55% or defect angle <50° were classified as small, and defect percentages >70% or > 90° were classified as large; all others were classified as moderate. To best account for variations in skeletal maturity and lesion size, we further subclassified each lesion based on whether the radial head and capitellar physis were open or closed, similar to Miyake and Masatomi.[24] For the capitellum and the radial head physis, lesions were labeled as either small open, small closed, moderate open, moderate closed, large open, or large closed.

Operative reports were investigated for information related to procedure performed, number of loose bodies present, and intraoperative lesion grade (as determined using the International Cartilage Repair Society classification system).[32] Grade I lesions were considered stable with softened intact cartilage; grade II lesions were stable with probing but had some partial discontinuity; grade III lesions have complete discontinuity with probing; and grade IV lesions had an empty defect or dislocated fragment laying within the defect. Diagnostic elbow arthroscopy with a short small joint 2.7-mm arthroscope was performed on all patients in the prone position with a tourniquet. Standard direct lateral, anterolateral, anteromedial, posterior, and posterolateral portals were used as indicated. Antegrade marrow stimulation/drilling was performed on grade I lesions (n = 1) with a 0.062 smooth pin using fluoroscopy in a trans-osseous articular cartilage-sparing manner. Grade III-IV lesions (n = 17) were treated with loose body removal, abrasion chondroplasty, and marrow stimulation via microfracture or drilling. Capitellar defects were debrided to fresh bleeding subchondral bone, approximately 2 to 3 mm on average,

Table 1. Proposed Classification for Osteochondritis Dissecans Lesions of the Capitellum

Classification	Capitellar Growth Plate	Radiographic Grade	Range of Motion	ICRS Classification
Stable	Open	I	Normal	I
Unstable	Closed	II or III	Restricted	II, III, or IV

NOTE. Adapted from Takahara et al.[12]

ICRS, International Cartilage Repair Society.

with combined use of a shaver and ringed curettes. Microfracture or drilling was then performed using an angled awl, smooth pin, or a PowerPick device (Arthrex, Naples, FL) to a depth of 4 mm based on access and patient body habitus. Inflow and tourniquet pressure were decreased after microfracture to ensure the egress of marrow elements and blood.

All surgeries were performed as same-day procedures, with patients discharged on the day of surgery. A compressive soft dressing was applied for the initial 7 to 10 days postoperatively. An arm sling was provided for comfort. Patients were allowed to begin gentle ROM exercises immediately after surgery. Physical therapy, consisting of full active and active assisted ROM exercises in all planes, began within 1 to 2 weeks from the date of surgery. Strengthening did not begin until full or near-full ROM was achieved and no sooner than 3 months after surgery. All patients were advised to refrain from participating in sports activity for a minimum of 4 to 6 months.

Postoperatively, patients were contacted via phone or seen in clinic at a minimum of 2 years for follow-up. Information on return to primary sport, return to other sports, level of play returned to, total recovery time, need for repeat surgery, and validated patient-reported outcome measurements (PROMs) were recorded. Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH) scores[33] were collected for all patients; Kerlan-Jobe Orthopaedic Clinic (KJOC) Overhead Athlete Shoulder and Elbow scores[34] were only collected on those who returned to their primary sport. Both of these PROMs have been validated for acquisition of information via telephone.[35,36] Length of follow-up was defined as time from surgery to collection of PROM via telephone or clinic visit. Postoperative ROM was recorded from the patient's final postoperative clinic visit.

Descriptive statistics were calculated for all variables. Change over time for ROM and lesion size was compared using the paired-samples t test. Bone age was compared with chronologic age using the paired-samples t test and the Pearson correlation coefficient to identify the presence of and magnitude of a linear relationship. Correlations between patient demographics or lesion characteristics and outcome scores were determined using the Spearman rho correlation coefficient. Differences between various groups of interest on outcomes scores were compared using the Mann−Whitney U test. Preoperative lesion grading was compared with intraoperative lesion grading using the χ^2 test. Factors potentially associated with return to sport were evaluated with either the Mann−Whitney U test or the χ^2 test, as appropriate for variable type. Analyses were performed using SPSS, version 27 (IBM Corp. [Released 2020. IBM SPSS Statistics for Macintosh], Armonk, NY). Alpha was set at $P < .05$ to declare significance.

Results

A total of 20 patients and 21 elbows treated surgically for capitellar OCD met the study's inclusion criteria. Of this cohort, 17 of 20 patients (85%) and 18 of 21 elbows (85.7%) were contacted via clinic follow-up or telephone with a minimum of 2-year follow-up and were included in the final cohort for our study. Our cohort included 3 female and 14 male patients. There was 1 female patient who had bilateral elbows treated surgically at different times. The mean age at time of surgery was 14.1 years (range, 11-17 years), and mean duration of follow-up was 4.4 years (2-10). Mean bone age at time of surgery was 13.9 years (12.5-15). Mean time symptomatic before surgery was 15.6 months (3.5-53.6), and duration of complete rest from sport before surgery was 4.6 months (0-14.8). In this study, primary sport played at time of symptom onset was as follows: baseball, n = 8; gymnastics/cheer, n = 4; and other (swimming, football, golf, mountain biking, tennis), n = 5. Table 2 summarizes the patient demographics for the overall study cohort.

All lesions were noted to be unstable based on the classification by Takahara et al.,[12] indicating a requirement for surgery. Four patients were noted to have an open capitellar physis at time of surgery, and 12 had open radial head physis. Table 3 summarizes the

Table 2. Demographics

	Total
No. of athletes	17
Male	14
Female	3
No. of elbows	18
Dominant arm affected	14
Mean time symptomatic before surgery, mo	15.6
Mean time of complete rest before surgery, mo	4.6
Mean age at surgery, y	14.1
Mechanical symptoms reported	9
Loss of motion reported	7
Sport	
Baseball	8
Gymnastics, cheerleading	4
Other	5

Table 3. Preoperative and Intraoperative Classification of Lesions

	Total
Lesion stability (Takahara)	
Stable	0
Unstable	18
Mean defect percentage	43% (23.4-64.6)
Mean defect angle	59.3° (40-154.6)
Lesion size (Takahara)	
Small	13
Moderate	4
Large	1
Open capitellar physis	3
Open radial head physis	11
Subclassification based on capitellar physis	
SMo	2
SMc	11
Mo	0
Mc	4
Lo	1
Lc	0
Subclassification based on radial head physis (Miyake and Masatomi)	
SMo	8
SMc	5
Mo	2
Mc	2
Lo	1
Lc	0
Intraoperative lesion grade (ICRS)	
I	1
II	2
III	5
IV	10

ICRS, International Cartilage Repair Society; Lc, large closed; Lo, large open; Mc, moderate closed; Mo, moderate open; SMc, small closed; SMo, small open.

preoperative and intraoperative lesion classifications for this study cohort.

Postoperatively, 16 of 18 (88.9%) elbows returned to sports, with 12 of 18 (66.7%) elbows returning to their primary sport at the same level of play or higher. Of those who did not return to their primary sport, 2 baseball players switched to golf by choice, 1 baseball player switched to lacrosse due to fear of injuring his elbow, and 1 football player switched to golf due to fear of injuring his elbow. The 2 patients who switched sports due to fear of injuring their elbow did not report continued pain postoperatively. Of the other athletes not returning to sport, 1 discontinued swimming by choice and 1 discontinued mountain biking due to continued pain in his elbow. Of note, 2 patients had a history of previous lateral condyle fracture years before operation; one discontinued mountain biking due to his elbow pain and the other switched from baseball to golf by choice.

There was a significant improvement in mean total arc ROM postoperatively (132.8°, range 120°-140° postoperatively, compared with 122.1°, range 80°-140°

pre-operatively) ($P = .002$). Mean recovery time before returning to sports for those who did return was reported to be 7.7 months (4.2-19.5). Postoperatively, KJOC Overhead Athlete Shoulder and Elbow scores were collected on 12 of 16 elbows (75%) in patients who returned to sports with a mean score of 94.1 (68.5-100). Of the 4 patients who returned to sports but did not have a KJOC score, 3 were no longer playing sports competitively or recreationally and 1 refused to participate but did report that he had returned to sport. QuickDASH scores were collected on 17 of 18 elbows (94.4%) with a mean score of 2.3 (0-18.2). The patient who refused the KJOC score was the only patient without a QuickDASH score recorded. Postoperative outcome scores and ROM are presented in Table 3. There were no reoperations in our cohort or postoperative complications. When cross-analyses were performed, there was no correlation between time symptomatic prior to surgery, preoperative lesion grade, intraoperative lesion grade, bone age, radial head or capitellar physeal status, or treatment type with outcome scores, range of motion, or return to sport.

Discussion

In this study, all patients showed significant improvement in elbow ROM and excellent PROMs at final follow-up; 16 of 18 (88.9%) elbows returned to sports postoperatively, with 12 of 18 (66.7%) returning to their primary sport at the same level or higher. These results are similar to those reported previously.[26-30] Our findings are presented in the context of those from similar studies in Table 4.

In 2006, Bojanić et al.[26] reported on the first known study to examine outcomes from arthroscopic debridement and microfracture in 3 adolescent gymnasts with a mean follow-up of 12 months. All athletes returned to sport at the same level or higher within 5 months, and postoperative MRI showed reparative fibrocartilaginous tissue filling in the defect site. However, the short-term follow-up and small patient cohort in this study do not allow for definitive conclusions to be drawn. In 2012, Wulf et al.[27] examined 10 patients with a mean age of 13.9 years, 7 skeletally immature and 3 skeletally mature at time of surgery, with mean follow-up of 42 months. Postoperative ROM and outcome scores demonstrated significant improvements in all patients, with 6 of 8 patients involved in competitive athletics returning to the same level of play or higher at an average of 5.1 months. Postoperative MRIs obtained at a mean of 27 months demonstrated a reparative process occurring at the defect site in 8 of 10 patients. Similarly, Lewine et al.[28] examined 21 patients with a mean follow-up of 2.4 years in 2016, reporting resolution on follow-up MRI in 59% of patients. They reported an 85.7% rate of return to sport, with only 66.7% of patients returning to their primary

Table 4. Comparison of Previous Studies on Adolescent Capitellar Osteochondritis Dissecans Treated with Arthroscopic Debridement and Marrow Stimulation with Microfracture/Drilling

Author	Year	Sample No.	Mean Age, y	Mean Time Symptomatic Before Surgery, mo	Mean F/U, y	Reoperation Rate, %	Return to Sport, %*	Mean Time Until Return to Sport, mo	Mean Patient-Reported Outcome Measures
Bojanić et al.[26]	2006	3	14	9	1	0%	100%	5	N/A
Wulf et al.[27]	2012	10	13.9	4.6	3.5	0%	75%	5.1	Timmerman/Andrews Score: 193 Mayo Elbow Performance Score: 97
Lewine et al.[28]	2016	21	13.4	11.6	2.2	19%	66.7%	Not reported	Timmerman/Andrews Score: 184
Bexkens et al.[29]	2017	75	15.7	18	3.5	4.3%	55%	Not reported	Oxford Elbow Score: 40.8
Matsuura et al.[30†]	2020	23	14.7	Not reported‡	11.5	4.3%	87%	4.1	Timmerman/Andrews Score: 195
Current study		18	14.1	15.6	4.4	0%	66.7%	7.7	Kerlan-Jobe Orthopaedic Clinic Score: 94.1 QuickDASH: 2.3

F/U, follow-up; N/A, not available.

*Return to sport percentage based on return to primary sport at same level or higher.

†Only 10 patients underwent marrow stimulation/drilling.

‡Reported a minimum of 6 months nonoperative treatment before surgery.

sport. They also reported 4 revision surgeries. It should be noted that patients in this study had grade IV lesions; in addition, lesion containment was found to be a better indicator of successful response more so than lesion area. This is contrary to Bexkens et al.,[29] who examined 71 patients, with mean age of 16 years (range, 11-26 years) and mean follow-up of 3.5 years, treated with arthroscopic microfracture and found no difference between outcome with contained (intact lateral wall) versus uncontained (loss of lateral wall) lesions. Interestingly, they reported only a 55% rate of return to sport at the same level or higher. This could potentially be explained by the older patients in their cohort, as there was an association between open capitellar physis at time of surgery and improved outcomes as well as shorter length of preoperative symptoms. There was also a high proportion of patients (26.5%) who had a history of previous elbow surgeries. As a follow-up to this study, they examined computed tomography scans at a mean of 29 months, reporting evidence of decreased lesion size and healing of subchondral bone in 85% of patients.[37] It also should be noted that there was no correlation between clinical outcomes and findings on imaging. While these studies do not provide definitive evidence for articular restoration with microfracture/marrow stimulation, they do demonstrate a clear short-term benefit to this treatment and the possibility that the natural progression of this disease can potentially be altered.

To our knowledge, the only study focused on arthroscopic microfracture with longer follow-up than ours was conducted by Matsuura et al.,[30] who examined 23 adolescent baseball players with varying lesion size, mean age of 14.7 years, and mean final follow-up at 11.5 years. In this study, the 10 patients who underwent microfracture were those with evidence on imaging of a sclerotic bone bed. There were no significant differences in PROMs between groups or based on lesion size. Twenty patients (87%) were able to return to competitive play, but only 1 of 5 (20%) baseball pitchers were able to return to pitching. This is an improvement from the 40% return to sport rate reported by Byrd and Jones,[22] in their study of baseball players who underwent arthroscopic abrasion chondroplasty alone; however, that study did not specify differences in symptoms and/or recovery between position players and pitchers. This further highlights the difficulty in evaluating outcomes in this population due to the different physical demands of various sporting activities as well as the different positions within a given sporting activity. The aforementioned results may suggest no difference between arthroscopic debridement alone and microfracture/marrow stimulation but do help to further confirm the long-term durability of arthroscopic treatment of this disease.

Looking closer at our 6 patients who did not return to their primary sport, only 3 of these patients reported that this change was related to their elbow injury, with 2 of them citing fear of continued symptoms and only 1 citing actual pain. This highlights the importance of the psychological toll this particular injury can take on a young athlete, which should be considered when evaluating return to sport rates in the literature. In addition, as highlighted by Wulf et al.[27], a sooner return to activity carries significant emotional and psychological benefit for these adolescents, something that is often overlooked in orthopaedic research. This further advocates for arthroscopic interventions (when indicated) over more invasive open mosaicplasty procedures. In this study, mean time to return to sport was 7.8 months postoperatively. This is longer than some of the recovery periods (4-6 months) reported in the recent

literature.[26,27,30] This could likely be attributed to our strict postoperative protocol of no graduated return to sport for a minimum of 4 to 6 months postoperatively. As suggested by Wulf et al.,[27] if resolution of clinical symptoms is noted beyond 3 months, there is likely mature healing at the injury site that may even benefit from biological loading for further maturation and remodeling. While this hypothesis is only theoretical, it does suggest that earlier return to play be considered in asymptomatic cases.

We additionally examined defect size/grade, bone age, and physeal status of the capitellum and radial head. We found no difference in ROM, outcome, or return to sport based on these factors, suggesting that marrow stimulation in adolescent patients produces mesenchymal stem cells for biologic healing, regardless of bone age or physeal status. Postoperative radial head enlargement in patients with an open radial head physis has previously been associated with a high rate of reoperation.[9,21,24] It should be noted that in these studies, patients were treated either conservatively or with debridement alone. While we did not obtain postoperative imaging in this study, there were no reoperations in our study cohort, which suggests that if postoperative radial head enlargement had occurred in patients with an open radial head physis at the time of surgery, it did not present with any long-term functional or clinical deficits. Furthermore, the reparative process triggered by marrow stimulation may have prevented this pathology. We also found no difference in outcome based on preoperative symptom duration, although previous reports have suggested longer time to surgery could lead to worse outcomes.[29] We continue to advocate for a period of conservative treatment and rest before considering surgical intervention, as long as there is no significant loss of motion and/or loose body present on initial presentation. With our study's excellent outcomes and the fact that patients reported symptoms for a mean of 15.4 months preoperatively, we suggest that there is minimal downside to trialing a period of rest if the above criteria are met. However, as stated previously, many of these patients present late in the disease course and have often attempted conservative care prior to presentation. In addition, it has been well documented that compliance can be challenging in the adolescent athlete population, especially with the psychological burden that comes with the long period of conservative care required for healing.[14] This may explain why patients in our study only reported 3.72 months of complete rest before surgery. All of these factors should be considered and discussed with the patient and parents in order to reach the optimal treatment decision for each individual patient.

Based on the findings of this study, we continue to advocate for initial arthroscopic treatment of capitellar

OCD when indicated especially in treating the adolescent athlete to avoid potential lengthy recovery and elbow stiffness incurred from the use of osteoarticular autograft. It should be noted that all lesions in this study were contained lesions with an intact lateral wall. In addition, while all lesions were found to be unstable based on the Takahara classification,[12] we believe using lesion size based on defect angle/percentage[11] and whether or not the capitellar physis is open or not, serve as better guides when deciding between arthroscopic marrow stimulation versus osteoarticular autograft. All defects in our study were either small or moderate in size with the exception of 1 patient who had a large defect but an open capitellar physis. This particular patient had follow-up at 24 months and did return to his primary sport of baseball with a KJOC Overhead Athlete Shoulder and Elbow score of 88.5. We typically reserve mosaicplasty as a salvage procedure if primary surgical treatment has failed or in rare cases with large uncontained defects and a closed capitellar physis.

Limitations

This study is not without limitations. The retrospective nature of the study and relatively small sample size limit the strength of our conclusions. In addition, we did not obtain any postoperative imaging more than 3 months after surgery. While the goal of this study was to examine clinical outcomes, future studies that include the evaluation of radiographic and other advanced imaging may provide further insight into the reparative process associated with microfracture/marrow stimulation and better clarify the correlation between clinical and imaging outcomes. Lastly, our clinical follow-up in this study was short and most information was collected via telephone. However, both the PROMs used in this study have been validated for use via telephone.[35,36]

Conclusions

Arthroscopic debridement and marrow stimulation for capitellar OCD in adolescent athletes leads to improvements in ROM, as well as a high rate of return to sport, and high levels of athletic and daily functional activity during follow-up, regardless of bone age and lesion grade/size at time of surgery.

Acknowledgments

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