Results of Bone Peg Grafting for Capitellar Osteochondritis Dissecans in Adolescent Baseball Players

Abstract

Background: Bone peg grafting (BPG) has been advocated for early stage humeral capitellar osteochondritis dissecans (COCD). However, the clinical and radiological results of BPG, along with its indications, have not been described in detail.

Hypothesis: COCD of OCD I or II of International Cartilage Repair Society (ICRS) classification in adolescent baseball players can be treated successfully by BPG.

Study design: Case series

Methods: Eleven male baseball players who underwent BPG for COCD were enrolled. Subjects' age at the time of surgery ranged from 12 to 15 years. No improvement had been seen in any case after 6 months of preoperative non-throwing observation. During surgery, 2 to 5 bone pegs were inserted into the COCD lesion after confirmation of lesion stability to the bony floor. All cases were directly evaluated at 12 and 24 months after surgery by physical findings, radiological prognosis, and MRI.

Results: Ten of 11 patients could return to comparable baseball ability levels within 12 months. The Timmerman/Andrews score improved significantly from 171.8 ± 12.1 (average ± SD) points preoperatively to 192.3 ± 6.5 points at the final observation. Radiological healing of the lesions was determined as complete in 8 cases and partial in 3. Patients possessing a centrally positioned lesion or one less than 75% of the size of the capitellum tended most strongly to achieve complete radiological healing, while growth plate status appeared unrelated to outcome. The average Henderson MRI score improved from 6.3 ± 1.5 to 4.8 ± 1.6 at 12 and 24 months after BPG, respectively. MRI findings also suggested that remodeling of COCD lesions had continued to up to 24 months postoperatively.

Conclusion: BPG enabled 91% of COCD patients with ICRS OCD I or II to return to preoperative baseball abilities within 12 months. Integration of the grafted site may continue until at least 24 months postoperatively. An ICRS OCD I or II lesion with central positioning

and/or occupying less than 75% of the size of the capitellum in the coronal plane is a good indication for BPG.

Key terms: Elbow, Baseball, Pediatric Sports Medicine, Osteochondritis Dissecans, Humeral Capitellum, Bone peg

What is known about the subject: COCD lesions do not necessarily require surgical intervention, but the literature suggests that patients may achieve better short- and mid-term results with certain types of surgical procedures depending on the size and location of the lesion as well as patient demands. At that time, the appropriate surgical method should be selected based on the International Cartilage Repair Society (ICRS) OCD classification. There have been no comparative studies between debridement with microfrature and/or loose body removal and mosaicplasty; lesions involving 50% or less of the surface area of the capitellum have excellent results with the former, while larger lesions may have better outcomes when treated with the latter. Bone peg grafting (BPG) has been reported as an effective treatment option for COCD to preserve local hyaline cartilage to the OCD lesion in the distal femur. However, in cases of an OCD lesion in the humeral capitellum, little is known on the clinical results, such as the possibility of returning to competitive sports or radiological healing prognosis, and the indications for this technique are unclear.

What this study adds to existing knowledge: The present study analyzed the clinical and radiological results of a retrospective series of COCD cases with ICRS OCD I or II after 24 months of observation following BPG. Clinical findings as determined by the elbow rating system of Timmerman and Andrews revealed significant improvements overall and in all cases. Ten of 11 patients could return to pre-injury baseball ability levels. Radiological healing of the lesions was complete in 8 cases and partial in 3. All subjects with a central lesion or one occupying less than 75% of the size of the capitellum in the coronal plane achieved complete radiological healing, while growth plate status was unrelated to outcome. Postoperative MRI revealed a significant sequential improvement in Henderson score from 12 to 24 months. This is the first study of its kind on the clinical and radiological results of BPG for COCD in adolescent baseball players that also provide several indications for this technique.

INTRODUCTION

Capitellar osteochondritis dissecans (COCD) is a focal injury of the articular cartilage involving separation of a segment of cartilage from subchondral bone that is rarely encountered in the dominant side elbow of adolescent throwing athletes.[3,6] The exact etiology of COCD is unclear, although repetitive microtrauma at the capitellum created by compressive and shearing forces from valgus stress during the acceleration phase of throwing, as well as immaturity of the articular surface, seem to trigger this condition.[3,16,21] If the COCD lesion is stable to the bony floor, it will likely heal with rest and conservative management. After the lesion becomes unstable or detached from the floor, however, surgical intervention provides better results.[29,30,35]

Minami et al.[22] first established the radiological grading of COCD in 1979. Grade I lesions included elbows in which a translucent cystic shadow was seen in the lateral or middle parts of the capitellum. Grade II lesions were split-type, whereby a clear zone or split line was seen between the lesion and adjacent subchondral bone. Grade III lesions exhibited detached free body formation.[22,26] As Grade I and II lesions are mostly stable, conservative therapy, such as suspension of throwing, avoidance of carrying heavy loads, and passive range of motion (ROM) exercise that include the hip, shoulder, and elbow joint constitute the first choice of treatment. The percentage of patients with Minami's radiological Grade I or II treated conservatively for more than 6 months who could return to previous levels of sports ability has ranged from 58%[23] to 76%.[20] When symptoms persist with no sign of radiological recovery after 6 months of conservative management, surgical intervention should be considered. The appropriate treatment procedure for COCD is commonly selected during intraoperative observation based on the International Cartilage Repair Society (ICRS) OCD classification system.[9] If the cartilage exhibits signs of advanced progression, such as dead *in situ* (i.e., ICRS OCD III) or free body formation (i.e., ICRS OCD IV), an autologous osteochondral

graft from the distal femur or rib may be the most suitable treatment course, especially for relatively large lesions, for which excellent clinical and radiological results have been reported.[11,12,27] If the defect is small in such advanced lesions, bone resurfacing by marrow stimulation via microfracture or drilling may also be effective.[14,33]

In rare instances of COCD, the hyaline cartilage of the capitellum is preserved to result in softening alone (i.e., ICRS OCD I) or a fissure in the cartilage (i.e., ICRS OCD II). At this early disease stage, procedures that retain the normal contour of the capitellum and stabilize the osteochondral fragment to the floor are indicated.[3,29] However, few studies on the surgical treatment of these lesions exist.

We hypothesized that cortical bone peg grafting (BPG) from the articular cartilage to the subchondral bone within the initial stages of COCD could unite the lesion with the bony floor and preserve the original local hyaline cartilage of the capitellum not only by bone marrow stimulation, but also by stabilization of the fragment. Accordingly, we consecutively performed BPG on adolescent players with ICRS OCD I or II and retrospectively assessed their clinical and imaging results.

MATERIALS AND METHODS

Participants

Eleven consecutive adolescent baseball players who underwent BPG for COCD at the last author's institution between February 2004 and May 2012 were enrolled in this study. The indications for BPG were as follows: 1) failure of at least 6 months of conservative non-throwing observation, 2) Grade I or II COCD lesions as proposed by Minami et al.[22] evaluated using plain tangential anteroposterior (AP) radiographs of the forearm with the elbow at 45 degrees of flexion within 1 month before surgery, and 3) ICRS OCD I or II confirmed by arthroscopy and direct observation immediately prior to the procedure. All cases were male and affected in the dominant side elbow (10 on the right and 1 on the left). Regarding fielding

position, 8 patients were pitchers, 2 were outfielders, and 1 was an infielder. All subjects had initially complained of elbow pain while playing baseball and were monitored by plain radiographs during an abstinence of throwing sports of at least 6 months. Since the lesions and symptoms persisted, all patients opted for surgical treatment. Average age at the time of surgery was 14 years (range: 13-16 years). Mean range of elbow flexion was 132 degrees. Mean extension and flexion restriction as compared with contralateral elbows were 9 and 6 degrees, respectively.

Immediately prior to surgery, plain radiographs demonstrated Minami's Grade I in 1 case and Grade II in 10 cases. Lesion size in the coronal plane was larger than half of the width of the capitellum in the tangential AP view for all cases, with an average size of 67.5% (range: 55.0-85.6%). Lesion locations as determined from plain radiographs in the tangential AP view were divided into 2 types: 1) lateral, in which the radiolucency or fragmented lesion involved the lateral wall of the capitellum (7 cases), and 2) central, whereby the lesion had not reached the lateral wall (4 cases). Growth plates at the lateral condyle of affected elbows were open in 5 cases at the time of surgery and closed in the remaining 6. Preoperative MR images were obtained for all patients using a 1.5 T MRI device (Signa Horizon LX 1.5T; GE Medical Systems, Milwaukee, Wisconsin, USA) with a 20 cm circular surface coil. We procured unenhanced oblique-sagittal T1-weighted spin-echo images (repetition time/echo time: 580 ms/16 ms) and oblique-coronal and oblique-sagittal T2-weighted fast spin-echo images (2000 ms/14 ms, respectively) with a section thickness of 2 mm, intersection gap of 0.5 mm, matrix of 320×(202-256), and field of view of 120 mm. The MRI classification system recently proposed by Itsubo et al.[10] was used for preoperative MRI assessment. Three cases were judged as stage 1, 5 as stage 2, 2 as stage 3, and 1 as stage 4. In terms of arthroscopic and direct visual findings just prior to the bone peg procedure, 2 cases were determined as ICRS OCD I and the remaining 9 as OCD II.

Surgical technique

All operations were performed under general anesthesia by the senior co-author who assessed the continuity of the capitellar cartilage surface by direct vision and arthroscopy and evaluated the stability of the capitellar lesion by palpation using an arthroscopic probe. The capitellar lesion was explored between the extensor carpi ulnaris (ECU) and the anconeus muscles. The elbow capsule was opened and the capitellar lesion was exposed, after which the lesion was graded according to ICRS OCD classification. Stable lesions with a continuous but softened area covered by visually and elastically normal cartilage were classified as ICRS OCD I (2 cases), while those with partial discontinuity that were stable when probed were determined as ICRS OCD II (9 cases).

Another skin incision of 3 cm in length was made at the posterior metaphysis of the ipsilateral olecranon. The ECU and the flexor carpi ulnaris muscle were separated and the medial side of the cortex of ulna was exposed. A rectangle measuring approximately 20×10 mm was outlined on the medial cortex of the ulna, after which the 4 corners of the rectangle were bored using a 1 mm diameter Kirschner wire. Thereafter, up to 3 bone pegs of roughly 20 mm in length were carefully harvested from the cortex using a surgical bone saw. A similar procedure was performed on the lateral side of the cortex of the ulna in cases requiring 4 or 5 bone pegs. The pegs were approximately 2 mm in diameter at the tip and 3 mm in diameter at the head (Figure 1A). Holes in the lesion for bone peg grafting were interspaced by approximately 5 mm. The depth of each hole made was approximately 25 mm using a 3 mm diameter Kirschner wire instead of a drill to protect the cartilage from excessive shearing stress. Bone pegs were inserted into the holes to a depth of 10 mm using tweezers, after which a flat surface rod was placed on the head of the bone peg to advance it by gentle tapping with a mallet to a depth slightly lower than the articular cartilage surface (Figure 1B). The incised joint capsule was left open, the fascia of the ECU and anconeus was firmly sutured, and the wound was closed.

Postoperatively, the elbow joint was immobilized in a plastic cast at 90 degrees of flexion for 3 weeks. Active and assisted passive ROM exercises were gently started after removal of the cast. Throwing was allowed 6 months after the operation, starting from short to longer distances at higher velocities. The patients were allowed to return to pre-injury levels of competitive baseball from between 8 and 12 months postoperatively.

This study has been approved by the institutional review board and ethics committee. All patients and legal guardians provided informed written consent for inclusion in the study.

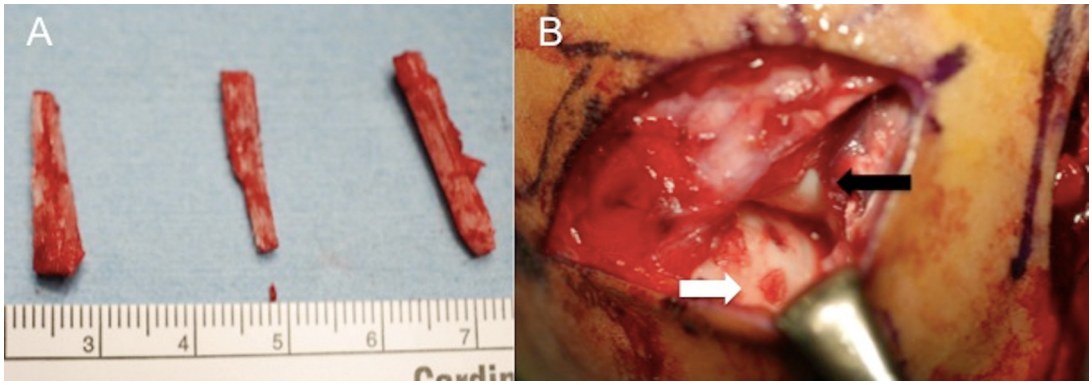

Figure 1. Intraoperative photographs (case 3)
A: Bone pegs harvested from the cortex of the ipsilateral olecranon.
B: Capitellum after insertion of 3 bone pegs (white arrows). The elbow is flexed at 90 degrees. Black arrow indicates radial head.

Postoperative evaluation

All patients were clinically evaluated at 24 months postoperatively during a mean follow-up period of 33.9 months (range: 24-59 months). The rating system of Timmerman and Andrews[32] was used for comparisons between preoperative and postoperative elbow conditions in each patient. We defined "return to sports" as a return to pre-injury levels of sports ability and recorded the time required after surgery for a return to sports for all subjects.

In terms of postoperative radiographic changes, we divided the subjects into the complete, partial, and no radiological healing groups based on plain radiographs in the

tangential AP and oblique views taken at 24 months after surgery. We regarded the following findings as indicative of complete radiological healing: 1) disappearance of the radiolucent area without free body formation, and 2) recovery of a spherical contour of the subchondral bone under the humeral capitellum on postoperative radiographs. We defined partial radiological healing as when the above findings were observed partly or when abnormal shadows remained in the capitellum. Cases displaying no improvement or worsening of radiological findings were classified into the no healing group. Moreover, preoperative radiographs were retrospectively investigated in these groups and compared for the following aspects: 1) size of the lesion as determined by width in the tangential AP view, 2) percentage of the lesion defined as the width of the lesion divided by the diameter of the capitellum in the tangential AP view, 3) location of the lesion as either central or lateral, and 4) condition of the growth plate as either open or closed.

Sequential changes in repair sites were evaluated on MR images taken at 12 and 24 months after surgery by the first author using the scoring system of Henderson et al.[8] Although originally designed as an assessment tool for repair sites of autologous chondrocyte implantation, this system was also found to be suitable for the evaluation of healing at surgically treated sites, especially those aimed at cartilage restoration.[12] The type and modality of MRI were identical throughout the study. The subcategories of fill of repair site, signal at repair site, bone marrow edema, and joint effusion were individually scored from 1 (best) to 4 (worst), and then overall scores were calculated for comparisons between 12 and 24 months of postoperative MRI change. A board-certified orthopedic surgeon who was not the main BPG procedure operator performed the radiological and MRI review.

Statistical analysis

All scoring data are presented as mean ± standard deviation. The paired *t*-test was used for comparisons between pre- and postoperative clinical scores and for those among

postoperative MRI scores. Receiver operating characteristic (ROC) curve analysis was adopted for determining the optimal cut-off value of lesion size in relation to radiological prognosis. For the analysis of correlations between preoperative growth plate status and radiological healing status, we employed Fisher's exact test. The level of statistical significance was set at a p value of less than 0.05. Statistical analyses were performed using the statistical package R, version 3.1.1 (http://.r-project.org).

RESULTS

We observed no postoperative complications, such as infection, neurological problems, fracture, or contracture, during the course of the study. No patients complained of elbow pain during activities of daily living or sports throughout follow-up. Ten of 11 (91%) participants could regain comparable baseball ability levels within 12 months after BPG, with the remaining adolescent switching to basketball between junior and senior high school (case 10). Timmerman/Andrews scores improved in all patients and significantly overall from 171.8 ± 12.1 (average ± SD) points preoperatively to 192.3 ± 6.5 points at the observation end point ($p<0.01$). The subjects in this study possessed stable lesions and had no complaints in ADL before surgery, stating occasional pain, swelling, and activity limitation for throwing activities only. Thus, the preoperative Timmerman/Andrews scores of the patients were high and ranged from 150 to 185 points (Table 1).

Table 1 Clinical results and radiological healing of the lesion

Case no.	Age (years)	X-ray grade[a]	MRI stage[b]	ICRS OCD	Timmerman / Andrews[32] clinical score (points)		Return to sports (M[d])	Position in baseball		Radiological evaluation of the OCD lesion at 24 M[d]
					Preop[c]	24 M[d]		Preop[c]	Postop[e]	
1	13	II	1	I	185	200	7	Infielder	Infielder	Complete
2	14	I	1	II	185	195	11	Infielder	Infielder	Complete
3	15	II	1	I	150	200	8	Pitcher	Pitcher	Complete
4	13	II	2	II	175	185	11	Outfielder	Outfielder	Partial
5	13	II	2	II	175	185	11	Outfielder	Outfielder	Complete
6	13	II	2	II	180	200	7	Pitcher	Pitcher	Complete
7	14	II	2	II	165	195	10	Pitcher	Infielder	Partial
8	15	II	3	II	175	190	7	Infielder	Infielder	Complete
9	16	II	2	II	175	195	7	Pitcher	Infielder	Complete
10	13	II	4	II	175	185	12	Infielder	Basketball	Partial
11	15	II	3	II	150	185	8	Pitcher	Pitcher	Complete

[a]: Preoperative X-ray grade by Minami M, et al.[15] [b]: Preoperative MRI stage by Itsubo T, et al.[10]
[c]: Preop: preoperation [d]: M: months after surgery [e]: Postop: postoperation
Radiograph of the lesion was evaluated as complete if both conditions were fulfilled: (1) Disappearance of radiolucent area or fragment without free body formation, and (2) Recovery of a spherical surface of the humeral capitellum from the postoperative plain radiographs in tangential AP and oblique views.

Complete radiological healing of lesions was confirmed at 24 months in 8 subjects, who had all resumed competitive baseball at preoperative ability levels (Figure 2). In the 3 partial radiological healing cases (cases 4, 7, and 10), whereas the lateral part of the lesion was healed and its size reduced, the radiolucent line between the lesion and the bony floor remained (Figure 3). There were no cases classified as no radiological healing.

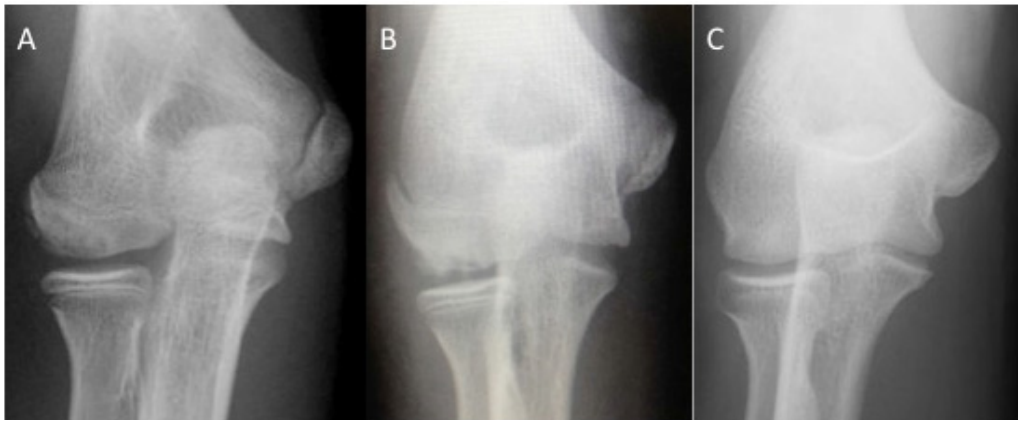

Figure 2. Tangential AP radiographs of an elbow exhibiting complete radiological healing (case 1)
A: Preoperative radiograph disclosing lateral type Grade II OCD. The growth plate is open. The lesion is 10 mm

in width and lesion percentage is 75.3%. B: Immediately after grafting 3 bone pegs. C: Postoperative radiograph at 24 months revealing complete healing of the lesion.

Figure 3. Tangential AP radiographs of an elbow exhibiting partial radiological healing (case 4)
A: Preoperative radiograph showing Minami Grade II, lateral type OCD. The growth plate is open. The lesion is 16.5 mm in width and lesion percentage is 85.6%. B: Immediately after grafting 5 bone pegs. C: Postoperative radiograph at 24 months disclosing partial radiological healing.

Table 2 summarizes the preoperative radiological features between the groups. In complete radiological healing patients, lesion size and percentage tended to be smaller than those in partial healing patients. According to ROC curve analysis, the cut-off point for percentage of the lesion leading to complete radiological healing was less than 75.3% (sensitivity: 66.7%, specificity: 100%, area under the ROC curve: 0.750). Four of the 8 cases in the complete healing group displayed lateral type COCD, while all 4 cases of central lesions achieved complete radiological healing. In contrast, 3 of 7 lateral type lesions resulted in partial healing. There was no relationship between the status of the growth plate and radiological healing (Fisher's exact test, $p = 0.55$). The bone pegs disappeared gradually and were undetectable at 12 months after surgery. There were no cases in which postoperative radiographs revealed fracture of grafted bone pegs.

Table 2 Comparison of preoperative radiographs at the capitellar OCD lesion between complete healing and partial healing groups

Group (Number of cases)	Percentage of lesion[a]		Location		Growth plate	
	＜75%	≥75%	Lateral	Central	Open	Closed
Complete healing (8)	7	1	4	4	3	5
Partial healing (3)	1	2	3	0	2	1

[a]: Width of the lesion divided by the diameter of the capitellum from tangential AP view×100.

MRI of the elbow was performed before BPG and at 12 and 24 months afterwards in all except 2 cases, which was due to claustrophobia at 24 months in case 10 and economical reasons at 12 months in case 11. In the remaining 9 data sets, the average overall MRI score improved significantly from 6.3 ± 1.5 to 4.8 ± 1.6 at 12 and 24 months after BPG, respectively ($p<0.01$) (Table 3). MRI evaluation category scores were improved in 6 cases for signal at the repair site, 3 cases for bone marrow edema, and 4 cases for effusion at 24 months from 12 months postoperatively. One case achieved an overall MRI score of 4 at 12 months after BPG, while 7 others attained this score at 24 months following surgery. Since capitellar hyaline cartilage signal was preserved postoperatively, we evaluated complete fill of the repair site for all cases at 12 and 24 months after BPG. Signals indicating that the grafted bone pegs remained were evident in 7 cases at 12 months postoperatively, but these had disappeared at 24 months in 5 cases (Figure 3). MRI revealed residual bone pegs in 2 cases at the study end point (cases 4 and 7). Several MR images disclosed that the lesion remained fragmented with a T2 high intensity gap between the subchondral bone and floor of the lesion. These were considered to represent an abnormal signal at the repair site. Bone marrow edema proximal to the bone pegs was observed in 5 of 10 cases, and joint effusion around the radial head or olecranon fossa was noted in 6 of 10 cases, at 12 months postoperatively. These signals were absent at the observation end point in most patients (Table 3).

Figure 3. Oblique-sagittal T2-weighted fast spin-echo MRI of an elbow exhibiting complete radiological healing (case 8)

A: Preoperative MRI. Normally shaped capitellum with several spotted areas of higher intensity than that of the cartilage, discontinuity of the chondral surface signal, and no high signal interface is apparent between the lesion and the floor. Itsubo MRI classification stage is 3. B: Postoperative MRI at 12 months revealing nearly normal signaling at the repair site with mild bone marrow edema and joint effusion. The signal of a grafted bone peg (white arrow) remains. C: Postoperative MRI at 24 months demonstrating normal signaling at the repair site without evidence of bone marrow edema, joint effusion, or residual bone peg.

Table 3 Postoperative MRI evaluation according to Henderson's scoring system

Case no.	Postoperative MRI score									
	Fill of repair site		Signal at repair site		Bone marrow edema		Effusion		Overall	
	12M[a]	24M[a]	12M[a]	24M[a]	12M[a]	24M[a]	12M[a]	24M[a]	12M[a]	24M[a]
1	1	1	1	1	1	1	1	1	4	4
2	1	1	2	1	1	1	2	1	6	4
3	1	1	2	1	1	1	1	1	5	4
4	1	1	3	3	2	2	2	1	8	7
5	1	1	2	1	2	1	1	1	6	4
6	1	1	2	1	1	1	1	1	5	4
7	1	1	3	3	2	2	2	2	8	8
8	1	1	2	1	2	1	2	1	7	4
9	1	1	3	1	2	1	2	1	8	4
10	1	NP	3	NP	2	NP	2	NP	8	-
11	NP[c]	1	NP	1	NP	1	NP	1	-	4
Ave.[b]									6.3	4.8

[a]: M: Months, [b]:Ave: Average of case 1 to 9, [c]NP: not performed
Fill of repair site: 1; Complete, 2; > 50% of defect, 3; < 50% of defect, 4; Full-thickness defect
Signal at the repair site: 1; Normal, 2; Nearly normal, 3; Abnormal, 4; Absent
Bone marrow edema: 1; Absent, 2; Mild, 3; Moderate, 4; Severe
Effusion: 1; Absent, 2; Mild, 3; Moderate, 4; Severe

DISCUSSION

The literature supports a high spontaneous healing potential of COCD in its early

stages and recommends conservative management as the first treatment choice.[20,29] However, there are some patients who persistently show no sign of radiological recovery after 3-6 months of throwing abstinence. In such situations, surgical intervention may be considered for competitive throwing athletes. The appropriate surgical procedure should be decided depending on lesion size, stability, viability, location, and patient age.[3,29] If the COCD lesion is progressed at ICRS OCD III or IV and unstable or detached from the floor, an autologous osteochondral graft from the distal femur or rib is generally the most suitable method, especially for a large lesion size.[11,27] In cases of stable ICRS OCD I or II COCD lesions after conservative treatment, however, there are several surgical options available. Mosaicplasty achieves excellent results, but may be too invasive for this early stage and sacrifices the intact cartilage of the femur or rib. Arthroscopic debridement of the softened or fissured cartilage with or without loose body removal has also been shown to relieve symptoms, although the rate of return to pre-injury sports activity varied from 40 %[28] to 81%.[4] Moreover, 38% of patients receiving this procedure experienced a recurrence of locking or catching.[4] Bradley et al.[3] found that drilling of small lesions measuring <55% of the capitellum along with debridement of the damaged cartilage to the stable margin may have a good prognosis. Other authors have described the efficacy of arthroscopic bone marrow stimulation via transhumeral or transarticular drilling/microfracture for COCD,[19,33] but these series contained various stages of cartilage lesion. Only Krijnen et al.[15] have reported good clinical results in 4 adolescent athletes with early stage COCD with a short average follow-up of 5 months. Therefore, the clinical and radiological results of cases of ICRS OCD I or II following failed conservative treatment have not been precisely investigated.

It is known that recovery after cartilage debridement with marrow stimulation is not the regeneration of hyaline cartilage, but rather the induction of fibrous cartilage. Since we believe that surgical intervention for early stage COCD should aim for osteochondral fragment fixation with preservation of local cartilage, we opted for BPG in order to conserve

391 the hyaline cartilage of the capitellum in our cohort with early stage COCD lesions that
392 involved over 55% of the surface area of the capitellum. The main advantage of BPG as
393 compared with simple drilling is that it secures the lesion to the floor as a physiological
394 scaffold and becomes integrated into the grafted site.

395 Bandi et al.[2] were the first to describe the technique of drilling and BPG. In their
396 single case of OCD in the distal femur, the fragment was solidly united with the floor.
397 Afterwards, BPG was performed on cases of lesions corresponding to ICRS OCD II or III in
398 the distal femoral articulation and resulted in a high rate of fragment union.[7, 13, 18, 24] Arcq[1] firstly
399 performed BPG for COCD, but did not describe the results in detail. Oka et al.[26] then
400 investigated the clinical and radiological results of BPG in 16 patients with Minami Grade I
401 or II COCD lesions and witnessed that 15 obtained bony union after an average period of 4.7
402 months for Grade I and 7.1 months for Grade II. Based on these findings, they proposed that
403 BPG might be effective for relatively early stage lesions. However, they did not address the
404 possibility of returning to previous levels of sports ability, nor did they evaluate pre- or
405 postoperative cartilage conditions in detail. Mihara et al.[20] treated 7 patients at various stages of
406 COCD by BPG in their 27-patient series. Two patients with early stage COCD receiving BPG
407 achieved Timmerman/Andrews scores of 185 and 200 points, respectively. Thus, this study
408 restricted the indication for BPG to ICRS OCD I or II only.

409 We observed excellent clinical results both for ICRS OCD I and II lesions in this
410 investigation. Timmerman/Andrews scores, pain, and ROM of the elbow were improved in all
411 patients. Ten of 11 (91%) subjects could return to comparable ability levels within 12 months.
412 However, the lesions remained fragmented at 24 months postoperatively in 3 of 11 patients. In
413 these 3 partial healing cases, Timmerman/Andrews scores were high and ranged from 185 to
414 195 points, although there were no obvious differences as compared with scores of complete
415 healing cases. A restriction in elbow extension motion was the main reason for most
416 deductions. The patient who quit baseball in this series belonged to this group. His cessation

might have been due to incomplete radiological recovery. Retrospective comparisons of preoperative radiographs between the complete and partial healing groups uncovered that a larger size and lateral position tended to be potential factors associated with a poor radiological prognosis. Similar findings were reported in a case series of arthroscopic debridement; Byrd et al.[5] pointed out that an avulsed lateral fragment may be indicative of an unfavorable result.

To our knowledge, this is the first study to perform pre- and postoperative MRI assessment of BPG for COCD. In 7 of 9 cases, a grafted bone peg signal clearly remained at 12 months following surgery with intensity different from that of the surrounding bone marrow. However, such signals were absent in 5 cases 12 months afterwards and contributed to the Henderson score improvement at 24 months from 12 months postoperatively. This observation implies that the integration of bone pegs may occur 12 months after BPG and that remodeling of the OCD lesion after BPG requires more than 12 months. Nobuta et al.[25] reported good clinical and radiological results for pull-out wiring in 28 patients with Minami Grade I or II lesions. Kuwahata et al.[17] described the short-term results of 7 cases of COCD lesions treated with Herbert screw fixation of iliac cancellous bone grafts. They witnessed that all patients could return to their previous sporting activities with an average of 18 degrees of elbow ROM increase. However, the metal hardware damaged the cartilage surfaces on both the embedded and facing sides and needed removal. Recently, biodegradable pins or screws made from poly-lactic acid (PLLA) or hydroxyapatite (HA)/PLLA have been used to arthroscopically fix osteochondral fragments.[31,34] Although BPG cannot secure the lesion to the floor as strongly as these fragment fixation techniques, it may serve as an adequate physiological scaffold that is integrated gradually into the grafted site with few, if any, complications.

There are several limitations to this retrospective study. First, the sample size was too small to obtain reliable statistical differences. Second, the minimum follow-up period was

only 2 years and insufficient to evaluate for radiological osteoarthritic changes. Third, we could not perform arthroscopic reassessment of the repaired sites and were unable to obtain histological proof of hyaline cartilage preservation. Lastly, we did not include any control cases in which marrow stimulation via drilling or microfracture, fragment fixation by wiring, or mosaicplasty were performed on cases of same stage COCD.

CONCLUSIONS

This investigation showed that BPG enabled 91% of COCD cases with ICRS OCD I or II to return to preoperative baseball ability levels within 12 months. Based on MRI findings, integration of the grafted site continued until at least 24 months postoperatively. This study suggests that an ICRS OCD I or II lesion with central positioning and/or occupying less than 75% of the size of the capitellum in the coronal plane is a good indication for the BPG technique.

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