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Treatment of osteochondritis dissecans of the humeral capitellum with a fragment fixation method using absorbable pins

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ABSTRACT

Hypothesis: This study aimed to investigate the results, indications, and limitations of absorbable pin fixation for osteochondritis dissecans of the humeral capitellum in the separation stage.
Methods: This study included 35 patients (mean age, 14.0 years). Patients were divided into two groups: Group A included those who obtained complete union within 6 months and Group B included those who did not observe complete union within 6 months. The clinical findings were compared between the groups.
Results: There were 26 and 6 patients in Groups A and B, respectively. Two patients did not obtain complete union. Clinical outcomes improved after the procedure. In univariate analysis, delayed union was associated with larger major diameter ($P = .0004$) and more depth ($P = .03$) of the osteochondral fragment measured by computed tomography, the presence of osteosclerosis in the subchondral bed on X-ray imaging ($P = .003$), and the presence of comminution of subchondral bone on ultrasound imaging ($P = .01$). In multivariate analysis, there was a significant difference only in the major diameter of the osteochondral fragment ($P = .03$). Receiver operating characteristic curves analysis shows that if the major diameter of the osteochondral fragment is 11 mm or less, 85% of patients achieve complete union of the osteochondral fragments within 6 months.
Conclusion: Absorbable pin fixation may be considered for the osteochondral fragments with major diameter of 11 mm or less and should not be considered for patients who demonstrate osteosclerosis in the subchondral bed or comminution of subchondral bone.

Osteochondritis dissecans (OCD) of the humeral capitellum frequently occurs in teenaged baseball players and gymnasts as a result of excessive use of the elbow[9,23,28]. Patients develop pain that results in a restricted range of motion. Importantly, OCD is the leading cause of disability preventing regular daily and sports activities that require elbow flexion, such as holding a heavy object, dressing, and pitching[38]. In Minami classification, it is divided into three stages based on radiographic findings: the radiolucent stage, separation stage, and free (advanced) stage[29,35]. During the radiolucent stage, OCD is generally treated by conservative methods[21,26,27]. In the separation and free stages, surgical treatments are often performed, including subchondral bone drilling, fragment fixation using bone grafts, removal of loose bodies, and osteochondral grafting with open or arthroscopic techniques[2,3,5,6,8,16-20,34,35,41-44,47,48]. Minimally invasive treatments are desirable as they may enable the patient resume throwing activities early, with good clinical results[12,39,40,44]. Since 2008, our hospital has employed an osteochondral fragment fixation technique using absorbable pins to treat OCD of the humeral capitellum in the separation stage. We previously reported good short-term clinical results with this method for the first time [39]. This approach is less invasive than traditional treatment strategies and achieves good results[40]. In most cases, the osteochondral fragment achieves union within 6 months after surgery, but sometimes, a longer period of over 8 months is required. Furthermore,

This clinical investigation has been approved by the Ethics Committee of Ehime University Hospital (approval no.1902010).
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reoperations are required in some cases because of nonunion. The hypothesis of this study is that there are some factors that influence the outcome of this method. The purpose of this study was to investigate the results of absorbable pin fixation for OCD of the humeral capitellum, and to determine the indications and limitations of this procedure.

Materials and Methods

This study included 34 patients with a mean age of 13.9 years (range, 12–16 years). All were baseball players and could be observed for more than 2 years after surgery (Table 1). Preoperatively, all patients underwent X-rays, ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI). Postoperatively, X-rays were taken every week for all patients. The study population was divided into 2 groups: Group A included 26 patients who completed union within 6 months as confirmed by X-ray and Group B included 8 patients in whom complete union was not observed within 6 months. The following preoperative factors were compared between the 2 groups: age at surgery, time from onset to surgery, International Cartilage Repair Society (ICRS) classification, presence or absence of an open epiphysis, diameter and depth of the osteochondral fragment measured by CT (Fig. 1), lesion location (Fig. 2), preoperative disabilities of the arm, shoulder and hand (DASH) score, presence or absence of osteosclerosis in the subchondral bed on X-ray imaging (Fig. 3), segmentation of the osteochondral fragment on MRI (Fig. 4), and comminution of subchondral bone on US imaging (Fig. 5). This study was a retrospective, case-control study, performed according to the Declaration of Helsinki and approved by the IRB of our hospital. All patients provided consent for their clinical data to be published. The method of absorbable pin fixation for OCD of the humeral capitellum was indicated for cases with failure of nonoperative treatments for more than 3 months and positive radiographic, CT, or MRI findings involving the anterior capitellum. This technique was used when we found one or both of the following intraoperatively: (1) OCD of grade III (detached phase) according to the ICRS, with instability demonstrated by probing or (2) OCD of ICRS grade IV (loose-body phase) with small, loose bone fragments present or with the osteochondral fragments that made up the principal lesions located in the bed without displacement. We performed 30 arthroscopic and 5 open surgeries. In each of the 5 open cases, the surgery was initially performed arthroscopically, but it was considered difficult to properly insert absorbable pins perpendicularly to the joint surface; therefore, the surgery was changed to an open procedure.

Surgical technique

Patients were placed in a lateral position, and general anesthesia was induced. Arthroscopic or open surgery was performed on the elbow at a flexion angle of 90°. When synovial proliferation or fringes and loose bodies were observed, these tissues were removed. Fixation of the osteochondral lesion was performed if the fragment was unstable. The osteochondral lesion and underlying subchondral bone were drilled with a smooth, 1.6-mm diameter Kirschner wire to a depth of 20 mm through a drill guide. The drilling was performed as perpendicular as possible to the articular surface. Fixation was performed using poly-L-lactide (Gunze Bone Fixation Device; Stryker, Tokyo, Japan) between November 2008 and August 2011 and hydroxyapatite (Osteotrans Plus; Takiron Co Ltd, Tokyo, Japan) since September 2011, using absorbable pins that were 1.5 mm in diameter and 15 mm in length. The entire osteochondral fragment was fixed until it was stable. Depending on the size of the lesion, 3–5 pins were used. For postoperative rehabilitation, a sling was immediately fixed in place after the surgery, and range of motion exercises involving active motion were initiated 2 days postoperatively. The sling was removed at 2 weeks, and active joint movement was initiated. It is important to begin regular muscle training of the arms, trunk, and legs soon after surgery. Pitching and bat swinging were initiated gradually beginning at 4 months. The goal was to resume full-strength pitching at approximately 6 months after surgery, but the exact time was based on postoperative plain radiographic results, physical examination, or standardized CT or MRI findings.

Table 1
Patient characteristics.

Variables			
Number of elbows			34
Demographics			
	Age (years)		13.9 ± 1.2 (12 - 16)
	Follow up period (months)		28.7 ± 11.5 (24 - 50)
	ICRS grade	III	28
		IV	6
	Epiphyses	open	6
		closed	28
	Affected region	lateral	25
		central	9
	Baseball position	pitcher	14
		catcher	5
		infielder	10
		outfielder	5
	Time to union (months)		6.1 ± 2.1 (3-12)
	Return to sports (months)		6.5 ± 1.3 (4-10)

Statistical analysis

Univariate analysis was performed using the Wilcoxon signed-rank test and the chi-squared test, while multivariate analysis was conducted with the logistic regression analysis. All analyses were performed with JMP statistical software v11.2 (SAS Institute, Tokyo, Japan). A P value < .05 was considered to indicate statistical significance.

Results

Twenty-nine patients had OCD of ICRS grade III, and 6 had OCD of grade IV. Six patients had open epiphyses and 28 had closed epiphyses (Table 1). Twenty-five lesions were located in the central joint area, while 9 were located both centrally and laterally. All 34 patients were baseball players; 14 were pitchers, 5 were catchers, 10 were infielders, and 5 were outfielders. The mean postoperative follow-up duration was 28.7 months (range, 24–50 months). During pin fixation surgery, we also removed small loose bodies in 10 patients. The DASH disability/symptom score improved from 15.5 ± 9.0 to 10.8 ± 6.2 (P < .001), and the DASH sports score improved from 69.2 ± 31.7 to 13.0 ± 8.2 (P < .001) (Table 2). These improvements met the minimal clinically important differences of the outcome score. The extension angle improved from -9.4 ± 9.7° to -1.9 ± 3.7° (P < .001), and the flexion angle improved from 130.3 ± 11.3° to 136.2 ± 7.9° (P < .001). No patients were found to have postoperative contractures after this treatment. On X-ray, complete union was observed at 6.1 ± 2.1 months (range, 3–12 months) after the surgery. Twenty-six patients observed complete union within 6 months (mean: 5.2 ± 1.3 months, range: 3 – 6 months). In 8 patients, complete union was not observed within 6 months. Among these patients, 6 observed complete union after 6 months (mean: 9.8 ± 1.3 months, range: 8–12 months), and other 2 patients did not observe complete union. Twenty-eight patients were able to resume playing baseball, at a mean of 6.5 ± 1.3 months (range, 4–10 months) postoperatively.

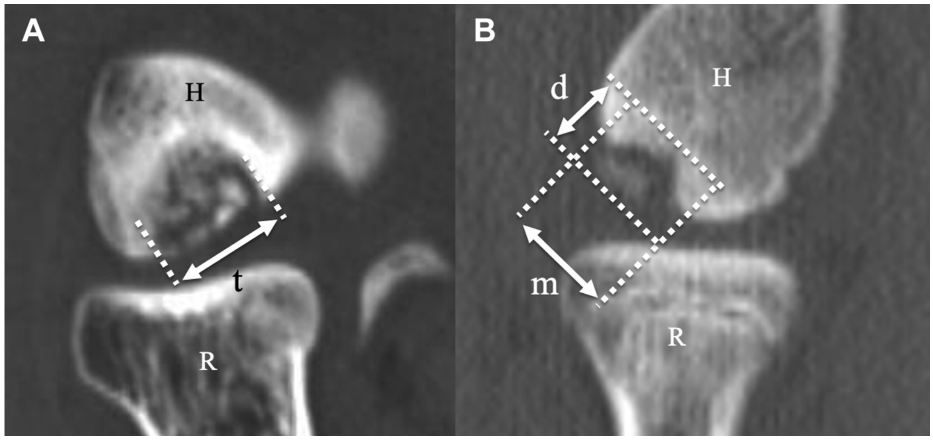

Figure 1 (A) Coronal CT image of the elbow; "t" indicates the transverse diameter of the osteochondral fragment. (B) Sagittal CT image of the elbow; "m" indicates the major diameter, "d" indicates the depth. CT, Computed tomography; H, Humerus; R, Radius.

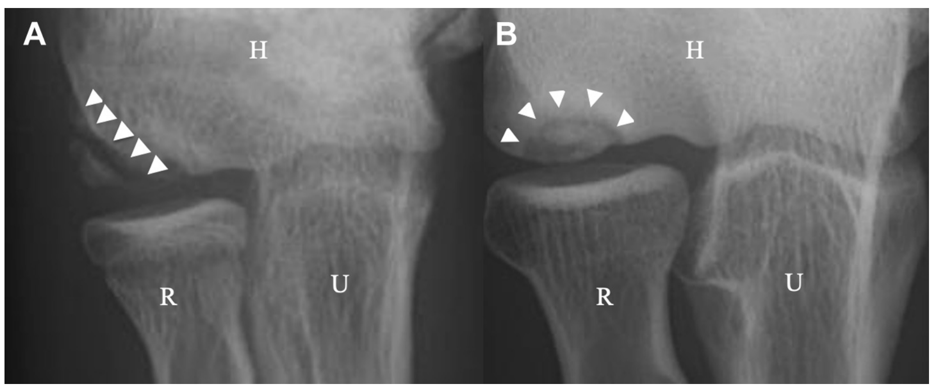

Figure 2 X-ray frontal images of the elbow. (A) Lateral type, (B) Central type. White arrowheads show lesion locations. H, Humerus; R, Radius; U, Ulna.

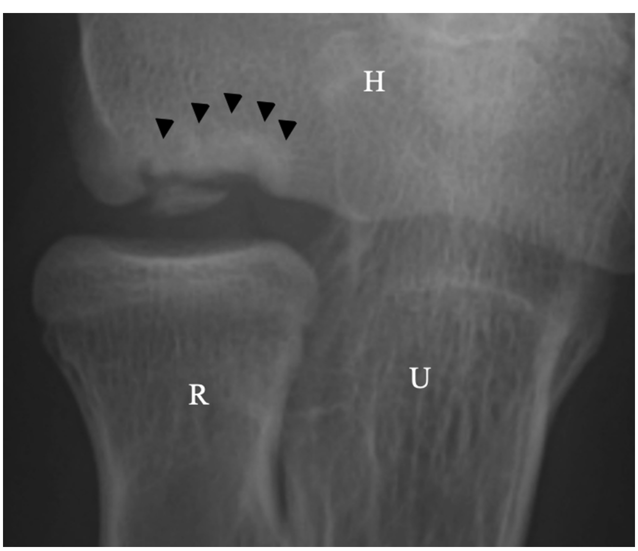

Figure 3 X-ray frontal image of the elbow. ▼ show the area of osteosclerosis in the subchondral bed. H, Humerus; R, Radius; U, Ulna.

The preoperative factors were compared between the two groups (Table 3). There were no significant differences between the two groups regarding age, time from onset to surgery, ICRS classification, presence of an open epiphysis, transverse diameter, lesion location, preoperative DASH score, and segmentation of the osteochondral fragment. In addition, no significant differences were observed in postoperative factors such as the number, material, or types of pins. In univariate analysis, patients with delayed union were more likely to demonstrate larger major diameter ($P = .0004$) and more depth ($P = .03$) of the osteochondral fragment measured by CT, the presence of osteosclerosis in the subchondral bed on X-ray imaging ($P = .003$), and the presence of comminution of subchondral bone on US imaging ($P = .01$). These four factors were investigated in multivariate analysis, and only the major diameter of the osteochondral fragment was associated with the time to complete union ($P = .03$) (Table 4).

Receiver operating characteristic (ROC) curves were created based on the major diameter of the oeochondral fragment, and showed significant differences in multivariate analysis, with a positive value corresponding to complete union within 6 months (Fig. 6). The false-positive rate was the lowest when the cutoff value of the major diameter was set at 11 mm. The sensitivity was 0.96, specificity was 0.64, positive predictive value was 0.85, negative predictive value was 0.88, and area under the curve was 0.92 (Table 5). This means that if the major diameter of the osteochondral fragment is 11 mm or less, 85% of OCD patients achieve complete union within 6 months; however, if the diameter is more than 11 mm, 88% of patients fail to achieve complete union within 6 months (Table 6).

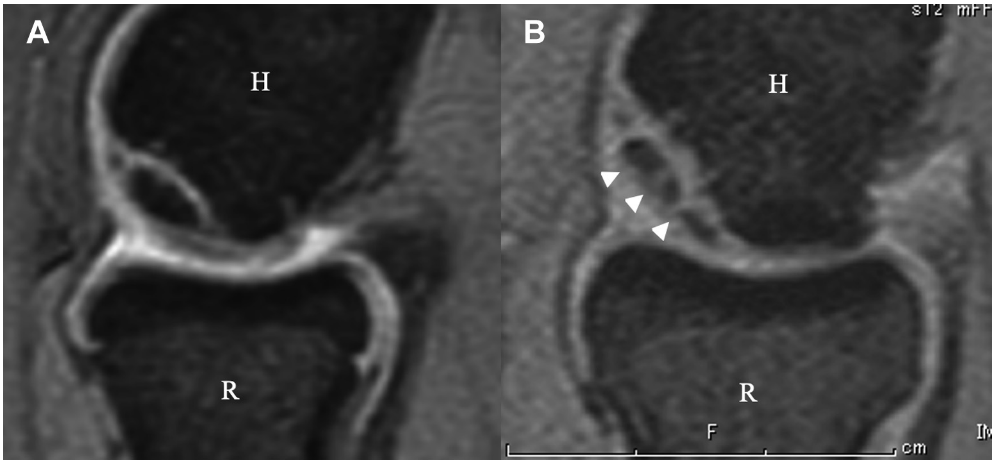

Figure 4 Sagittal MRI image of the elbow. (A) Capitellum of the humerus shows osteochondritis dissecans. (B) White arrowheads show segmentation of an osteochondral fragment. MRI, Magentic resonance imaging; H, Humerus; R, Radius.

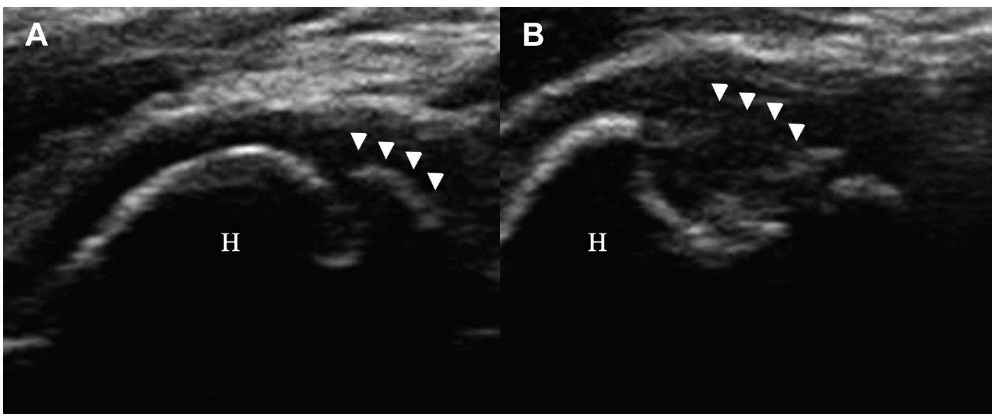

Figure 5 Long-axis view of the elbow by US imaging. (A) Capitellum of the humerus shows osteochondritis dissecans. (B) Comminution of subchondral bone. White arrowheads show lesion locations. US, Ultrasound; H, Humerus.

Table 2
Pre and postoperative clinical assessment.

Variables	Preoperative	Postoperative	*P* value
DASH			
Disability/symptom	15.5 ± 9.0	10.8 ± 6.2	< .001
Sports	69.2 ± 31.7	13.0 ± 8.2	< .001
ROM			
Extension (°)	-9.4 ± 9.7	-1.9 ± 3.7	< .001
Flexion (°)	130.3 ± 11.3	136.2 ± 7.9	< .001

Discussion

For ICRS grade III, surgical treatment is necessary if osteochondral fragments are unstable. For grades III and IV OCD, favorable results have been reported with mosaicplasty[1,13,14,15,18,24,33,37,43,46,47], fixation of osteochondral fragments[12,19], lesion débridement[30,45], and removal of loose bodies[5,22]. Arthroscopic surgeries are being more frequently used for the treatment of capitellar OCD[4,5,7,8,17,30,32,36,42,45].

Several studies[25,31] have identified factors affecting postoperative results of bone peg fixation for osteochondral segmentation in elbow OCD. In these reports, poor outcomes were associated with ICRS grade III, a lesion area depth of 9 mm or more, fixation before epiphyseal closure, central lesion type, and large fragment size. The occurrence of OCD is thought to be associated with impaired vascular perfusion. Before epiphyseal closure, the humeral capitellum is nourished only by the posterior recurrent interosseous artery[10,11]. This may have been the reason for no difference in the postoperative factors in this study.

A previous study investigated factors influencing outcomes of osteochondral fragment fixation using absorbable pins. Henrrikus preop. performed absorbable pin fixation in 26 cases of elbow OCD[12], and found that 20 patients demonstrated complete healing, 6 had persistent clinical symptoms, and 2 underwent revision surgeries. Further, healing was more common in patients younger than 15.3 years and those whose lesions had a sagittal width of less than 13 mm.

In this study, univariate analysis showed that the factors affecting osteochondral repair were the major diameter and depth of the osteochondral fragment, osteosclerosis of the subchondral bed, and comminution of subchondral bone. These factors reflected the extent of degeneration of both the osteochondral fragment and subchondral bone. On the other hand, factors that did not affect osteochondral repair were age, the period from onset to surgery, ICRS classification, lesion location, preoperative function, and impairment of sports activities. This procedure achieved good results, similar to those of bone peg fixation. The ROC curves based on the major diameter indicated that if the major diameter of the osteochondral fragment is 11 mm or less, 85% of OCD patients

Table 3
Univariate analysis of preoperative factors.

Variables	Group A	Group B	*P* value
Number of elbows	26	8	
Age (years)	14.0 ± 1.2	13.5 ± 1.1	.258 (#1)
Period to surgery (months)	12.2 ± 11.7	15.5 ± 10.8	.246 (#1)
ICRS grade			
III	22	6	.608 (#2)
IV	4	2	
Epiphyses			
open	4	1	1.000 (#2)
closed	22	7	
Maximum size of osteochondral fragment			
transverse diameter (mm)	11.0 ± 1.9	11.9 ± 1.8	.228 (#1)
major diameter (mm)	9.0 ± 2.8	14.0 ± 2.1	.0004 (#1)
depth (mm)	5.1 ± 1.6	6.4 ± 1.1	.032 (#1)
Affected region			
lateral	6	4	.194 (#2)
central	20	4	
Preoperative DASH			
disability/symptom	14.0 ± 8.6	19.6 ± 8.8	.165 (#1)
sports	65.0 ± 31.4	81.3 ± 29.3	.306 (#1)
Osteosclerosis of subchondral bed on X-ray imaging			
-	16	0	.0031 (#2)
+	10	8	
Segmentation of osteochondral fragment on MRI			
-	19	3	.098 (#2)
+	7	5	
Comminution of subchondral bone on US imaging			
-	25	4	0.0128 (#2)
+	1	4	

#1 Wilcoxon signed-rank test #2 Fisher's exact test

Table 4
Multivariate analysis of the factors showing a significant difference in univariate analysis.

Variables	Odds ratio	95% CI	*P* value
Major diameter of osteochondral fragment	1.87	1.23 − 3.98	.03
Depth of osteochondral fragment	0.80	0.18 − 2.94	.74
Osteosclerosis of subchondral bed on X-ray imaging	4.72×10^{-7}	0.19 − 5.76	.24
Comminution of subchondral bone on US imaging	6.30	0.28 − 4.23	.23

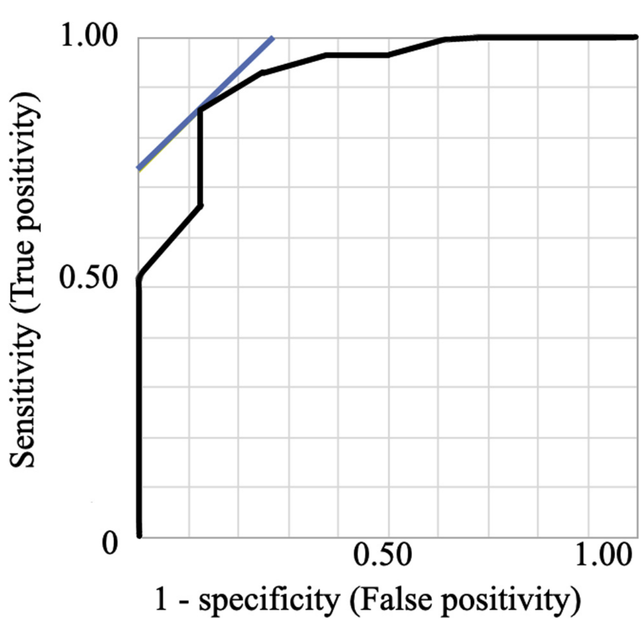

Figure 6 Receiver operating characterisitc curve based on the major diameter of osteochondral fragment, with positive values indicating complete union within 6 months.

Table 5
Outcomes of ROC analysis.

Outcomes	Ratio (%)
Sensitivity	95.7
Specificity	63.6
Positive predictive value	84.6
Negative predictive value	87.5
AUC	91.8

achieve complete union within 6 months. The ROC curves suggest that this procedure may be considered for cases where the major diameter of the osteochondral fragment is 11 mm or less. If the major diameter is larger than 11 mm, the procedure should not be considered and osteochondral grafting should be recommended. While the absorbable pin fixation procedure is widely applicable, these results suggest that its use cannot be determined by arthroscopic findings alone.

In almost all cases, this procedure can be performed with minimal invasion and simply under arthroscopy. However, it is impossible to precisely observe degeneration of the osteochondral fragment and subchondral bone via arthroscopy alone. Decisions about surgical procedures should also be based on one or more preoperative imaging studies, such as CT, MRI, and US. Particular attention must be paid in cases showing osteosclerosis in the

Table 6
Outcomes based on cutoff value defined by ROC analysis.

		Complete union of osteochondral fragment	
		≤ 6 months	> 6 months
Major diameter of osteochondral fragment	≤ 11mm	22	4
	> 11mm	1	7

subchondral bed on X-ray imaging or comminution of subchondral bone on US imaging.

One limitation of this study is the small number of cases. In addition, it is necessary to examine whether osteoarthritic changes occur in 5 or more years after absorbable pin fixation.

Conclusions

This study suggests that osteochondral fragment fixation using absorbable pins is indicated for OCD of the humeral capitellum when the major diameter of the osteochondral fragment is 11 mm or less. The procedure should not be considered for patients who demonstrate osteosclerosis in the subchondral bed on X-ray imaging or comminution of subchondral bone on US imaging.

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References

1. Ansah P, Vogt S, Ueblacker P, Martinek V, Woertler K, Imhoff AB. Osteochondral transplantation to treat osteochondral lesions in the elbow. J Bone Joint Surg Am 2007;89:2188-94. https://doi.org/10.2106/JBJS.F.00299.
2. Baker CL 3rd, Baker CL Jr, Romeo AA. Osteochondritis Dissecans of the capitellum. J Shoulder Elbow Surg 2010;19(Suppl):76-82. https://doi.org/10.1016/j.jse.2009.11.058.
3. Baumgarten TE, Andrews JR, Satterwhite YE. The arthroscopic classification and treatment of osteochondritis Dissecans of the capitellum. Am J Sports Med 1998;26:520-3.
4. Bexkens R, van den Ende KIM, Ogink PT, van Bergen CJA, van den Bekerom MPJ, Eygendaal D. Clinical outcome after arthroscopic debridement and microfracture for osteochondritis Dissecans of the capitellum. Am J Sports Med 2017;45:2312-8. https://doi.org/10.1177/0363546517704842.
5. Brownlow HC, O'Connor-Read LM, Perko M. Arthroscopic treatment of osteochondritis Dissecans of the capitellum. Knee Surg Sports Traumatol Arthrosc 2006;14:198-202. https://doi.org/10.1007/s00167-005-0623-z.
6. Byram IR, Kim HM, Levine WN, Ahmad CS. Elbow arthroscopic surgery update for sports medicine conditions. Am J Sports Med 2013;41:2191-202. https://doi.org/10.1177/0363546513482106.
7. Byrd JW, Jones KS. Arthroscopic surgery for isolated capitellar osteochondritis Dissecans in adolescent baseball players: minimum three-year follow-up. Am J Sports Med 2002;30:474-8. https://doi.org/10.1177/03635465020300040401.
8. de Graaff F, Krijnen MR, Poolman RW, Willems WJ. Arthroscopic surgery in athletes with osteochondritis Dissecans of the elbow. Arthroscopy 2011;27:986-93. https://doi.org/10.1016/j.arthro.2011.01.002.
9. Glait SA, Rokito AS, Jazrawi LM. Osteochondritis Dissecans of the capitellum: diagnosis and treatment. Bull Hosp Jt. Dis 2016;74:37-45.
10. Haraldsson S. The intra-osseous vasculature of the distal end of the humerus with special reference to capitulum; preliminary communication. Acta Orthop Scand 1957;27:81-93.
11. Haraldsson S. On osteochondrosis deformas juvenilis capituli humeri including investigation of intra-osseous vasculature in distal humerus. Acta Orthop Scand Suppl 1959;38:1-232.
12. Hennrikus WP, Miller PE, Micheli LJ, Waters PM, Bae DS. Internal fixation of unstable in situ osteochondritis Dissecans lesions of the capitellum. J Pediatr Orthop 2015;35:467-73. https://doi.org/10.1097/BPO.0000000000000308.
13. Iwasaki N, Kato H, Ishikawa J, Masuko T, Funakoshi T, Minami A. Autologous osteochondral mosaicplasty for osteochondritis Dissecans of the elbow in teenage athletes. J Bone Joint Surg Am 2009;91:2359-66. https://doi.org/10.2106/JBJS.H.01266.
14. Iwasaki N, Kato H, Ishikawa J, Masuko T, Funakoshi T, Minami A. Autologous osteochondral mosaicplasty for osteochondritis Dissecans of the elbow in teenage athletes: surgical technique. J Bone Joint Surg Am 2010;92(Suppl. 1 Pt 2):208-16. https://doi.org/10.2106/JBJS.J.00214.
15. Iwasaki N, Kato H, Ishikawa J, Saitoh S, Minami A. Autologous osteochondral mosaicplasty for capitellar osteochondritis Dissecans in teenaged patients. Am J Sports Med 2006;34:1233-9. https://doi.org/10.1177/0363546506286343.
16. Janarv PM, Hesser U, Hirsch G. Osteochondral lesions in the radiocapitellar joint in the skeletally immature: radiographic, MRI, and arthroscopic findings in 13 consecutive cases. J Pediatr Orthop 1997;17:311-4.
17. Jones KJ, Wiesel BB, Sankar WN, Ganley TJ. Arthroscopic management of osteochondritis Dissecans of the capitellum: mid-term results in adolescent athletes. J Pediatr Orthop 2010;30:8-13. https://doi.org/10.1097/BPO.0b013e3181c3be83.
18. Kirsch JM, Thomas J, Bedi A, Lawton JN. Current concepts: osteochondritis Dis secans of the capitellum and the role of osteochondral autograft transplantation. Hand (N Y) 2016;11:396-402. https://doi.org/10.1177/1558944716643293.
19. Koehler SM, Walsh A, Lovy AJ, Pruzansky JS, Shukla DR, Hausman MR. Outcomes of arthroscopic treatment of osteochondritis Dissecans of the capitellum and description of the technique. J Shoulder Elbow Surg 2015;24:1607-12. https://doi.org/10.1016/j.jse.2015.06.013.
20. Krijnen MR, Lim L, Willems WJ. Arthroscopic treatment of osteochondritis Dissecans of the capitellum: report of 5 female athletes. Arthroscopy 2003;19:210-4. https://doi.org/10.1053/jars.2003.50052.
21. Kusano H, Furushima K, Mitsui Y, Miyamoto A, Urata D, Serita Y, et al. 7. Usefulness of low-intensity pulsed ultrasound (LIPUS) for the treatment of osteochondritis Dis secans (OCD) of the humeral capitellum. J Orthop Trauma 2016;30:S3–S4. https://doi.org/10.1097/01.bot.0000489980.94587.85.
22. Lewine EB, Miller PE, Micheli LJ, Waters PM, Bae DS. Early Results of Drilling and/or microfracture for Grade IV osteochondritis Dissecans of the Capitellum. J Pediatr Orthop 2016;36:803-9. https://doi.org/10.1097/BPO.0000000000000575.
23. Lyman S, Fleisig GS, Andrews JR, Osinski ED. Effect of pitch type, pitch count, and pitching mechanics on risk of elbow and shoulder pain in youth baseball pitchers. Am J Sports Med 2002;30:463-8. https://doi.org/10.1177/03635465020300040201.
24. Lyons ML, Werner BC, Gluck JS, Freilich AM, Dacus AR, Diduch DR, et al. Osteochondral autograft plug transfer for treatment of osteochondritis Dissecans of the capitellum in adolescent athletes. J Shoulder Elbow Surg 2015;24:1098-105. https://doi.org/10.1016/j.jse.2015.03.014.
25. Maruyama M, Harada M, Satake H, Tomohiro U, Takagi M, Takahara M. Bone-peg grafting for osteochondritis Dissecans of the humeral capitellum. J Orthop Surg Hong Kong 2016;24:51-6. https://doi.org/10.1177/230949901602400113.
26. Matsuura T, Kashiwaguchi S, Iwase T, Takeda Y, Yasui N. Conservative treatment for osteochondrosis of the humeral capitellum. Am J Sports Med 2008;36:868-72. https://doi.org/10.1177/0363546507312168.
27. Mihara K, Tsutsui H, Nishinaka N, Yamaguchi K. Nonoperative treatment for osteochondritis Dissecans of the capitellum. Am J Sports Med 2009;37:298-304. https://doi.org/10.1177/0363546508324970.
28. Mihata T, Quigley R, Robicheaux G, McGarry MH, Neo M, Lee TQ. Biomechanical characteristics of osteochondral defects of the humeral capitellum. Am J Sports Med 2013;41:1909-14. https://doi.org/10.1177/0363546513490652.
29. Minami MN. Twenty-five cases of osteochondritis Dis secans of the elbow. Rinsho Seikei Geka 1979;14:805-10.
30. Miyake J, Masatomi T. Arthroscopic debridement of the humeral capitellum for osteochondritis Dissecans: radiographic and clinical outcomes. J Hand Surg Am 2011;36:1333-8. https://doi.org/10.1016/j.jhsa.2011.05.024.
31. Oka Y, Ohta K, Fukuda H. Bone-peg grafting for osteochondritis Dissecans of the elbow. Int Orthop 1999;23:53-7.
32. Rahusen FT, Brinkman JM, Eygendaal D. Results of arthroscopic debridement for osteochondritis Dissecans of the elbow. Br J Sports Med 2006;40:966-9. https://doi.org/10.1136/bjsm.2006.030056.
33. Richter DL, Tanksley JA, Miller MD. Osteochondral autograft transplantation: a review of the surgical technique and outcomes. Sports Med Arthrosc 2016;24:74-8. https://doi.org/10.1097/JSA.0000000000000099.
34. Ruch DS, Cory JW, Poehling GG. The arthroscopic management of osteochondritis Dissecans of the adolescent elbow. Arthroscopy 1998;14:797-803.
35. Ruchelsman DE, Hall MP, Youm T. Osteochondritis Dissecans of the capitellum: current concepts. J Am Acad Orthop Surg 2010;18:557-67. https://doi.org/10.5435/00124635-201009000-00007.
36. Schoch B, Wolf BR. Osteochondritis Dissecans of the capitellum: minimum 1-year follow-up after arthroscopic debridement. Arthroscopy 2010;26:1469-73. https://doi.org/10.1016/j.arthro.2010.03.008.
37. Shimada K, Yoshida T, Nakata K, Hamada M, Akita S. Reconstruction with an osteochondral autograft for advanced osteochondritis Dissecans of the elbow. Clin Orthop Relat Res 2005;435:140-7. https://doi.org/10.1097/01.blo.0000160025.14363.f9.
38. Takahara M, Mura N, Sasaki J, Harada M, Ogino T. Classification, treatment, and outcome of osteochondritis Dissecans of the humeral capitellum. Surgical technique. J Bone Joint Surg Am 2008;90(Suppl. 2 Pt 1):47-62. https://doi.org/10.2106/JBJS.G.01135.

39. Takeba J, Takahashi T, Hino K, Watanabe S, Imai H, Yamamoto H. Arthroscopic technique for fragment fixation using absorbable pins for osteochondritis Dissecans of the humeral capitellum: a report of 4 cases. Knee Surg Sports Traumatol Arthrosc 2010;18:831-5. https://doi.org/10.1007/s00167-009-0945-3.
40. Takeba J, Takahashi T, Watanabe S, Imai H, Kikuchi S, Umakoshi K, et al. Short-term clinical results of arthroscopic osteochondral fixation for elbow osteochondritis Dissecans in teenaged baseball players. J Shoulder Elbow Surg 2015;24:1749-56. https://doi.org/10.1016/j.jse.2015.07.009.
41. Takeda H, Watarai K, Matsushita T, Saito T, Terashima Y. A surgical treatment for unstable osteochondritis Dissecans lesions of the humeral capitellum in adolescent baseball players. Am J Sports Med 2002;30:713-7. https://doi.org/10.1177/03635465020300051501.
42. Tis JE, Edmonds EW, Bastrom T, Chambers HG. Short-term results of arthroscopic treatment of osteochondritis Dissecans in skeletally immature patients. J Pediatr Orthop 2012;32:226-31. https://doi.org/10.1097/BPO.0b013e31824afeb8.
43. Tsuda E, Ishibashi Y, Sato H, Yamamoto Y, Toh S. Osteochondral autograft transplantation for osteochondritis Dissecans of the capitellum in nonthrowing athletes. Arthroscopy 2005;21:1270. https://doi.org/10.1016/j.arthro.2005.06.006.
44. Uchida S, Utsunomiya H, Taketa T, Sakoda S, Hatakeyama A, Nakamura T, et al. Arthroscopic fragment fixation using hydroxyapatite/poly-L-lactate Acid thread pins for treating elbow osteochondritis Dissecans. Am J Sports Med 2015;43:1057-65. https://doi.org/10.1177/0363546515570871.
45. van den Ende KI, McIntosh AL, Adams JE, Steinmann SP. Osteochondritis Dissecans of the capitellum: a review of the literature and a distal ulnar portal. Arthroscopy 2011;27:122-8. https://doi.org/10.1016/j.arthro.2010.08.008.
46. Westermann RW, Hancock KJ, Buckwalter JA, Kopp B, Glass N, Wolf BR. Return to sport after operative management of osteochondritis Dissecans of the capitellum: A systematic review and meta-analysis. Orthop J Sports Med 2016;4:2325967116654651. https://doi.org/10.1177/2325967116654651.
47. Yamamoto Y, Ishibashi Y, Tsuda E, Sato H, Toh S. Osteochondral autograft transplantation for osteochondritis Dissecans of the elbow in juvenile baseball players: minimum 2-year follow-up. Am J Sports Med 2006;34:714-20. https://doi.org/10.1177/0363546505282620.
48. Yeoh KM, King GJ, Faber KJ, Glazebrook MA, Athwal GS. Evidence-based indications for elbow arthroscopy. Arthroscopy 2012;28:272-82. https://doi.org/10.1016/j.arthro.2011.10.007.