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Qualitative and quantitative assessments of radiographic healing of osteochondritis dissecans of the humeral capitellum

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Background: Little is known about the optimal timing of early return to sports after which the osteochondritis dissecans (OCD) lesion can completely heal. The aims of this study were to investigate the clinical outcomes of nonoperative treatment and elucidate the relationship between the radiographic findings and the timing for the return to sports.

Methods: We performed a retrospective review of 32 patients who presented with stable OCD of the capitellum and were treated nonoperatively for a minimum of 3 months. The mean follow-up period was 22.1 months. OCD lesions were assessed qualitatively and quantitatively on anteroposterior radiographs of the elbow at 45° of flexion every 3 months. The width of the OCD lesion (OCDw) and lateral width of the normal capitellum were measured and were associated with return to sports activities.

Results: In 21 patients (66%), the progression of ossification was seen at a mean period of 4.1 months. Eighteen (56%) had partial union at a mean period of 4.3 months. Twenty-nine cases (91%) returned to sports activities after a mean of 4.6 months. Nine cases (28%) achieved complete union after a mean period of 15.0 months. Fifteen (47%) required surgery after a mean period of 11.8 months. The mean OCDw (%) was 10.2 ± 3.9 mm (56%) at the initial presentation and 8.0 ± 6.0 mm (41%) at the final follow-up examination, and the decrease in OCDw was 2.2 ± 3.1 mm (15%). The mean decrease in OCDw in patients with progression of ossification during the first 3 months was significantly larger than in patients without progression of ossification (4.9 ± 4.7 mm and -0.7 ± 4.5 mm, respectively; $P = .002$). In patients who had both an OCDw value of <8.0 mm and a lateral width value of >2.0 mm at the time of the return to sports, the rate of successful nonoperative treatment (86%) and complete union (71%) was significantly higher in comparison with other patients ($P = .03$ and $P = .02$).

Conclusions: OCD lesions showed difficult healing in the middle one-third of the capitellum. The progression of ossification during the first 3 months was a significant predictor of successful nonoperative treatment and complete union. Surgery should be considered for lesions without the progression of ossification during the first 3 months. We propose both an OCD lesion width of <8.0 mm and a lateral normal width of >2.0 mm as radiographic landmarks of the timing of the return to sports.

Osteochondritis dissecans (OCD) of the humeral capitellum is a common sports-associated elbow injury in baseball players, especially pitchers.[1,2,5] The repetitive, excessive compression and shear forces in the radiocapitellar joint caused by elbow valgus stress during throwing on the upper limbs in skeletally immature patients are considered to be important etiologic factors of this disease.[1,2,5,21]

The earliest feature of OCD is subchondral bone flattening, over which new bone subsequently forms.[33] The new bone can then unite with the underlying bone. However, if subjected to repetitive forces over a given time, unstable fragments develop.[33] The healing rates of capitellar OCD with nonoperative treatment, including activity restriction were 64-90.5% in stage I (localized flattening or radiolucency) and 31-52.9% in stage II (nondisplaced fragment).[18,30] The healing rates of nonoperative treatment were high in patients who had a stage I lesion, a stable lesion, small size without a cyst-like lesion, open capitellar physis, short symptom duration, and in

Institutional review board approval was obtained before the start of this study from Izumi Orthopedic Hospital (study no. IOH IRB-17). Informed consent was obtained from all subjects.

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those who were compliant for activity restriction for >6 months.[18,19,23,30,37] Funakoshi et al[9] reported that radiographic findings of radial head enlargement and advanced skeletal age on the throwing side in comparison with the nonthrowing side were predictors of advanced-stage capitellar OCD and unsuccessful nonoperative management of OCD.

The period required for healing (delayed ossification and union) is often ≥1 year: 14.9 months in stage I and 12.3 months in stage II as noted by Matsuura et al.[18] In contrast, an early return to sports resulted in failure of nonoperative treatment.[18,23] However, little is known about the optimal timing of early return to sports after which the OCD lesion can completely heal.

To our knowledge, previous studies on OCD of the capitellum have not described the quantitative changes during the nonoperative observation period or the radiographic indicators of the timing of a return to sports with a subsequent successful outcome. We qualitatively and quantitatively assessed the radiographic findings during nonoperative observation and analyzed factors associated with the outcome. The aims of this study were to investigate the clinical outcomes of nonoperative treatment and the relationships between radiographic findings and the timing of the return to sports.

Material and methods

This study was performed in accordance with the World Medical Association Declaration of Helsinki and was approved by the institutional ethics committee. Between 2010 and 2014, a total of 125 patients of <20 years of age were diagnosed with OCD of the capitellum at our hospital. Of these, 32 patents were selected as subjects in this study because they were assessed to have a stable lesion and treated nonoperatively for a minimum of 3 months. Ninety-three patients were excluded from the analysis: 79 patients underwent surgery within 3 months after the initial presentation; one had nonoperative observation period of 1 month and dropped out; and the remaining 13 patients had only examination without any treatments.

There were 30 male and 2 female patients. The average age at presentation was 12.7 years (range, 10.1-14.6 years). All patients had a unilateral OCD lesion on the dominant side; the affected side was right in 27 patients (84%) and left in 5 (16%). All patients belonged to sports clubs, which included baseball (n = 29, 91%), dodgeball (n = 2, 6%), and gymnastics (n = 1, 3%). Players who had practiced and played as pitchers were considered to be pitchers even if they also played other positions. Among baseball players, the percentages of pitchers, catchers, infielders, and outfielders were 59%, 17%, 14%, and 10%, respectively. In 4 baseball players (13%), OCD was detected by sonography of the elbow in the field.[10] At the initial presentation, 29 patients (91%) had elbow pain during sports or activities, and 3 had no symptoms. Of the 3 asymptomatic cases, 2 were detected by examining cohorts of adolescent baseball players using sonography,[10,13,18,34] and 1 had 3 months of elbow rest before the initial presentation. The average range of motion of the elbow was minus 4 degrees (range, - 20 to 10 degrees) of extension and 136 degrees (range, 120 to 150 degrees) of flexion. At the initial presentation, 9 patients (28%) had restriction of elbow motion.

We ordinally took the following 4 radiographs for the adolescent athletes with OCD of the capitellum: anteroposterior, lateral, external rotation oblique, and anteroposterior with the elbow in 45° of flexion. On the anteroposterior radiography with the elbow in 45° of flexion (APR45),[19] the capitellar OCD lesion was assessed in this study. The lesion at the initial presentation was assessed to be stage I (localized flattening or radiolucency) in 13 patients and stage II (a nondisplaced fragment) in 19 patients, as per the radiographic staging system.[18,19,30,33] Abnormalities of the humeral medial epicondyle were seen in 20 patients: fragmentation (n = 11) and deformity (n = 9). The mean skeletal age score for the elbow, as determined using the Sauvegrain method,[9,31] (4.0-27.0 points) was 21.9 points (range, 10.0-27.0 points).

Nonoperative treatment was indicated for adolescent patients with a stable OCD lesion of the capitellum. Stable lesions were selected as per the previously described criteria.[27,30] Throwing was prohibited. When we allow batting, instruction was given to them to tap a slow roller. Running and fielding (only catching the ball) were approved. We recommended avoiding heavy use of the elbow, including actions such as arm wrestling, push-ups, and weightlifting. General stretching, such as the sleeper stretch[6] or core and hip stretches, was performed to resolve general tightness.[20,25]

Sports activities, such as throwing with the affected arm, were principally allowed when all of the following 3 conditions had been met: 1) asymptomatic elbow with no restriction of the elbow motion, 2) radiographic normalization of both the lateral wall and lateral articular area in the capitellum, and 3) patients' eagerness and parents' approval to return to sports. When a patient had either increased symptoms or findings of instability on imaging during nonoperative observation, surgery was recommended, and that day was defined as the final day of nonoperative observation. The mean clinical follow-up period was 22.1 months (range, 3.5-70.2 months), and the mean follow-up period of radiographic assessment was 17.1 months (range, 3.0-70.2 months).

We examined the period required for a return to sports, the presence or absence of elbow pain at the final follow-up, and the need for surgery. Radiographic healing of OCD on APR45 was qualitatively and quantitatively assessed every 3 months during nonoperative observation. In addition to the radiographic OCD stages, the changes in the lesion width were also assessed. When the lesion width was obviously decreased by partial bony union, we added "+" to the stage number of I or II (Fig. 1, *b*, *e*, and *f*). In contrast, we added "-" when the lesion width was obviously enlarged (Fig. 1, *k* and *l*). When the lesion was normalized by bony union, the stage was defined as III (Fig. 1*c*).

The OCD lesion width (OCDw) on APR45 was measured along a straight line parallel to the subchondral bone surface of the radial head. We also measured the lateral width (Lw) and medial width (Mw) of the normal capitellum (Fig. 2*a*). The APR45 images were enlarged using the Vox-Base software program (J-Mac System, Sapporo, Japan) to obtain an accurate size to 0.01 mm and rounded the number was to the nearest tenth. The ratio of OCDw relative to the capitellum width was used to calculate the normalized value: normalized OCDw (%OCDw),[23] normalized lateral width (%Lw) and normalized medial width (%Mw). The decreases in OCDw and % OCDw from the initial presentation to the final radiographic examination were calculated as follows: decrease in OCDw (OCDw at initial presentation − OCDw at final observation) and decrease in % OCDw (%OCDw at initial presentation − %OCDw at final observation).

We slightly modified "successful nonoperative treatment (successful outcomes)", described by Wall et al[36] (reossification of the lesion on radiographs) and Krause et al[16] (≥15% decrease in lesion size), as return to sports activities and radiographic healing, as previously described by Niu et al.[23] In this study, we assessed either partial or complete union as radiographic healing. Failed nonoperative treatment (failed outcomes) was defined as decrease of activity level owing to the capitellar lesion, the need for surgery during the treatment period, or a lack of radiographic healing at the final follow-up examination.

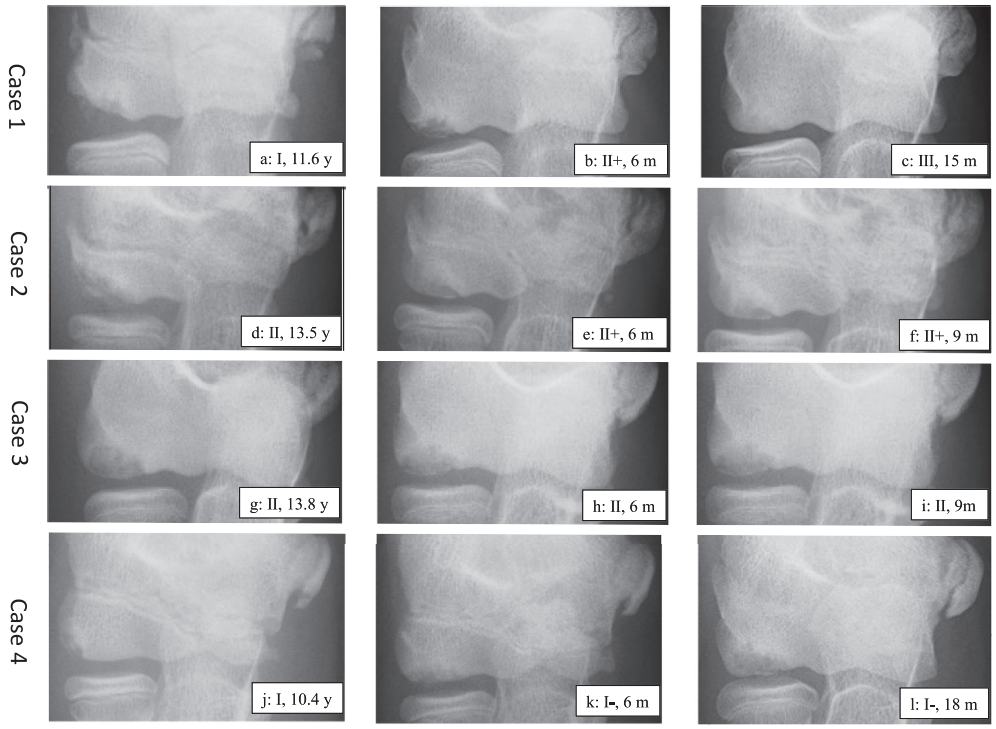

Figure 1 Radiographic OCD stages .Anteroposterior radiographs with the elbow in 45° of flexion in Case 1, an 11.6-year-old baseball player (**a, b, c**); Case 2, a 13.5-year-old baseball player (**d, e, f**); Case 3, a 13.8-year-old baseball player (**g, h, i**); and Case 4: a 10.4-year-old baseball player (**j, k, l**). APR45 at the initial presentation (**a, d, g, j**), and 6 months (**b, e, h, k**), 15 months (**c**), 9 months (**f, i**), and 18 months (**l**) after the initial presentation. Stage I, localized flattening or radiolucency (**a, j**); Stage I-, stage I with obvious enlargement of the lesion width (**k, l**); Stage II, delayed ossification or nondisplaced fragment (**d, g, h, i**); Stage II+, stage II with partial bony union and an obvious decrease in lesion width (**b, e, f**); and Stage III, normal or bony union of the delayed ossified fragment with the surrounding bone (**c**). The periods required for a return to sports were 12.4 months in Case 1, 7.8 months in Case 2, 0.9 months in Case 3, and 19.0 months in Case 4. The mean stage was calculated as follows: stage I-, zero points; stage I and II-, one point; stage II, 2 points; stage II+, 3 points; and stage III, 4 points. *OCD*, osteochondritis dissecans.

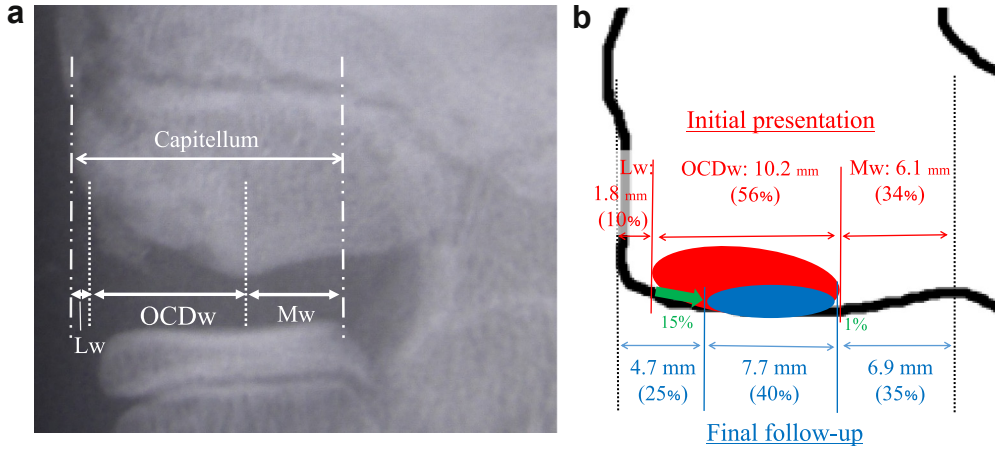

Figure 2 Quantitative radiographic assessment. (**a**) The OCD lesion width (OCDw) on an anteroposterior radiograph with the elbow at 45° of flexion was measured along a straight line parallel to the subchondral bone surface of the radial head. The lateral width of the normal capitellum (Lw) and medial width (Mw) of the normal capitellum were also measured. The ratio relative to the capitellum width was used to calculate the normalized value: normalized OCDw (%OCDw), normalized lateral width (%Lw) and normalized medial width (%Mw). (**b**) The results of the quantitative assessment at the initial presentation (shown in *red*) and the final follow-up examination (shown in *blue*). The changes of %Lw and %Mw are shown in *green*. The decrease in %OCDw was 15%. *OCD*, osteochondritis dissecans.

Statistical methods

Values were presented as the means and standard deviation. The association of the skeletal age score at the initial presentation with the qualitative outcome was evaluated using the Mann-Whitney U test. The outcomes between patients with and without ossification progression at the first 3 months were compared using the Mann-Whitney U test, or Fisher's exact probability test, as appropriate. The correlation between the quantitative assessments at the time of the return to sports and the subsequent decrease in OCDw after 3 months was analyzed using Spearman rank correlation coefficient (r).

The cutoff values of OCDw and Lw at the time of a return to sports, which resulted in success or stage III were determined based on an

Table I
Radiographic assessments.

	Modified radiographic OCD stage							OCD lesion width[†]	
	I-	I	II-	II	II+	III	Mean[†] (points)	OCDw (mm)	%OCDw (%)
Initial	/	13	/	19	/	0	1.6 ± 0.5	10.2 ± 3.9	56 ± 21
Three mo	2	13	0	3	14	0	1.9 ± 1.1	10.4 ± 3.5	56 ± 18
Six mo[*]	3	7	1	1	15	1	2.1 ± 1.2	9.2 ± 4.2	50 ± 23
Final	3	8	2	2	8	9	2.6 ± 1.3	7.7 ± 6.2	40 ± 31

OCD, osteochondritis dissecans.
Data represent the number of patients, unless otherwise indicated.
[*] n = 28 (4 patients were excluded from the analysis because the observation period was less than 6 months).
[†] Values are presented as the mean and standard deviation.

ROC curve analysis. The outcomes were then compared considering the OCDw and Lw at the time of the return to sports. A multivariate logistic regression analysis with stepwise selection was performed to identify independent predictors of failure of nonoperative treatment. All statistical analyses were performed using EZR,[12] version R-3.6.1. (Saitama Medical Center, Jichi Medical University). *P* values of < .05 were considered to indicate statistical significance.

Results

Clinical assessments

Twenty-six of 31 overhead athletes (84%) stopped throwing from the initial presentation, and 1 gymnast avoided heavy use of their elbow. Although elbow rest was recommended, 5 patients continued throwing from the initial presentation because the patients and their parents were extremely eager to participate in games. Twenty-nine patients (91%) returned to sports activities of throwing or gymnastics after a mean period of 4.6 months (range, 0-19 months) from the initial presentation. The remaining 3 patients underwent surgery after 6.7 months (range, 4.0-10.6 months) of elbow rest. The return to sports was complete without a decrease in level in 15 patients (47%), including the previous sports in 14 patients and another favorite sport in 1 patient. The mean duration required for a complete return to sports was 11.2 months (range, 0-26 months). Fifteen patients (47%) made an incomplete return to sports with a decreased level of sports activity, including a return to the previous sport in 14 patients and a change in sports owing to capitellar OCD in 1 patient. Three patients (9%) could not return to sports owing to the capitellar OCD during the observation periods. Among 29 baseball players, the rate of a complete return to sports did not differ between the pitchers (47%) and the players of other positions (50%).

At the final follow-up of nonoperative treatment in all 32 patients, elbow pain during sports or daily activities was observed in 13 patients, and locking phenomena were observed in 3 patients. Restriction of elbow motion (10 to 20 degrees) remained in 3 patients who had the restriction at the initial presentation. Surgery was performed in 15 patients because the nonoperative treatment failed after a mean period of 11.8 months (range, 3.5-37.3 months). The main reasons for the need for surgery were as follows: elbow pain (n = 7), locking phenomena (n = 3), and difficulty in sports activities (n = 5). The surgical procedures were principally determined as per the size and stability of the OCD lesion,[4,17,30] reconstruction with osteochondral autograft transplantation from the knee was performed in 7 patients, and arthroscopic débridement/loose body removal was performed in eight patients.

Qualitative assessments

The qualitative assessments of the radiographic findings at the initial presentation, 3 months, 6 months, and the final follow-up examination are shown in Table I. In 21 patients (66%), the progression of ossification was seen after a mean period of 4.1 months (range, 3-12 months) from the initial presentation. Eighteen patients (56%) had partial union (stage II+) after a mean period of 4.3 months (range, 3-12 months) from the initial presentation. In addition, 9 patients (28%) achieved complete union (stage III) after a mean period of 15.0 months (range, 6-24 months) from the initial presentation. Only 1 (9%) of the 11 patients who returned to sports within 3 months showed complete union (stage III).

The progression of ossification was seen in 9 of 13 (69%) patients with stage I at initial presentation and 12 of 19 (63%) patients with stage II. Five of 13 stage I lesions (38%) at the initial presentation showed complete union, while complete union was achieved in 4 of the 19 stage II lesions (21%). In 11 patients, the progression of ossification was not seen during a mean observation period of 7.5 months (range, 3-12.8 months).

Lesion enlargement was observed in 5 patients at a mean of 15.6 months (range, 3-33 months) after the initial presentation. The final qualitative assessment was stage III in 9 patients (28%), stage II+ in 8 patients (25%), stage II in 2 patients (6%), stage II- in 2 patients (6%), stage I in 8 patients (25%), and stage I- in 3 patients (10%).

Quantitative assessments

The quantitative radiographic assessments at the initial presentation and the final follow-up examination are shown in Table I and Fig. 3. The mean OCDw (%OCDw) on APR45 was 10.2 ± 3.9 mm (56%) at the initial presentation and 7.7 ± 6.2 mm (40%) at the final assessment, and the decrease in OCDw (decrease in %OCDw) was 2.4 ± 2.8 mm (16%). The OCD lesion size tended to decrease within 1 year, although a further decrease was rarely seen. The mean Lw (%Lw) on APR45 was 1.8 ± 2.1 mm (10%) at the initial presentation and 4.7 ± 3.7 mm (25%) at the final assessment, and the mean increase of Lw (increase of %Lw) was 2.9 ± 3.9 mm (15%). The mean Mw (%Mw) on APR45 was 6.1 ± 3.3 mm (34%) at the initial presentation and 6.9 ± 3.9 mm (36%) at the final assessment, and the mean increase of Mw (increase of %Mw) was 0.8 ± 2.7 mm (1%). Nonoperative treatment was assessed as successful in 13 (41%) patients, and the mean period required for success was 8.8 months (range, 3.0-19.9 months).

Skeletal age score and the healing of OCD

The skeletal age score at the initial presentation tended to be lower in patients who achieved complete union in comparison with patients without complete union (20.6 points and 23.1 points, respectively; *P* = .27); however, the result was not statistically significant. The skeletal age score for the elbow, including the total score and the scores of each of the epiphyses, was not associated with the progression of ossification during the first 3 months or with partial union of the lesion.

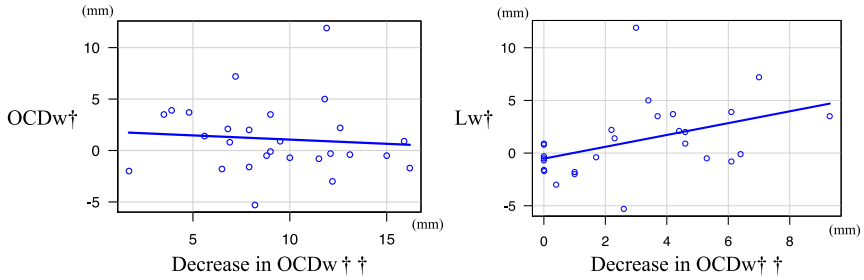

Figure 3 Quantitative radiographic assessments before and after the return to sports. n = 27 (patients with more than 3 months of nonoperative observation after the return to sports were analyzed). The OCD lesion width (OCDw) at the time of return to sports were not correlated with the subsequent decrease in OCDw after 3 months ($r = -0.18$, $P = .38$). The lateral width of the normal capitellum (Lw) at the time of return to sports was significantly correlated with the subsequent decrease in OCDw after 3 months ($r = 0.50$, $P = .008$). † OCDw and Lw at the time of return to sports. † † Decrease in OCDw during 3 months after return to sports. * Calculated using Spearman rank correlation coefficient (r). P values of < .05 were considered to indicate statistical significance. *OCD*, osteochondritis dissecans.

Table II
Comparison of the outcomes between 2 groups with or without the progression of ossification during the first 3 months.*

Outcomes	Progression of ossification		*P* value‡
	First 3 mo		
	Yes (O3m)	No (NO3m)	
	n = 16	n = 12	
Pain	5 (31%)	6 (50%)	.44
Return to sports	15 (94%)	12 (100%)	1.00
Duration for return (mo)§	6.0 ± 5.9	3.1 ± 3.1	.23
Complete return to sports	11 (69%)	4 (33%)	.13
Duration for complete return (mo)§	12.1 ± 8.9	8.7 ± 2.7	.85
Need for surgery	4 (25%)	7 (58%)	.12
OCDw decrease (mm)	4.9 ± 4.7	-0.7 ± 4.5	**.002**
%OCDw decrease (%)§	30 ± 26	0 ± 23	**.001**
Mean stage (points)§	3.3 ± 1.0	1.4 ± 1.3	**.003**
Union (stage II+ and III)	16 (100%)	2 (17%)	**<.001**
Duration for union§	3.4 ± 1.0	12.0 ± 0.0	**.003**
Complete union (III)	7 (44%)	2 (17%)	.22
Duration for complete union (mo)§	15.9 ± 5.9	12.0 ± 0.0	.30
Success†	11 (69%)	2 (17%)	**.009**
Duration for success (mo)§	8.0 ± 5.6	12.0 ± 0.0	.77

OCD, osteochondritis dissecans; *OCDw*, width of OCD.
Data represent the number of patients, unless otherwise indicated.
Bold values indicate statistical significance.
* n = 28 (4 patients were excluded from the analysis because the observation period was less than 6 months).
† Success was defined as a return to sports activities and radiographic healing as previously described by Niu et al.
‡ Calculated using the Mann-Whitney U test, or Fisher's exact probability test, as appropriate. *P* values of <.05 were considered to indicate statistical significance.
§ Values are presented as the mean and standard deviation.

The effects of the progression of ossification on the healing of OCD

Table II shows a comparison of the outcomes between 2 groups divided as per whether or not patients showed the progression of ossification in the lesion during the first 3 months: the ossification progression (O3m, n = 16) group and the no progression of ossification (NO3m, n = 12) group. Twenty-eight patients were selected for this analysis, as they had a nonoperative period of 3 months or longer since the grouping. The rate of union (stages II+ and III) in the O3m group (16 of 16, 100%) was significantly higher than that of the NO3m group (2 of 12, 17%, Fisher's exact probability test: $P < .001$). The mean duration required for union (stage II+) was 3.4 ± 1.0 months in the O3m group and 12.0 months in NO3m group. The mean qualitative score at the final follow-up examination in the O3m group was significantly higher than that in NO3m group (3.3 ± 1.0 points and 1.4 ± 1.3 points, respectively; Mann-Whitney U test: $P = .003$). The mean decreases in OCDw and % OCDw in the O3m group (4.9 ± 4.7 mm, 30%) were significantly larger than those of the NO3m group (−0.7 ± 4.5 mm, 0%, Mann-Whitney U test: $P = .002$, $P = .001$).

The effect of a return to sports on the healing of OCD

We examined OCDw and Lw at the time of return to sports and analyzed whether these data were associated with a decrease in OCDw and the outcomes (success or complete union). Figure 3 shows the correlation between the quantitative assessments at the time of the return to sports and the subsequent decrease in OCDw after 3 months. OCDw at the time of return to sports was not correlated with the subsequent decrease in OCDw after 3 months ($r = -0.18$, Spearman rank correlation coefficient: $P = .38$). Lw at the time of return to sports was significantly correlated with the subsequent decrease in OCDw after 3 months ($r = 0.50$, Spearman rank correlation coefficient: $P = .008$). Table III shows a comparison of the outcomes considering OCDw and Lw at the time of the return to sports. In the patients whose OCDw was <8.0 mm at the time of return to sports, the rate of successful nonoperative treatment was significantly higher than other patients (73% and 28%, Fisher's exact probability test, respectively; $P = .03$). Furthermore, in the patients with both OCDw <8.0 mm and Lw > 2.0 mm at the time of return to sports, the rate of successful nonoperative treatment was significantly higher than other patients (86% and 32%, Fisher's exact probability test, respectively; $P = .03$).

In the patients whose OCDw was <8.0 mm at the time of return to sports, complete union (stage III) was more frequently achieved in comparison with other patients (55% and 17%, Fisher's exact probability test, respectively; $P = .048$). Furthermore, in patients with both OCDw <8.0 mm and Lw > 2.0 mm at the time of the return to sports, complete union (stage III) was more frequently achieved in comparison with other patients (71% and 18%, Fisher's exact probability test, respectively; $P = .02$).

The multivariable logistic regression analysis to identify independent predictors of failed radiographic healing

We performed multivariable logistic regression analysis to identify independent predictors of failed radiographic healing. We set radiographic union (stages II+ and III) and successful nonoperative treatment at the final assessment as the objective variable and the followings as explanatory variables: elbow joint pain at the presentation,[13,37] pitcher, restriction of elbow motion,[30] no detection by sonography of the elbow in the field for baseball players, no prohibition throwing from the initial presentation, and no progression of ossification within the first 3 months. Regarding radiographic union, odds ratio was 30.0 (95% confidence interval:

Table III
Comparison of the outcomes considering the width of Lw and OCDw at the time of the return to sports.*

Radiographic assessment at return to sports	Outcomes		*P* value†
	Success	Failure	
OCDw < 8.0 mm			**.03**
Yes	8 (73%)	3 (27%)	
No	5 (28%)	13 (72%)	
Lw > 2.0 mm			.45
Yes	9 (53%)	8 (47%)	
No	4 (33%)	8 (67%)	
OCDw < 8.0 mm and Lw > 2.0 mm			**.03**
Yes	6 (86%)	1 (14%)	
No	7 (32%)	15 (68%)	
Radiographic assessment at return to sports	Complete union (stage III)		
	Achieved	Not	
OCDw < 8.0 mm			**.048**
Yes	6 (55%)	5 (35%)	
No	3 (17%)	15 (83%)	
Lw > 2.0 mm			.23
Yes	7 (41%)	10 (59%)	
No	2 (17%)	10 (83%)	
OCDw < 8.0 mm and Lw > 2.0 mm			**.02**
Yes	5 (71%)	2 (29%)	
No	4 (18%)	18 (82%)	

Lw, lateral width; *OCD*, osteochondritis dissecans; *OCDw*, width of OCD.
Data represent the number of patients, unless otherwise indicated.
Bold values indicate statistical significance.
* n = 29 (3 patients were excluded from the analysis because they underwent surgery before the return to sports).
† Calculated using Fisher's exact probability test. *P* values of < .05 were considered to indicate statistical significance. Cutoff values were determined by an ROC curve analysis.

4.3 to 210.0, $P < .001$) in no progression of ossification within the first 3 months. In addition, regarding successful nonoperative treatment, odds ratio was 11.9 (95% confidence interval: 2.0 to 71.4, $P = .007$) in no progression of ossification within the first 3 months.

Discussion

Matsuura et al[18] and Mihara et al[19] reported that the complete union rate of capitellar OCD in patients who received nonoperative treatment was 88-90.5% in stage I OCD (localized flattening or radiolucency) and 37.5% to 52.9% in stage II OCD. Matsuura et al[18] reported that gentle overhead throwing was allowed once the lesion had healed (14.9 months) and that noncompliant patients had a significantly lower union rate (22.7%). In this study, the duration of activity restriction was 4.4 months, and the complete union rate was 38% in stage I and 21% in stage II. These results indicate that complete union depends on the duration of activity restriction and that an early return to sports results in failure of complete union. A return to sports within 3 months should not be accepted because it results in complete union in <10% of patients in this study.

Niu et al[23] reported that progression of ossification was seen in 64.3% of patients with Ferti [11] stage I and 31.4% of patients with Ferti stage II with 7.6 months of activity restriction. This study showed similar rates of the progression of ossification (stage I, 69%; stage II, 63%). In this study, the success rate of nonoperative treatment (40.6%) was lower than that of Niu et al[23] (53.8%) because treatment was considered to have failed in patients who successfully returned to sports and later required surgery. Most patients and their parents would hope to return to sports before union could be completely achieved after 1 year or longer. This low rate of complete union may reflect the actual clinical situation, as Niu et al[23] also commented. It is desirable for OCD lesions to completely heal within 6 months; however, we are unaware of any nonoperative treatment that provides such excellent results. More stringent elbow joint rest or additional active treatment would be required to provide both of an early return to sports and complete union.

Recently, the size of OCD lesion has been studied.[3,8,23,31] Niu et al[23] performed a retrospective review about stable OCD with magnetic resonance imaging and concluded that small lesions without cyst-like lesions are more likely to heal with nonoperative treatment. Although the lesion size at the initial presentation was assessed, the quantitative changes during activity restriction or after the return to sports were not addressed. We repeatedly assessed the coronal size (width) of the lesion with the lateral and medial width of the normal capitellum. The mean %OCDw finally changed from 56% to 41%, and the mean %Lw changed from 10% to 25%. This quantitative study revealed that OCD lesions often remained in the middle one-third of the capitellum and that the central area of the capitellum showed more difficult healing in comparison with the lateral area. The reason for these results is that the center of the capitellum may be most subject to mechanical stress. When treating capitellar OCD, it is useful to consider the locations that show more difficulty in healing.

The rates of both union and success were significantly higher in patients with the progression of ossification during the first 3 months in comparison with those without progression, and both the qualitative and quantitative outcomes were significantly better in the former group. When APR45 shows no progression of ossification during the first 3 months of nonoperative treatment, the lesion should be reevaluated by MRI for decision-making in relation with operative treatment. A histologic study on OCD of the capitellum revealed that ossification of the lesion was associated with a significantly dominant fibrocartilage connection to the underlying bone, in other words, the arrest of ossification was associated with separation rather than fibrocartilage connection.[29] We consider that the arrest of ossification during nonoperative treatment can be caused by micromovement of the OCD lesion. This study showed that the progression of ossification during the first 3 months was one of the predictors of successful nonoperative treatment and radiographic healing.

As predictors of good or poor results, Pappas[24] suggested that younger patients display better outcomes. This study found no correlation between the outcome and age, as previous studies described.[26,32] The complete healing rates of capitellar OCD in patients with open (90%) and closed (50%) growth plates of the capitellum were significantly different.[19] In this study, the skeletal age score at the initial presentation tended to be low in patients with complete union. However, a low skeletal age score could not be a significant predictor of complete healing.

Many authors have advocated that an accepted cause of OCD is either acute or repetitive microtrauma applied to the immature epiphysis during sports, which makes the lesions unstable.[7,14,15,22,28,30,31,35] However, little is known about the timing of the return to sports, followed by success and complete union. This quantitative analysis revealed that a larger lateral normal area at the timing of the return to sports was more likely to heal (Fig. 3). As one of the landmarks for the timing of the return to sports, for example throwing, we would like to propose both an OCD lesion width of <8.0 mm and a lateral normal width of >2.0 mm. When both criteria were met, the success and complete union rates were both more than 70%. In contrast, we could not find the optimal period required for achieving a successful outcome.

The present study was associated with some limitations. This study was not prospective in nature. Furthermore, the number of patients with stable OCD lesions was relatively small, while 76 patients with unstable lesions underwent operations during the same period. While elbow rest was recommended, activity restriction actually depended on the patients themselves. This may

reflect the actual clinical situation of nonoperative treatment for OCD. In this study, we simply evaluated the OCD lesion on APR45, which is best radiograph for capitellar OCD[18,19,31] and which is commonly used in the clinical follow-up. Even if a capitellar OCD lesion is asymptomatic, when progression of ossification is not seen on APR45 for more than 3 months, the instability should be reevaluated using magnetic resonance imaging or computed tomography to determine treatment options.

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