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Long-term results of closed-wedge osteotomy of the lateral humeral condyle for osteochondritis dissecans of the capitellum

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Background: Various surgical methods are used for osteochondritis dissecans of the capitellum; however, we have consistently performed a closed-wedge osteotomy of the lateral humeral condyle since 1983. The purpose of this study is to clarify the long-term results of closed-wedge osteotomy for osteochondritis dissecans of the capitellum.

Methods: Seventy-seven elbows with all lesion types of osteochondritis dissecans of the capitellum were treated with closed-wedge osteotomy. Unstable osteochondral fragments were fixed with a bone graft and bone pegs in combination with osteotomy. The mean age of the patients was 14.0 years. The patients were clinically and radiographically evaluated at a median value of 9.0 years after surgery.

Results: The range of elbow motion and standard deviation were increased significantly from 119° ± 22° preoperatively to 131° ± 18° postoperatively ($P < .001$). The Timmerman and Andrews score were improved significantly from 141 ± 26 points preoperatively to 184 ± 21 points postoperatively ($P < .001$). The Timmerman and Andrews score and the range of elbow motion at final examination in patients with preoperative osteoarthritic changes were significantly inferior to those in patients without preoperative osteoarthritic changes. Good remodeling of the capitellar lesions was radiographically observed in 53 elbows (69%). In the long-term follow-up evaluation, although 41 elbows (53%) had advanced osteoarthritic changes that were classified as grade II or III, disease progression was controlled in most of these cases.

Conclusions: Good or excellent long-term clinical results were maintained in most of our patients. Closed-wedge osteotomy of the lateral humeral condyle is a useful method that can provide acceptable long-term clinical results.

Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Closed-wedge osteotomy; lateral humeral condyle; osteochondritis dissecans; capitellum; ICRS classification; baseball

IRB information: The Ethics Committee of Niigata Central Hospital has approved this clinical study (IRB approval number: et2018-01).

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Many surgical techniques have been previously described for osteochondritis dissecans (OCD) of the capitellum, including fragment fixation with a bone graft and débridement with or without drilling or curettage. However, these techniques may only relieve symptoms temporarily and fail to control osteoarthritic changes in the elbow.[3,10,14,25,26,28] Some recent reports have proposed the use of osteochondral autografts from the periphery of the femoral condyle or osteochondral junction of the rib; however, to our knowledge, no reports have described the long-term results in a large cohort of patients.[1,7,11,12,13,19,21,30,29] Since 1983, we have been treating advanced OCD of the capitellum with a closed-wedge osteotomy of the lateral humeral condyle to reduce the radiocapitellar compression force, promote the remodeling of the capitellar lesion, and fix unstable fragments with bone pegs that were harvested from the resected bony wedge.[31] This surgical procedure is not widely known, and its efficacy has not yet been assessed. The purpose of the present study was to clarify the clinical and radiographic long-term results of closed-wedge osteotomy for all lesion types of OCD with a minimum follow-up period of 5 years and to investigate the relevance of our clinical results vis-à-vis the intraoperative International Cartilage Repair Society (ICRS) classification. [4]

Materials and methods

Patients

This study was a review of a retrospective case series. Between 1983 and 2006, a total of 77 elbows in 76 patients (74 male, 2 female) with all lesion types of OCD were treated by a closed-wedge osteotomy of the humeral lateral condyle at our institution. Of these patients, only 1 male patient had an advanced bilateral OCD of the capitellum. Sixty-two patients had been engaged in baseball, and others had participated in competitive sports such as gymnastics, judo, kendo, basketball, table tennis, badminton, and football. The mean age of the patients at the time of surgery was 14.0 years (range, 11-16 years). According to the ICRS classification system, which is widely acknowledged for its validity, 10 elbows were assigned to ICRS stage I, 12 to stage II, 15 to stage III, and 40 to stage IV. We determined the classification at time of surgery under direct visualization.

Surgical technique

A skin incision was made over the lateral aspect of the elbow that was approximately 8 cm long from a point 5 cm proximal to the lateral epicondyle to the radial head. We approached the elbow joint between the extensor carpi radialis longus and the extensor carpi radialis brevis muscles. The anterior joint capsule was detached anteriorly and subperiosteally (Fig. 1). To create a better operative field, we incised the origin of the annular ligament of the elbow in most cases. During this procedure, the posterior aspect of the lateral condyle of the humerus was not exposed to maintain circulation in the capitellum. Using a power saw, we carried out a laterally based closed-wedge osteotomy with an intervening angle of 10° at approximately 2 cm proximal to the lateral epicondyle, with its apex just medial to the capitellum (Fig. 2).

After assessing the capitellar lesion using the probe, fragment fixation with bone pegs was additionally performed for stable osteochondral fragments classified as ICRS stage II. Cancellous bone grafts from the resected wedge and fragment fixation with bone pegs were also performed if any unstable osteochondral fragments were observed. For ICRS stage IV cases, we did not manipulate the lesion and only removed the loose body. Although we prefer to leave the articular cartilage of the apex intact, some cases required a complete discontinuity of the articular cartilage when fixing the large osteochondral fragment (Fig. 3). Finally, we achieved rigid fixation with a cortical screw and Kirschner wire.

Postoperative treatment

Postoperatively, a long arm cast was applied for 3 weeks with the elbow immobilized at 90° flexion and the forearm in a neutral position. After removing the cast, the patient began active and assisted passive motion exercises of the elbow and forearm. Implants were routinely removed by 5 months after surgery in all cases. Throwing was permitted at 6 months after surgery, provided that the elbow was asymptomatic. Subjects should be able to return to their previous level of sports at approximately 8 months after surgery.

Assessment

Clinical assessment

Surgeons who had been part of the treatment team assessed all patients preoperatively and at the last examination for range of elbow motion, elbow pain, and sports activities. A clinical rating system described by Timmerman and Andrews was used to assess elbow function, which consisted of both subjective (pain, swelling, locking and/or catching, and activities) and objective (range of motion) evaluations.[27] The calculated scores were classified into the following 4 categories: excellent (180-200), good (160-179), fair (120-159), or poor (<120). In addition, the Timmerman and Andrews score and range of motion were postoperatively compared between elbows with and without advanced osteoarthritic changes.

Radiographic assessment

Three radiographs including an anteroposterior, lateral, and tangential view in 40° of flexion were obtained preoperatively and at long-term follow-up. Radiographic evaluation included remodeling of the capitellar lesion and whether or not osteoarthritic change had advanced. The long-term follow-up for the remodeling of the capitellar lesion was evaluated using a system described by Iwahori et al[5] and classified into the following 4 categories: excellent (completely remodeled), good (partial irregularity or flattening), fair (slight defect or partial nonunion), and poor (severe defect, complete nonunion, or advanced osteoarthritic change in the radiocapitellar joint). The osteoarthritic state of the elbow joint was evaluated preoperatively and at final examination, according to a system described by Shinomiya,[22] which consisted of the following 4 grades: normal, grade I (presence of a small bony spur), grade II (presence of a large bony spur or slight narrowing of the joint space), and grade III (presence of a loose body or severe narrowing of the joint space). Grade II and III elbows were considered advanced osteoarthritic changes, and we compared the conditions revealed by the preoperative and final radiographic examinations. All radiographs were evaluated by the first author. When the exact osteoarthritis

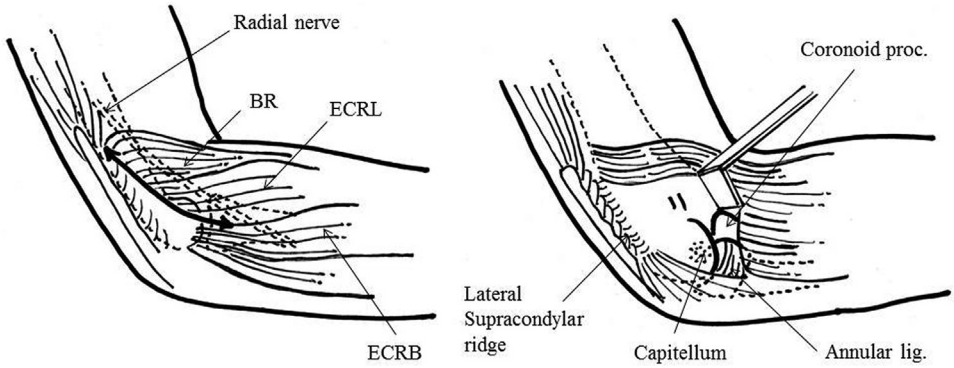

Figure 1 The surgical approach for the capitellum.

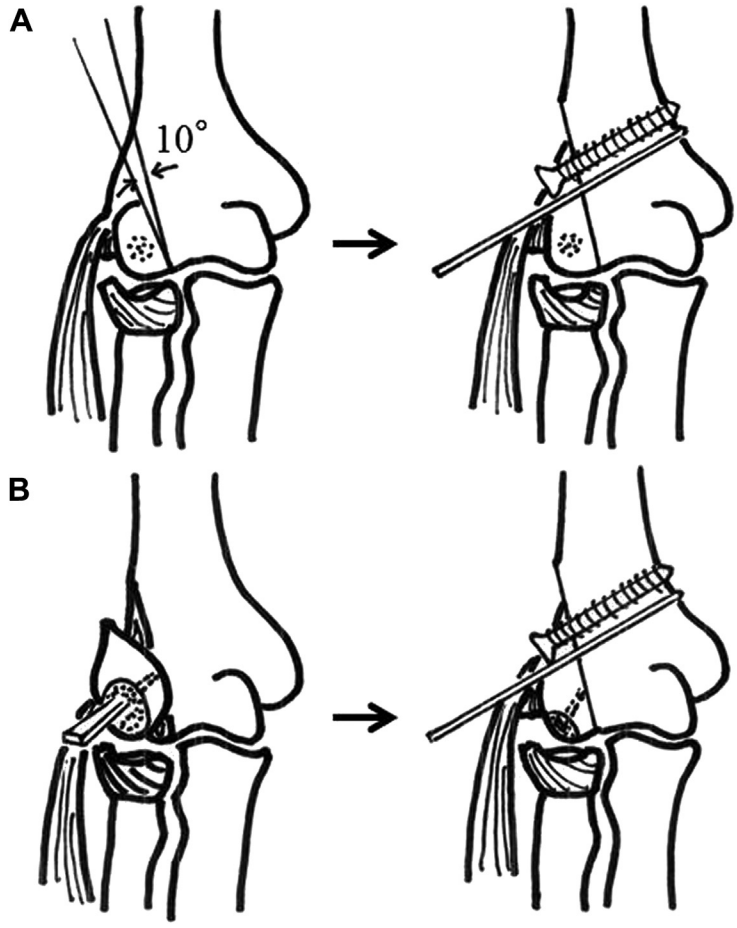

Figure 2 The procedures of closed-wedge osteotomy. (**A**) Original method. (**B**) Modified method for unstable lesion with bone peg.

grade was difficult to determine in selected patients, grading was decided after careful discussion with the senior author (K.M.).

Statistical analysis

Statistical comparisons between the preoperative and postoperative (at final examination) conditions were performed. The Timmerman and Andrews score and range of motion were assessed using the Wilcoxon *t* test. Statistical comparisons between the preoperative range of motion and clinical score, postoperative range of motion and clinical score, and preoperative and postoperative osteoarthritis grades according to the ICRS classification were assessed using the Kruskal-Wallis test. If the *P* value indicated significance, multiple post hoc analyses were conducted using the Mann-Whitney *U* test with Bonferroni correction. Differences in clinical results between elbows with and without advanced osteoarthritic changes were assessed using the Mann-Whitney *U* test. In all tests, *P* values $<.05$ were considered statistically significant.

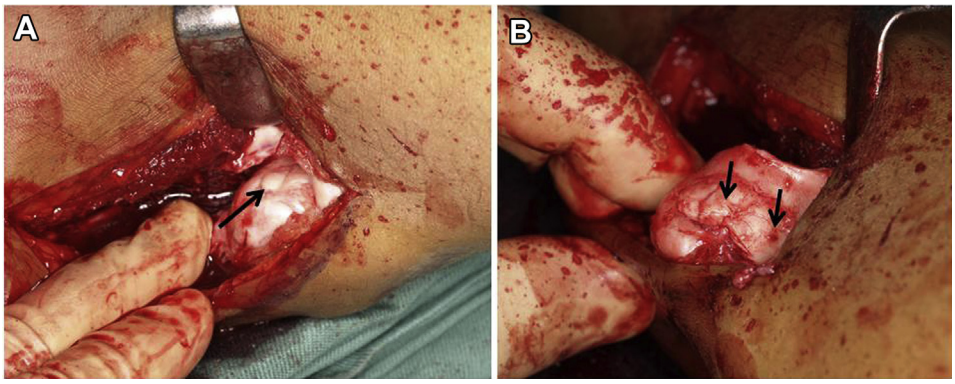

Figure 3 Operative technique. (**A**) Exposure of the capitellar lesion (→) with lateral approach. (**B**) Fixation of unstable fragments with bone pegs (↓).

Results

Clinical evaluation

After a median follow-up of 9.0 years (range, 5-25 years), the range of elbow motion increased significantly from 119° ± 22° to 131° ± 18° postoperatively ($P < .001$). With regard to postoperative pain, 51 elbows were pain-free. Seventeen elbows occasionally presented slight pain during intense activity of the elbow, such as throwing and heavy labor, 6 elbows frequently exhibited pain with moderate activity, and the remaining 3 elbows usually exhibited pain with all activities. Flexion contracture was noted in 27 elbows: 5°-15° in 19, 16°-35° in 6, and >35° in 2. The Timmerman and Andrews score improved significantly from 131 ± 18 points preoperatively to 184 ± 21 points postoperatively ($P < .001$). Postoperative evaluation was excellent in 57 elbows, good in 12, fair in 6, and poor in 2.

The preoperative Timmerman and Andrews score and range of motion were significantly different in terms of the ICRS classification ($P = .002$, $P = .023$). The clinical results in stage I were significantly better than those in stage III ($P = .068$, $P = .05$) and stage IV ($P = .034$, $P = .007$) before surgery. The preoperative Timmerman and Andrews score in stage II were significantly better than those in stage IV ($P = .017$). However, the postoperative Timmerman and Andrews score and range of motion did not vary significantly among the various ICRS classification grades (Table I). The postoperative Timmerman and Andrews score and range of motion were 189 ± 20 points and 136° ± 17°, respectively, in elbows that showed no preoperative osteoarthritic changes. For elbows that had already shown preoperative osteoarthritic changes, the corresponding postoperative values were 170 ± 19 points and 116° ± 16°, respectively. The postoperative Timmerman and Andrews score and range of motion in elbows with preoperative osteoarthritic changes were significantly worse than those in elbows without them ($P < .001$) (Table II).

Return to sports activities

Fifty of the 76 patients were able to return to the sports they had played previously at a competitive level. Eight patients were able to return to their previous sports, but at a lower level. Although the remaining 18 patients did not return to their previous sports, their clinical scores were not necessarily low. Their evaluation based on the Timmerman and Andrews score was excellent in 10 patients, good in 3, fair in 4, and poor in 1. Most of these patients were able to attain competitive levels of performance in other sports.

Radiographic evaluation

Although the enlargement of the radial head facing the capitellum occurred in almost all elbows, excellent and good remodeling of the capitellum were observed at final examination in 20 and 33 elbows, respectively. In terms of remodeling of the lesion, 15 elbows were graded as fair and 9 were graded as poor. Excellent or good remodeling was seen in 100% of ICRS stage I cases, 67% of stage II cases, 73% of stage III cases, and 60% of stage IV cases. The degrees of remodeling were significantly different in terms of the ICRS classification ($P = .004$). Those in stage I showed a significantly greater degree of remodeling than those in stage II ($P = .008$), stage III ($P = .017$), and stage IV ($P = .003$) (Table III).

The preoperative osteoarthritic states were classified as normal in 37 elbows, grade I in 20, and grade II in 20, with the differences between the ICRS grades being statistically significant ($P = .006$). Postoperatively, the state of osteoarthritis was normal in 13 elbows, grade I in 23, grade II in 31, and grade III in 10 and it differed significantly among the ICRS grades ($P = .012$). In both findings, the radiologic results in stage I were significantly better than those in stage II ($P = .002$, $P = .007$, respectively), stage III ($P = .02$, $P = .005$, respectively), and stage IV ($P = .001$, $P = .0001$, respectively). Three of 10 elbows at preoperative ICRS stage I showed progression of the osteoarthritis grade, compared with 7 of 12 at stage II, 12 of 15 at stage III, and 23 of 40 at stage

Table I Comparisons of clinical results with respect to ICRS classification

ICRS stage (no. of elbows)	Initial presentation			Results at final examination		
	Mean age, yr	Mean range of motion, degrees*	Mean Timmerman and Andrews Score†	Mean duration of follow-up, yr	Mean range of motion, degree	Mean Timmerman and Andrews score
I (10)	14.2	135 ± 18	162 ± 19	13.5	144 ± 14	194 ± 8
II (12)	13.6	128 ± 17	151 ± 16	9.1	133 ± 18	185 ± 13
III (15)	14.1	116 ± 21	143 ± 29	8.2	132 ± 19	185 ± 27
IV (40)	14	113 ± 22	132 ± 27	9.1	127 ± 18	181 ± 22

ICRS, International Cartilage Repair Society.
The difference among ICRS stages was significant (*$P = .002$, †$P = .023$). The range of motion and Timmerman and Andrews score in stage I were significantly better than those in stage III ($P = .07$ and $P = .05$, respectively) and stage IV ($P = .034$ and $P = .007$, respectively) before surgery. The preoperative Timmerman and Andrews scores in stage II were significantly better than those in stage IV ($P = .017$).

Table II Comparisons of results concerning preoperative advanced osteoarthritic changes

Preoperative advanced osteoarthritic changes (no. of elbows)	Initial presentation			Results at final examination		
	Mean age, yr	Mean range of motion, degree	Mean Timmerman and Andrews score	Mean range of motion, degree*	Mean Timmerman and Andrews score*	Mean duration of follow-up, yr
Yes (20)	14.5	109 ± 19	124 ± 27	116 ± 16	170 ± 19	9.3
No (57)	13.9	122 ± 21	147 ± 24	136 ± 17	189 ± 20	9.6

* The postoperative range of motion and Timmerman and Andrews score in elbows with preoperative osteoarthritic changes were significantly worse than those in elbows without them ($P < .001$).

Table III Radiologic evaluation of remodeling

ICRS stage (no. of elbows)	Results at final examination			
	Excellent	Good	Fair	Poor
I (10)	8	2	0	0
II (12)	1	7	3	1
III (15)	5	6	2	2
IV (40)	7	17	10	6

ICRS, International Cartilage Repair Society.
The degrees of remodeling were significantly different in terms of the ICRS classification ($P = .004$). Those in stage I were significantly better than those in stage II ($P = .008$), stage III ($P = .017$), and stage IV ($P = .003$).

IV. However, no statistical differences were observed (Table IV).

In the long-term follow-up evaluation, 36 elbows (47%) showed no advanced osteoarthritic changes and were managed to prevent progression past a near-normal stage (Figs. 4 and 5). Although the remaining 41 elbows (53%) had advanced osteoarthritic changes to varying degrees, disease progression was controlled in most of these cases.

Complications

No patients developed infection, delayed union or nonunion in the osteotomized area. Loose body formation occurred in 11 elbows, and additional surgery was performed on 5 of these elbows for the removal of loose bodies. There was no deformity, osteonecrosis, and obstacle of capitellar growth in our series. In addition, our clinical results offer no evidence to suggest ulnohumeral joint instability.

Discussion

The present study examined the long-term results of closed-wedge osteotomy of the lateral humeral condyle for osteochondritis dissecans of the capitellum. In the context of this study, OCD and Panner disease should be differentiated.[16] Panner disease is typically found in young patients aged <10 years with no history of trauma, and the entire capitellar epiphysis is involved.[2,8] Its clinical course is usually benign, because intra-articular loose bodies never form. In contrast, OCD of the capitellum usually affects adolescent athletes between ages 12 and 15 years who are involved in repetitive overloading or weight-bearing activities, and only the anterolateral aspect of the capitellum is involved. In advanced stages, fragmentation and loose body formation are often observed. Although Singer and Roy proposed that Panner disease and OCD of the capitellum represent different stages of changes in endochondral ossification, we believe that the 2 conditions appear to be distinct processes.[23] In our series, initial symptoms in the elbows occurred in patients between 11 and 16 years of age, and there were no lesions involving the entire capitellar epiphysis that was suggestive of Panner disease.

In our study, 69 of 77 elbows (90%) showed excellent or good results in the postoperative Timmerman and Andrews

Table IV Radiologic evaluation of osteoarthritic changes

ICRS stage (n = elbows)	Initial presentation*				Results at final examination†			
	Normal	Grade I	Grade II	Grade III	Normal	Grade I	Grade II	Grade III
I (10)	10	0	0	0	7	1	2	0
II (12)	4	5	3	0	1	7	3	1
III (15)	9	4	2	0	2	3	7	3
IV (40)	14	11	15	0	3	12	19	6

ICRS, International Cartilage Repair Society.
The difference between the ICRS stages was significant (*$P = .006$, †$P = .012$). The preoperative and postoperative osteoarthritic changes in stage I were significantly better than those in stage II ($P = .002$ and $P = .007$, respectively), stage III ($P = .02$ and $P = .005$, respectively), and stage IV ($P = .001$ and $P < .001$, respectively).

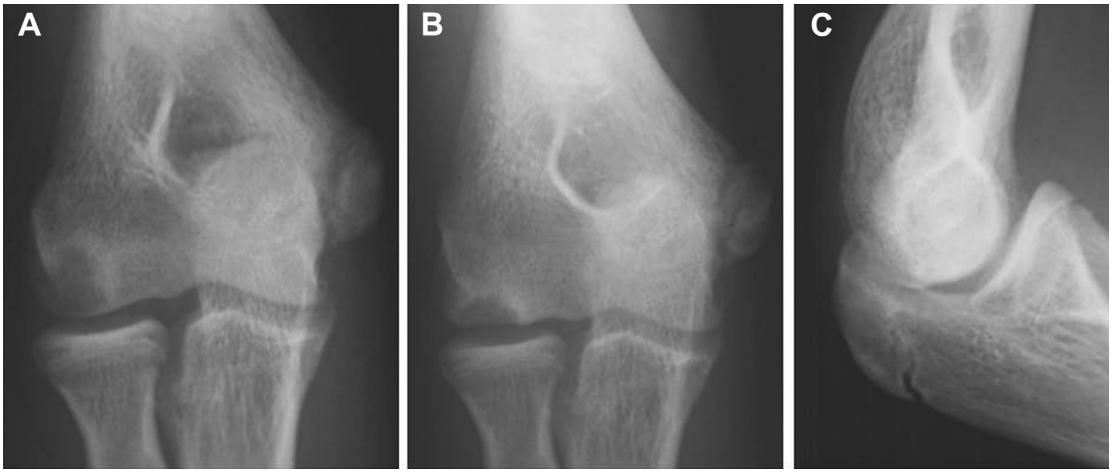

Figure 4 Preoperative radiographs of a 13-year-old boy with osteochondritis dissecans of the capitellum, classified as ICRS stage IV. The patient had been playing baseball since he was 8 years old. (**A**) Anteroposterior view; (**B**) tangential view; (**C**) lateral view. The radiographs showed no osteoarthritic changes. *ICRS*, International Cartilage Repair Society.

score, and 51 (66%) were free of elbow pain. In terms of radiologic results, 36 (47%) elbows showed minimal osteoarthritic changes (normal in 13 and grade I in 23), and 53 elbows (69%) showed sufficient remodeling. Although the postoperative osteoarthritis grades tended to advance in parallel with the preoperative ICRS stage, a few elbows showed advanced osteoarthritis at an earlier stage. These results revealed that closed-wedge osteotomy of the lateral humeral condyle could provide acceptable long-term clinical results; however, our method was unable to fully prevent the long-term advancement of osteoarthritis. Enlargement of the radial head facing the capitellum occurred in most elbows, but it did not seem to directly influence the clinical and functional results. Radiographic assessments in the current study showed that both the preoperative and postoperative osteoarthritis grades differed significantly as the ICRS stage advanced. The Timmerman and Andrews score and range of motion of the elbows with preoperative osteoarthritic changes became significantly worse than those without preoperative osteoarthritic changes. These results revealed that treatment should be initiated before any subsequent osteoarthritic changes occur. Furthermore, this recommendation implies our method is more effective for lesions in early stages of OCD.

Closed-wedge osteotomy of the lateral humeral condyle has unique features such as reduction of radiocapitellar compression force and revascularization of the capitellar lesion. Radiographs immediately after surgery showed that the radiohumeral joint space was obviously widened by a closed-wedge osteotomy at 10°; therefore, we believe that the radiocapitellar joint may be decompressed by osteotomy. Although there is no biomechanical analysis on this operation in the literature, an animal study has confirmed the increase of blood flow in fracture sites,[17] and similar results are likely to be found in osteotomized sites. In addition to the osteotomized area, the blood supply may increase and promote the revascularization of the capitellar lesion. Thus, revascularization could stimulate the potential for bone remodeling of the lesion, as seen after osteotomy in Kienböck disease and Freiberg disease.[24] We applied our method for patients in all stages of ICRS classification, because we believe that osteotomy may have advantages for revascularization and remodeling of the capitellar lesion.

In 2000, Kiyoshige et al[9] reported the effectiveness of closed-wedge osteotomy for OCD in a series of 7 patients that was followed up for 7-12 years. The lesion of the capitellum was revascularized and remodeled within a half

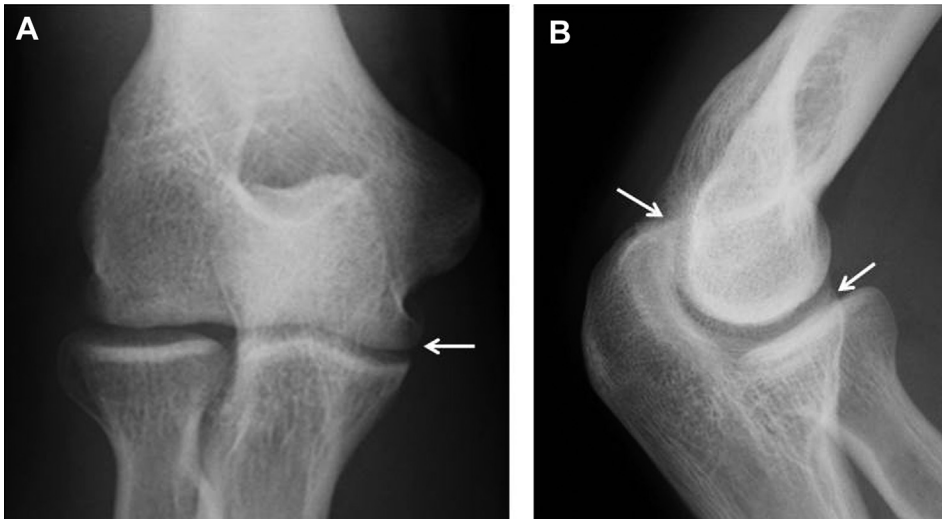

Figure 5 Postoperative radiographs of the patient depicted in Fig. 4 showed slight osteoarthritic changes at 10-year follow-up (→). (**A**) Tangential view; (**B**) lateral view. The patient had been engaged in baseball at an amateur level. He had no elbow pain, and his range of elbow motion was 150° (hyperextension 10°; flexion 140°). His Timmerman and Andrews score improved from 150 points to 200 points.

year in all of their patients; however, like our study, enlargement of the radial head was observed in all patients. These changes appear to be a compensatory process for remodeling of the capitellum. All patients except 1 who continued to only have mild elbow pain during throwing had returned to playing baseball, and the patient continued to play baseball until the final examination. Oka et al[14] described the long-term results of fragment fixation using bone peg grafting for OCD of the capitellum, and reported that only 5 of 10 patients had sufficient healing of the capitellar lesion and that most of these patients showed some kind of long-term osteoarthritic changes. Oshiba et al[15] also performed bone peg grafting for OCD of the capitellum that were classified as ICRS stage I or II and reported that healing of the lesion was incomplete in 3 of 11 patients (27%). In contrast to fragment fixation, our method may have the advantage of remodeling the capitellar lesion and preventing any advanced osteoarthritic changes, and these potential advantages led us to believe that our method should be applied even at an early stage of the disease. In terms of ICRS stage III or IV, we believe that our long-term results may be better than those of previously described methods such as fragment fixation using bone peg grafting, open débridement, and simple excision of the capitellar lesion.[3,14,25,26]

Our method is not necessarily an isolated technique. Associated procedures such as bone peg grafting and cancellous bone graft were performed in 27 elbows (35%) that were classified as ICRS stage II or III, and these procedures enhance the results of closed-wedge osteotomy. Furthermore, the combined use of osteochondral autografts may be critical for closed-wedge osteotomy.

In recent years, studies of osteochondral autografts from the periphery of the femoral condyle or osteochondral junction of the rib have reported excellent midterm follow-up results in an adequate number of patients.[6,18,20] The mean Timmerman and Andrews score and the range of motion in our series were comparable. If attention is drawn to the results alone, our return rate was inferior to those of previous studies that showed that approximately 90% of patients were able to return to their original sports activity. However, we believe that the prevention of long-term limitations in activities of daily living outweighs the prospects of returning to previous sports activities. Although a greater number of patients in our study may have been able to return to their original sports activities, we refrained from recommending our patients to engage in throwing sports or weight-bearing activities. Especially in the early stages of applying our technique, we suggested that athletes not return to their previous sports that involve repetitive overloading or weight-bearing activities, which may have affected the lower return rate. Generally, osteochondral autografts have been applied for cases graded as stage III or IV with the ICRS classification system. In this current study, approximately half of the elbows classified as ICRS stage III or IV demonstrated some degree of osteoarthritic change before surgery. Studies on osteochondral autografts for OCD of the capitellum have reported that few patients develop subsequent osteoarthritic changes postoperatively.[6,20] However, the standards employed for the evaluation of these subsequent osteoarthritic changes were not clearly described in these studies. On the other hand, Sato et al[18] described that postoperative osteoarthritis was seen in 33 of 72 patients (46%) at the latest follow-up. We believe that future research must reveal subsequent osteoarthritic changes after osteochondral autografts with long-term follow-up.

Our study has some limitations. First, this study is retrospective in design. Second, there were selection and observer biases, as patients were recruited from a single hospital. Third, there was variability in terms of the number of patients

distributed under the ICRS classification. Fourth, neither postoperative evaluation of joint surface using magnetic resonance imaging nor second-look observation with or without arthroscopy was carried out. Therefore, a prospective study with a patient satisfaction questionnaire and direct physical examination is needed to overcome these limitations. Finally, there was no biomechanical analysis on decompression of the radiocapitellar joint and revascularization of the lesion with closed-wedge osteotomy.

Conclusions

The unique closed-wedge osteotomy of the lateral humeral condyle described in this study provides acceptable long-term clinical results and stable radiologic results with regard to remodeling of the capitellar lesion. Although our method was unable to fully prevent the long-term progression of osteoarthritis, we conclude that closed-wedge osteotomy of the lateral humeral condyle is a reliable option for treatment of OCD of the capitellum.

Disclaimer

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