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Lateral wall fixation with bone pegs for advanced osteochondritis dissecans of the humeral capitellum



Hideaki Imada, MD, PhD ^{a,*}, Ryo Mori, MD, PhD ^a, Hayatoshi Shibuya, MD, PhD ^a, Satoshi Ujigo, MD, PhD ^a, Hiroki Kaneta, MD ^a, Yuji Kado, MD ^a, Kazuhiko Kishi, MD ^a, Nobuo Adachi, MD, PhD ^b

^a Department of Orthopedic Surgery, National Hospital Organization, Higashi-Hiroshima Medical Center, Hiroshima, Japan

^b Department of Orthopaedic Surgery, Graduate School of Biomedical and Health Sciences, Hiroshima University, Hiroshima, Japan

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Background and hypothesis: It is generally considered that fragment fixation with bone pegs (FFBP) for osteochondritis dissecans (OCD) of the humeral capitellum can be indicated for stages I and II according to the International Cartilage Repair Society (ICRS) classification of OCD and it is difficult to obtain complete bone union for advanced lesions. However, the clinical and radiologic results of FFBP with cancellous bone graft for ICRS-OCD stage III with lateral wall involvement have not been described in detail. Good bone union can be achieved with the lateral wall fragment of the capitellum by FFBP in combination with refreshing the sclerotic surface at the base of the lesion and cancellous bone grafting even in ICRS-OCD stage III lesions.

Methods: In total, 10 adolescent baseball players with a diagnosis of OCD, a median age of 13.5 years at the time of surgery, and 26.7 months of postoperative follow-up were included. Preoperative imaging showed that all patients had lesions in the late detached stage and of the lateral-widespread type based on the site of the focal lesion. The intraoperative ICRS-OCD classification was stage III. We aimed to preserve and fix the lateral wall fragment with cancellous bone grafting if the condition of the articular cartilage was good and the size and thickness of the segment could withstand fixation.

Results: Bone union of the lateral wall fragment was achieved in all cases. The elbow extension range of motion was $-3.9^\circ \pm 9.7^\circ$ before surgery and was eventually $-0.4^\circ \pm 6.7^\circ$ at the final assessment. Flexion range of motion ranged from $138.1^\circ \pm 10.5^\circ$ to $142.4^\circ \pm 6.2^\circ$. The Timmerman and Andrews score significantly improved from 165.5 ± 10.9 points before surgery to 197.0 ± 6.3 points after surgery, demonstrating excellent results in all patients. All patients were able to return to competitive baseball.

Conclusion: The radiographic and clinical outcomes of FFBP for lateral wall fragments with cancellous bone graft were satisfactory, showing that the indications for this procedure could be extended to ICRS-OCD stage III.

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Osteochondritis dissecans (OCD) of the humeral capitellum is an osteochondral disorder involving separation of the articular cartilage from the subchondral bone. In general, OCD of the humerus is considered to occur from the lateral side of the capitellum and spread to the central side. It tends to occur in young athletes, especially baseball players. Early and stable lesions are treated conservatively, usually with satisfactory results. When conservative

treatment fails or the lesions are unstable, surgical management is recommended. Surgical procedures comprise arthroscopic drilling after removal of loose bodies and fragments,^{18,12} fragment fixation with bone pegs (FFBP),^{7,10,11,13,14,18,21} or implantation of osteochondral grafts from the knee^{4,17,18,22} or rib.¹⁶ The appropriate treatment procedure is usually selected during intraoperative observation based on the International Cartilage Repair Society (ICRS) classification of OCD.² Generally, it has been considered that FFBP can be indicated for ICRS-OCD stages I and II and it is difficult to obtain complete bone union for ICRS-OCD stage III lesions.

If the reported results of successful bone union after FFBP^{7,10,11,13,14,18,21} are assessed by distinguishing between the lateral and central sides of the capitellum, however, it can be observed that all patients exhibited complete bone union when the

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* Corresponding author: Hideaki Imada, MD, PhD, Department of Orthopedic Surgery, National Hospital Organization, Higashi-Hiroshima Medical Center, 531 Jike, Saijouchou, Higashihiroshima, Hiroshima, 739-0041, Japan.

E-mail address: handimada@gmail.com (H. Imada).

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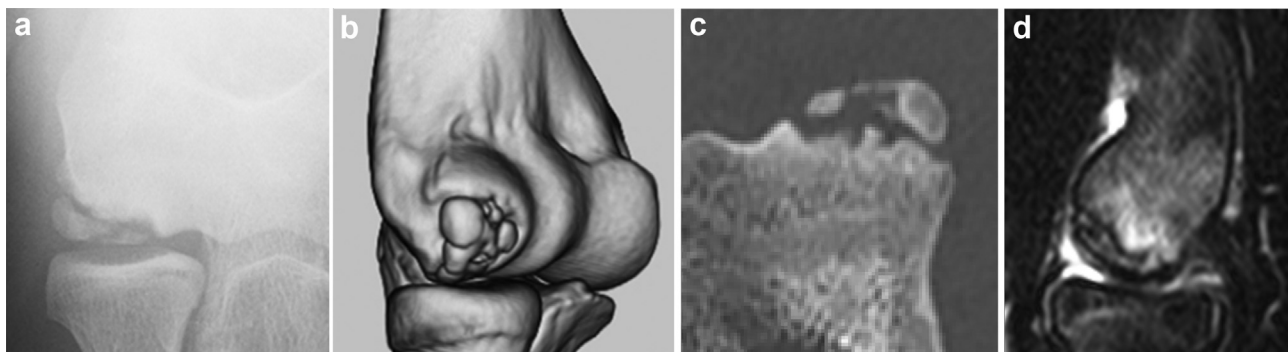


Figure 1 Imaging findings in patient 7 prior to surgery (right elbow). (a) Coronal image on plain radiography. (b) Three-dimensional computed tomography image. (c) Axial computed tomography image. A segmented but nondisplaced fragment of the subchondral bone from the lateral wall to the central part was observed (a–c). (d) Sagittal magnetic resonance image. T2-weighted imaging showed irregular contours on the articular surface of the capitellum; therefore, this case was classified as being in the detached stage.

lesion was on the lateral side, showing that bone healing more easily occurs on the lateral side than on the central side. In addition, good results have been reported for fragment fixation in combination with cancellous bone graft for advanced-stage OCD of the capitellum.^{3,19}

On the basis of the aforementioned information, we hypothesized that good bone union could be obtained on the lateral side, including the lateral wall of the capitellum, by refreshing the sclerotic surface at the base of the lesion and performing cancellous bone grafting even in advanced-stage disease. We performed FFBP with cancellous bone graft for lateral wall fragments of ICRS-OCD stage III in adolescent baseball players and retrospectively assessed their imaging and clinical results.

Materials and methods

Patient population

Between 2012 and 2018, 54 adolescent baseball players with OCD of the humeral capitellum were surgically treated in our institution. Indications for surgical treatment included failure after >6 months of conservative treatment or an unstable fragment visualized radiographically or on magnetic resonance imaging (MRI) scans. The instability of the fragment was determined by the presence of an irregular contour of the articular surface and/or a high-signal intensity interface between the fragments and their bed on T2-weighted magnetic resonance images. We excluded 36 patients (13 who underwent removal of the fragment with drilling, 19 who underwent osteochondral bone grafting from the knee, and 4 who underwent FFBP for central-type lesions). Of the remaining 18 patients, 8 with a follow-up period of <2 years were further excluded. As a result, 10 patients (10 elbows) were included in this study.

Among these patients, 1 had to undergo reoperation after initial fixation using an absorbable pin at another hospital. All patients were young male baseball players, and in all patients, the onset of OCD occurred on the dominant side. The average age at the time of surgery was 13.5 years (range, 12–16 years), and the average post-operative duration of follow-up was 26.7 months (range, 24–36 months).

At the initial examination, plain radiography including an anteroposterior view in full extension and 45° of flexion (tangential view) and a lateral view, computed tomography, and MRI of the elbow were performed in all patients. On the basis of the radiographic findings, the capitellum was classified into 3 grades¹²: grade 1 indicated localized flattening and/or radiolucency; grade 2, a nondisplaced fragment; and grade 3, a displaced fragment. In

addition, grade 2 cases were divided into early and late detached stages on the basis of MRI criteria.¹⁵ The late detached stage was defined as a condition that involved the presence of an irregular contour of the articular surface and/or a high-signal intensity interface between the fragments and their bed on T2-weighted images. This indicated an unstable and advanced lesion (Fig. 1). Our 10 patients were all classified as having lesions in the late detached stage.

Furthermore, on the basis of the site of the focal lesion, subjects were divided into those with centralized vs. lateral types; the lateral type was further divided into the lateral-localized type (<33% of the width of the capitellar articular surface) or lateral-widespread type (≥67% of the width of the capitellar articular surface).⁷ All 10 patients were classified as having the lateral-widespread type.

Surgical techniques

All operations were performed with patients under general anesthesia. The operation was initiated in the lateral position; the presence of loose bodies was confirmed using an arthroscope, and any loose bodies were excised under the scope as much as possible. An anterolateral working portal and anteromedial viewing portal were used for the anterior radiocapitellar joint, and trans-triceps and posterolateral portals were added for operating in the posterior joint space, if necessary.

Subsequently, after changing to the supine position, an incision was made using the Kocher approach to assess the lesions in the capitellum that developed with the elbow in flexion; the extent and instability of the lesions were observed and evaluated based on the ICRS-OCD classification (Fig. 2, a). When the lesion was segmented, the stage of the most unstable part was adopted.

Next, a scalpel was used to cut into the boundary between the normal and degenerated cartilage to separate the lesion, including the lateral wall to the central part as 1 piece as much as possible, from the floor bed of the lesion. A surgical chisel was used for parts that were difficult to cut using a scalpel.

After removing the scar tissue on the back of the detached lesion, we meticulously confirmed the status of the attachment of the cancellous bone. Concerning the lateral side, including the lateral wall, if degeneration of the articular cartilage was mild and the size and thickness of the segment could withstand fixation, we attempted to preserve and fix the segment, even if the attachment of the cancellous bone was partial in nature (Fig. 2, b). In contrast, if the articular cartilage was small and segmented or only scar tissue was found to be vulnerable on the back of the detached segment, we abandoned fixation and switched to an osteochondral plug graft

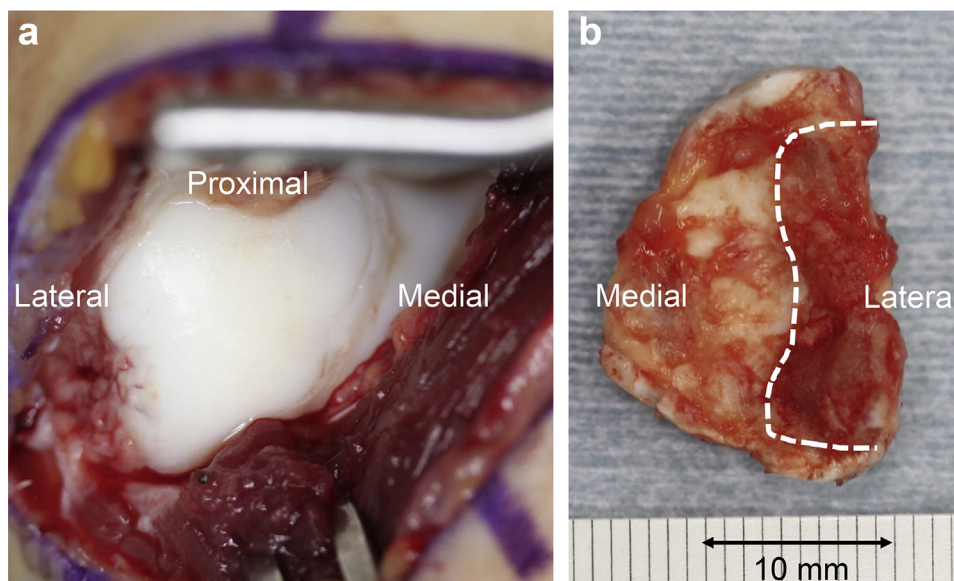


Figure 2 Intraoperative findings in patient 7 (right elbow). (a) Intraoperative findings showed a stage III lesion based on the International Cartilage Repair Society classification of osteochondritis dissecans. (b) Back surface of osteochondral fragment. Because stable cancellous bone was adherent to the back of the lateral side of the isolated osteochondral fragment, this part (enclosed by the dashed line) was preserved.

from the knee. On the central side, only the segment where uniform and stable cancellous bone adhered to the back was preserved, and the rest was resected.

Before fixation, we refreshed the sclerotic surface at the base of the lesion by performing curettage with an osteotrite until adequate bleeding was confirmed and grafted good-quality cancellous bone from the olecranon (Fig. 3, a). Subsequently, the lateral wall fragment was restored and fixed using 2–3 bone pegs of 2–3 mm in diameter formed from the cortical bone of the olecranon (Fig. 3, b). If the size of the cartilage defect resulting from the aforementioned procedure on the central side of the capitellum was ≥ 10 mm, we added an osteochondral plug graft from the knee (Fig. 3, c).

Postoperative immobilization was performed in a plastic cast at 90° of flexion for 3 weeks. Active and assisted range-of-motion exercises were started gently after removal of the cast. Strengthening exercises of the elbow and forearm were allowed after 4 weeks. Furthermore, 4 months after the surgical procedure, throwing practice was resumed, and 6 months after the operation, the patients were all deemed to have a complete recovery.

Postoperative evaluation

For imaging evaluation of the patients, bone union of the fixed lateral wall fragment and the morphology were evaluated from the tangential anteroposterior views and axial and sagittal computed tomography images (Fig. 4). We defined bone union as the disappearance of the radiolucent area without free body formation, as well as the recovery of the spherical contour of the subchondral bone under the humeral capitellum.¹⁴ For functional evaluations, the change in range of motion of the elbow joint, the Timmerman and Andrews (T-A) score,²⁰ and the ability to return to physical activities or sports in 3 stages—competitive, recreational, and substantial limitation—were evaluated. The T-A score was classified as excellent (180–200 points), good (160–179 points), fair (120–159 points), or poor (<120 points).

Statistical analyses

Statistical analyses were performed using Wilcoxon signed rank tests, and risk ratios < 5% were considered significantly different.

Results

All patients were classified as ICRS-OCD stage III based on intraoperative findings. During surgery, the central edge of the lesion had deep fissures and part of the cartilage surface was unstable; however, the lateral fissures were shallow, and the lesions were stable in all patients. In terms of the condition of the cancellous bone on the back of the lesion, the quantity of cancellous bone and status of attachment to the articular cartilage were better on the lateral side of the capitellum than on the central side. Fixation of osteochondral fragments as 1 piece with the lateral wall segment and central part was performed in 2 patients. Preservation and fixation of only the lateral wall fragments with excision on the central side were performed in 2 patients, whereas preservation of only the lateral wall fragments with osteochondral plug grafts from the knee on the central side was performed in 6 patients. The mean intraoperative dimensions of the fixed osteochondral fragment were 14.0 mm (range, 8–19 mm) in length, 8.8 mm (range, 7–13 mm) in width, and 5.9 mm (range, 4–8 mm) in thickness.

Bone union was achieved for the lateral wall fragments fixed in all patients, and the structure of the lateral wall was preserved until the final assessment in 9 patients; however, in patient 8 (Figs. 5–7), resorption of the lateral fragment occurred after bone union, with development of migration of the radial head over time.

Elbow extension range of motion was $-3.9^\circ \pm 9.7^\circ$ before surgery and $-0.4^\circ \pm 6.7^\circ$ at the final assessment, whereas flexion range of motion was $138.1^\circ \pm 10.5^\circ$ before surgery and $142.4^\circ \pm 6.2^\circ$ at the final assessment, with no significant differences observed before surgery compared with after surgery. The T-A score significantly improved from 165.5 ± 10.9 points before surgery to 197.0 ± 6.3 points after surgery, demonstrating excellent results in all patients. All patients were able to return to competitive baseball (Table I).

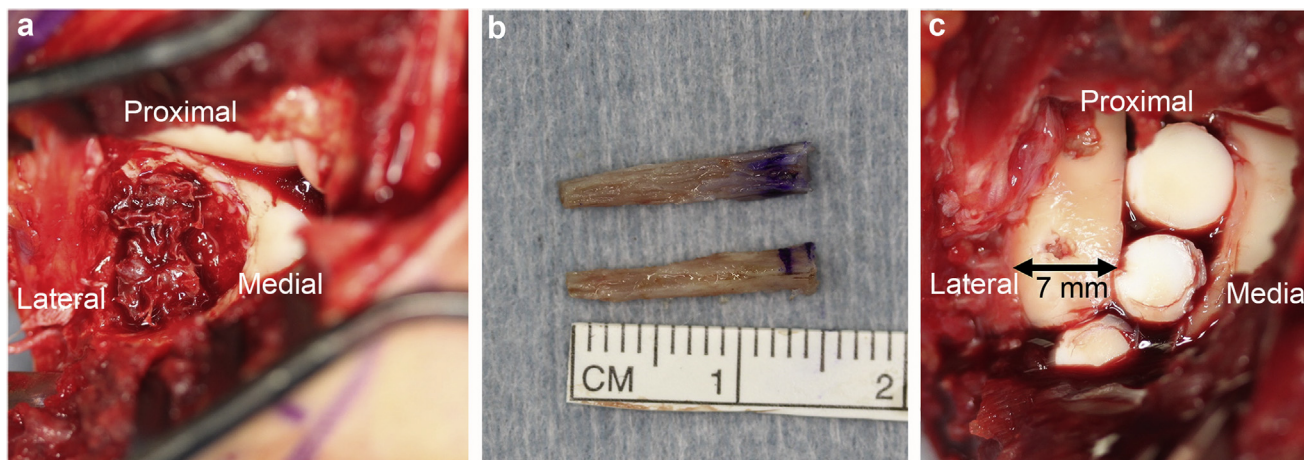


Figure 3 Surgical techniques in patient 7. (a) Before fixation, refreshing of the sclerotic surface at the base of the lesion and cancellous bone grafting from the olecranon were performed. (b) Bone pegs (2-3 mm in diameter) were fashioned from the cortical bone of the olecranon. (c) The lateral wall fragment was restored and fixed using 2-3 bone pegs. In this case, the lateral wall fragment (14-mm long, 7-mm wide, and 4-mm thick) were fixed with 2 bone pegs. The ↔ indicates the width of the lateral wall fragment. Three osteochondral plugs (2 with a 4.75-mm diameter and 1 with a 6.0-mm diameter) from the knee were implanted into the central part.

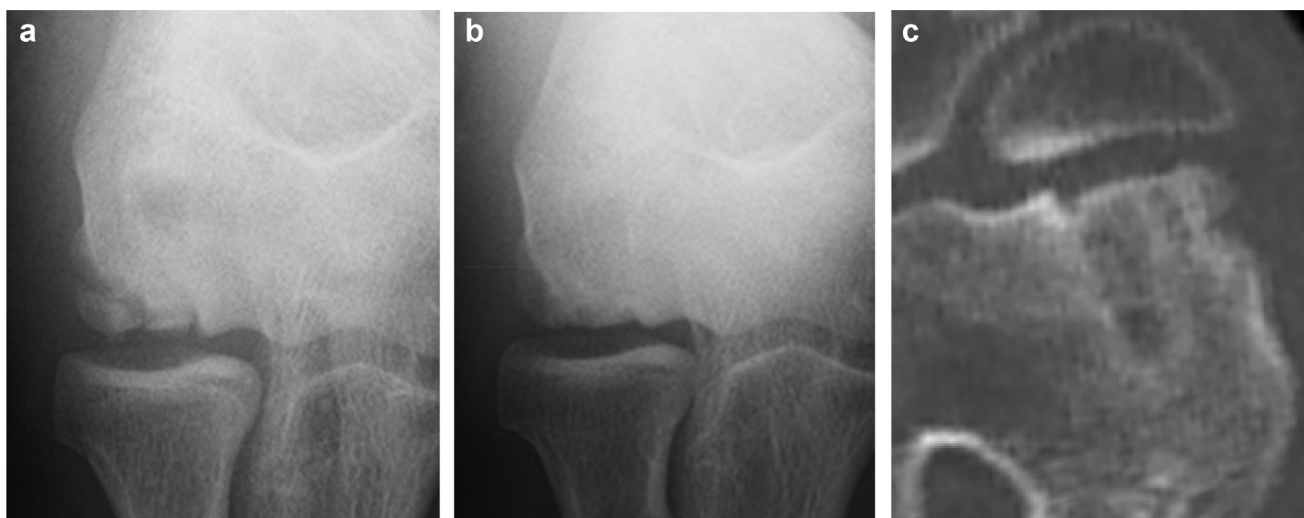


Figure 4 Imaging in patient 7 after surgery. (a) Coronal image on plain radiography just after surgery. (b) Coronal image on plain radiography 20 months after surgery. (c) Axial computed tomography image. The lateral wall had fused, and the structure of the lateral wall was satisfactory (b, c).

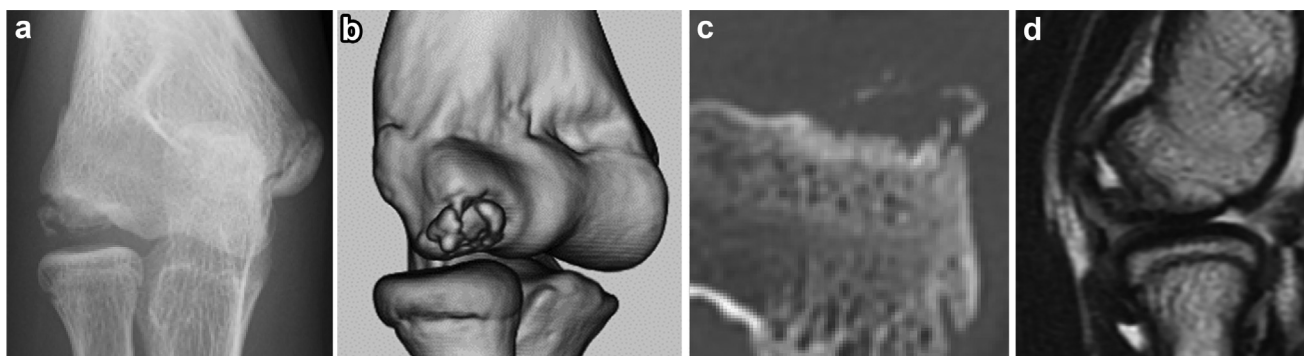


Figure 5 Imaging findings in patient 8 before surgery (right elbow). (a) Coronal image on plain radiography. (b) Three-dimensional computed tomography image. (c) Axial computed tomography image. Segmentation of the subchondral bone was observed from the lateral wall to the central side, and enlargement of the radial head and proximal migration were evident (a-c). (d) Sagittal magnetic resonance image. Irregular contours of the articular surface and a high-signal intensity interface between the fragments and their bed were observed on T2-weighted magnetic resonance imaging scans. Therefore, this case was classified as being in the detached stage.

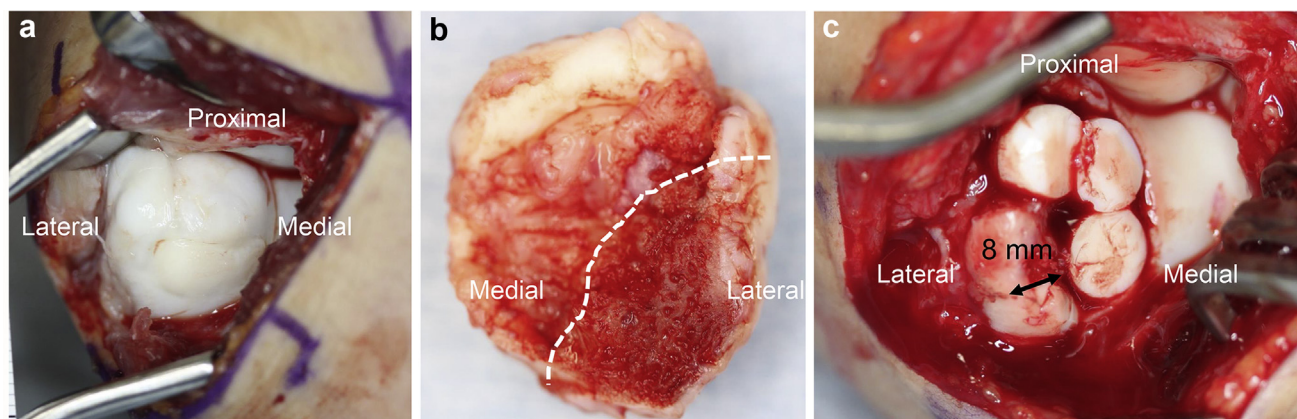


Figure 6 Intraoperative findings in patient 8 (right elbow). (a) Intraoperative findings showed a stage III lesion based on the International Cartilage Repair Society classification of osteochondritis dissecans. (b) Back surface of osteochondral fragment. Because cancellous bone adhered only to the posterolateral side of the isolated osteochondral fragment, this part (enclosed by the dashed line) was preserved. (c) Lateral wall fragments (10-mm long, 8-mm wide, and 6-mm thick) were fixed with a bone peg. The ↔ indicates the width of the lateral wall fragment. Three osteochondral plugs (all 6.0 mm in diameter) from the knee were implanted on the central side.

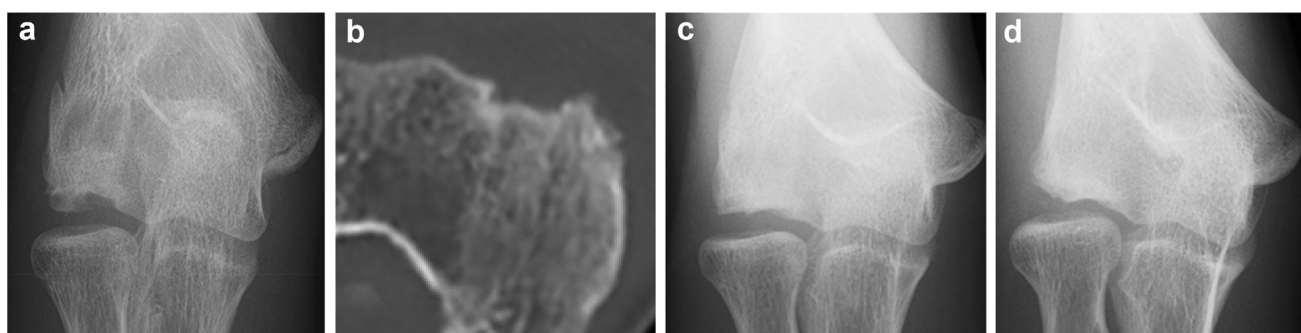


Figure 7 Imaging findings in patient 8 after surgery. (a) Coronal image on plain radiography 4 months after surgery. (b) Axial computed tomography image 4 months after surgery. Bone union of the lateral wall fragment was confirmed (a, b). (c) Coronal image on plain radiography 9 months after surgery. Flattening of the lateral articular surface was observed. (d) Coronal image on plain radiography 13 months after surgery. Resorption of the lateral wall of the capitellum and enlargement and proximal migration of the radial head had progressed.

Discussion

In the treatment of advanced-stage lateral-type OCD of the humeral capitellum, the extent to which the structure of the lateral wall can be favorably reconstructed is the key to improving clinical results.^{5,11} Concerning reconstruction methods, osteochondral FFBP,^{7,10,11,13,14,18,21} osteochondral bone plug grafting from the knee,^{4,17,18,22} and costochondral cartilage grafting¹⁶ have been performed; however, it is not yet clear which method is the best.

Good clinical results have been reported for osteochondral plug grafts from the knee.^{4,17,18,22} Conversely, for lateral-type disease, issues such as difficulty in implanting osteochondral grafts perpendicular to the articular surface and difficulty in reproducing the anatomic curvature of the lateral wall of the capitellum have been noted.^{17,22}

Sato et al¹⁶ have cited the advantages of costochondral grafting, in that it is easy to perform arthroplasty even in patients in whom the lateral wall is widely deficient. However, they mentioned that the associated long-term results are unknown and there are limits to the size of the graft. Complications such as pneumothorax at the time of sample collection have also been reported.⁹

The results of osteochondral FFBP for advanced-stage lateral-type OCD of the capitellum have generally been recognized as being unstable, with Tomatsuri²¹ reporting a study in which 5 of 6 patients with lateral-type cases and apparent ICRS-OCD stage III or higher disease experienced incomplete bone union and Kosaka

et al⁷ reporting a study in which 4 of 8 lateral-widespread-type cases with apparent ICRS-OCD stage III or higher disease failed to achieve bone union and required reoperation. In addition, more recently, Maruyama et al¹⁰ and Oshiba et al¹⁴ reported that even among stage I and II cases, 8 of 19 were incompletely repaired.

However, if the results of bone union in these reports are examined closely by distinguishing between the lateral and central sides of the capitellum, it can be observed that despite cancellous bone grafting not being performed in either study, all patients except 2 experienced complete bone union on the lateral side, showing that bone union more easily occurred on the lateral side than on the central side. Similar trends have been reported by other researchers.^{6,13} In addition, satisfactory results have been observed for fixation in combination with cancellous bone grafting for advanced-stage OCD of the capitellum. Takeda et al¹⁹ reported that bone union was observed in all 11 patients with apparent ICRS-OCD stage II and III disease with cancellous bone graft and pullout wiring. Horii et al³ reported that good bone union was obtained with FFBP and cancellous bone grafts in all 14 patients with apparent ICRS-OCD stage III disease.

On the basis of these reports, we hypothesized that good bone union can be obtained on the lateral side, including the lateral wall of the capitellum, by refreshing the sclerotic surface at the base of the lesion and performing cancellous bone grafting even in advanced-stage disease. From 2012 onward, we performed FFBP with cancellous bone grafting for the lateral wall fragment of the

Table 1
Patient characteristics

Patient No.	Age, yr	Stage	ICRS classification	Duration of postoperative follow-up, mo	Surgical method	No. of bone pegs	No. and size of osteochondral grafts	Size of fixed lateral wall fragment, mm			T-A score, points		Elbow extension angle, °		Elbow flexion angle, °	
								Length	Width	Thickness	Before surgery	After surgery	Before surgery	After surgery	Before surgery	After surgery
1	12	Late detached	III	24	Fixed together	3		8	10	7	170	195	-6	-5	140	145
2	13	Late detached	III	32	Fixed together	3		18	11	6	160	200	15	0	155	150
3	16	Late detached	III	27	Only lateral wall fixed, medial side excised	2	Left as is	19	13	6	170	200	-8	0	143	150
4	12	Late detached	III	25	Only lateral wall fixed, medial side excised	2	Left as is	13	7	8	160	180	9	3	150	145
5	14	Late detached	III	36	Only lateral wall fixed, osteochondral grafts from knee implanted into medial side	2	2 with 3.5-mm diameter and 2 with 4.5-mm diameter	17	7	7	160	200	-4	-10	145	143
6	13	Late detached	III	24	Only lateral wall fixed, osteochondral grafts from knee implanted into medial side	2	1 with 6.0-mm diameter	14	9	4	170	200	-7	0	135	143
7	15	Late detached	III	26	Only lateral wall fixed, osteochondral grafts from knee implanted into medial side	2	2 with 4.75-mm diameter and 1 with 6.0-mm diameter	14	7	4	160	200	-10	0	125	140
8	12	Late detached	III	25	Only lateral wall fixed, osteochondral grafts from knee implanted into medial side	1	3 with 6.0-mm diameter	9	8	6	185	195	0	15	135	135
9	14	Late detached	III	24	Only lateral wall fixed, osteochondral grafts from knee implanted into medial side	2	1 with 4.75-mm diameter and 2 with 6.0-mm diameter	10	8	6	175	200	-10	0	130	143
10	14	Late detached	III	24	Only lateral wall fixed, osteochondral grafts from knee implanted into medial side	4	2 with 6.0-mm diameter	18	8	5	145	200	-18	-7	123	130

ICRS, International Cartilage Repair Society; T-A, Timmerman and Andrews.

lateral-widespread type of ICRS-OCD stage III lesion and achieved good bone union with satisfactory clinical results. Consequently, we consider that there is a distinction between the lateral and central sides in terms of the treatment of this stage of OCD of the capitellum and it may be possible to extend the indications for FFBP in combination with cancellous bone grafting to the lateral wall fragment of the lateral-widespread type of ICRS-OCD stage III lesion.

There are limitations to this study, such as the small sample size and short-term follow-up period, as well as the use of mixed reconstruction procedures for the central side of the capitellum, such as débridement, FFBP, and osteochondral plug graft, which make it difficult to clearly evaluate the effects of each method on the clinical outcomes. Other limitations include lack of experience with lateral wall fragment fixation for ICRS-OCD stage IV disease that affected the conclusion regarding the extent to which indications can be expanded, as well as lack of prevention and treatment methods regarding resorption of the lateral fragment and the development of migration of the radial head over time, even if bone union was observed for the lateral wall fragment, as occurred in the case of patient 8.

Furthermore, Kusumi et al⁸ reported that fibrosis, degeneration, and subchondral bone damage were observed on histologic examination of lesions in all 25 patients with OCD of the capitellum, whereas Adachi et al¹ showed that if the free osteochondral fragment was fixed in knee OCD, cartilage regeneration occurred in osteochondral fragments based on second-look biopsy findings. In the future, long-term evaluations of cartilage and subchondral bone using needle biopsy and high-resolution MRI may be necessary even in OCD of the humeral capitellum.

Conclusion

We reported the treatment outcomes of lateral wall fixation using bone pegs in combination with cancellous bone grafting for ICRS-OCD stage III disease of the humeral capitellum. We achieved good bone union of the lateral wall fragment with satisfactory clinical results. On the basis of our results, extending the indications for FFBP in combination with cancellous bone grafting to the lateral wall fragment of ICRS-OCD stage III lesions may be feasible.

Disclaimer

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Supplementary Data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jseint.2020.09.002>.

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