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Effects of trochlear fragmentation on functional outcome in coronal shear fractures: a retrospective comparative study

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Background: Coronal shear fractures of the distal humerus are rare injuries, and fragmentation of the capitellum and trochlea with posterior comminution is challenging for surgeons. We retrospectively evaluated the functional outcomes of patients with coronal shear fractures managed with open reduction and internal fixation, focusing on the number of trochlea fragments in Dubberley type 3B fractures.

Materials and methods: The functional outcomes of 25 patients, including 8 patients with type 3B fractures, with a mean age (and standard deviation) of 57 ± 20 years, were evaluated at a mean follow-up duration of 15 ± 9 months. Type 3B fractures were classified into two groups: those with two trochlea fragments or less group (group A) and those with three or more fragments (group B). Patient outcomes were assessed with clinical and radiographic examination, range of motion, and the Mayo Elbow Performance scale (MEPS).

Results: Two patients with type 3B in group B experienced nonunion, and two patients with type 3B in group A and 1 patient with type 1B demonstrated avascular necrosis on radiographs. The average MEPS score was 96.3 points (range, 70-100), with 18 excellent, 5 good, and 1 fair results. The average range of motion was 10 ± 8 to 130 ± 12. The MEPS score worsened as Dubberley classification progressed from type 1 to type 3 (98.3 vs. 96.7 vs. 88, $P = .014$, respectively) and subtypes A to B (97.9 vs. 90, $P = .014$, respectively). In comparing groups A and B, the MEPS score was significantly worse in group B (93.8 vs. 76.3, $P = .006$).

Conclusion: Our open reduction and internal fixation results were largely good, although functional outcomes were diminished as Dubberley classification progressed from type 1 to type 3 and subtype A to B. Type 3B fractures with three trochlea fragments or more in the elderly were the most difficult to treat with open reduction and internal fixation and possibly 1-term total elbow arthroplasty.

Coronal shear fractures of the distal humerus are rare injuries that account for less than 1% of elbow fractures.[12] These fractures result from direct axial loading from the radial head to the capitellum and trochlea in a semiflexed or hyperextended elbow or from spontaneous reduction of a posterolateral subluxation or dislocation.[22] A higher incidence among women has been attributed to anatomic differences in carrying angle and prevalence of osteoporosis.[25,27] These fractures are easily displaced because of the paucity of soft-tissue attachment; therefore, operative treatments including open reduction and internal fixation (ORIF) and total elbow arthroplasty (TEA) are recommended.

The Dubberley classification for coronal shear fractures of the distal humerus focusing on posterior comminution and medial extension has recently been proposed[4] and widely spread. They classified fractures as involving the capitellum with or without the lateral trochlear ridge (type 1), fracture of the capitellum and trochlea as a single piece (type 2), and the capitellum and trochlea with fragmentation (type 3). Each type is subclassified as per the presence (subtype B) or absence (subtype A) of posterior fracture comminution (Fig. 1). Among the classifications, type 3B fractures

Institutional review board approval was not required for this retrospective study.

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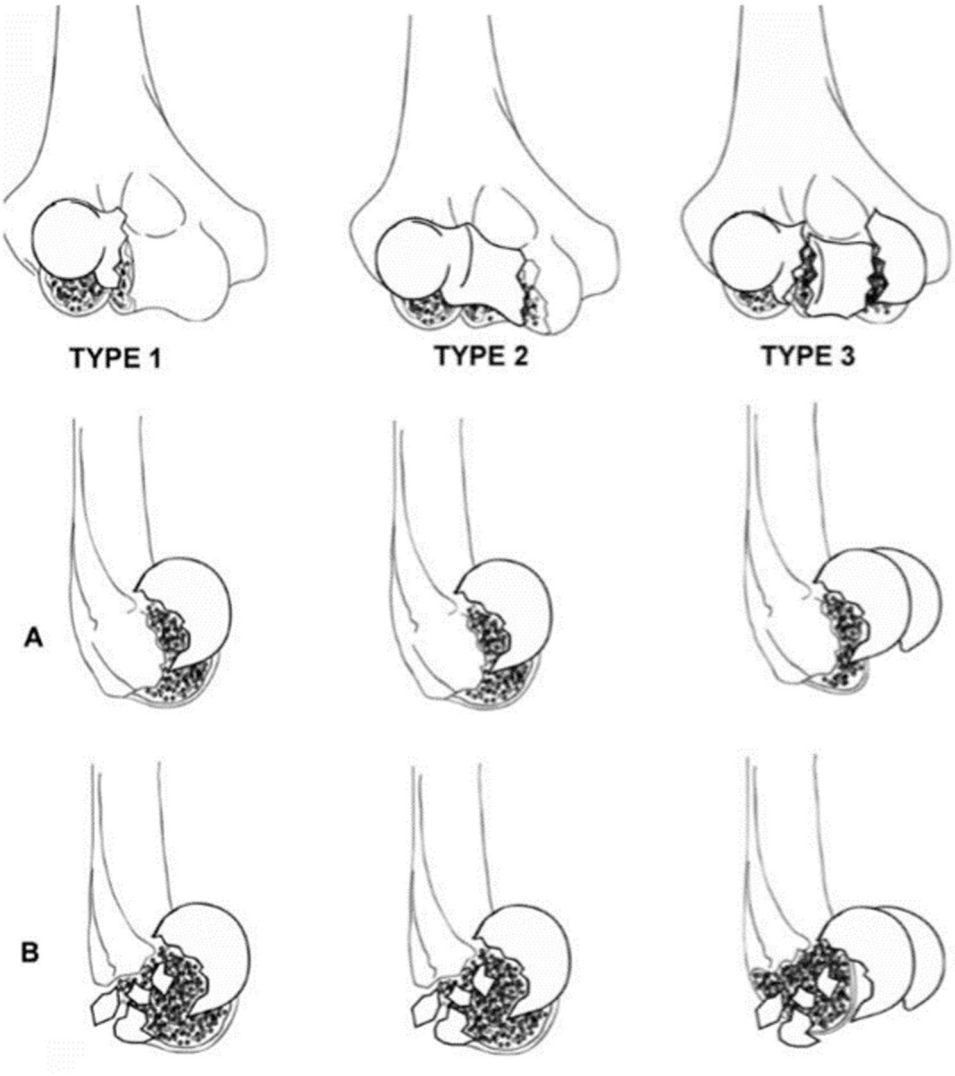

Figure 1 Dubberley classification. A fracture of the capitellum with or without the lateral trochlear ridge (type 1) and fracture of the capitellum and trochlea as a single piece (type 2) or as separate pieces (type 3). Each type is subclassified as per the presence (subtype B) or absence (subtype A) of posterior fracture.

(the fragmentation of capitellum and trochlea with posterior comminution) are the most difficult to treat, and the optimal treatment strategy remains unknown.

In the type 3B fractures, there are no reports examining the medial region in detail, so we focused on the number of trochlea fragments and hypothesized that effective reconstruction of the trochlea was important for successful ORIF outcome. Thus, we classified patients into two groups: those with two fragments or less (group A) and those with three fragments or more (group B) (Fig. 2).

The purpose of this study was to retrospectively evaluate the functional outcomes of patients with coronal shear fractures managed with ORIF and to compare the functional outcomes of group A and group B in Dubberley type 3B fractures.

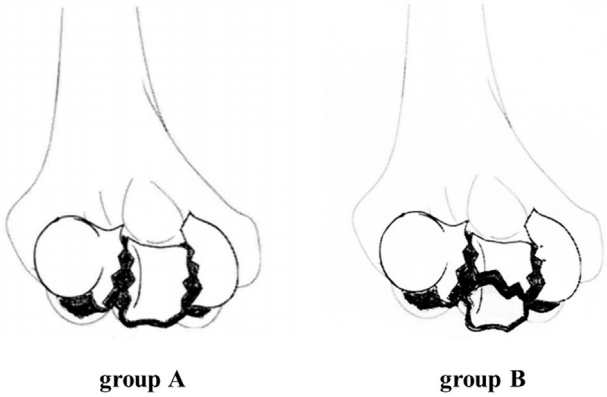

Figure 2 Type 3B fractures were classified into two groups: those with two trochlea fragments or less group (group A) and those with three or more fragments (group B).

Materials and methods

Patients

Between January 2009 and October 2018, 25 patients (22 women and 3 men) underwent ORIF by 4 experienced surgeons in our hospital and our affiliated hospitals. The mean age (and standard deviation) was 57 ± 20 years (range, 12-79 years). The mean duration of follow-up was 15 ± 9 months (range, 4-36 months). The injury mechanisms were low-energy trauma in 21 cases and included falls from standing height and high-energy

Table I
Epidemiologic data of patients.

Pt	Age	Sex	Mechanism of injury	Dubberlery classification	Concomitant injury approach		Fixation method	Follow-up. MEPS	Mon
1	78	F	Low energy	1A	Lateral condyle	Lateral	TBW	24	95
2	74	F	Low energy	3B (group A)	Lateral condyle. Olecranon	Posterior. Lateral	HCS, lateral LCP	24	90
3	68	F	Low energy	3B (group A)		Posteiror	HCS. Lateral LCP	24	100
4	59	F	Low energy	3B (group B)	Medial condyle	Posteiror. Lateral	HCS. medial LCP	21	75
5	40	F	High energy	IB		Lateral	HCS. BP	6	100
6	74	F	Low energy	IB	Lateral condyle. Radial head	Lateral	HCS. Lateral LCP	27	100
7	66	F	Low energy	2B		Posteiror	HCS. BP	10	100
8	12	F	Low energy	1A		Lateral	HCS	6	100
9	14	M	Low energy	2A		Lateral	HCS. BP	4	100
10	79	F	Low energy	3A	Lateral condyle	Posteiror	HCS. BP. TBW	16	100
11	67	F	Low energy	2A	Lateral condyle	Lateral	HCS. BP. TBW	16	85
12	21	F	High energy	2A	Lateral condyle	Lateral	HCS. BP. TBW	13	95
13	66	F	Low energy	3B (group B)	Lateral condyle. Olecranon	Posterior. Anteromedial	HCS. BP	12	85
14	44	F	Low energy	1A		Lateral	HCS. BP	3.5	100
15	39	F	High energy	3B (group A)	Lateral condyle	Posterior	HCS, BP. TBW	9.5	100
16	78	F	Low energy	3B (group B)	Lateral condyle, Olecranon	Posterior	HCS. Medial LCP, TBW	36	80
17	72	F	High energy	3A		Lateral	HCS	6	100
18	70	F	Low energy	3B (group A)	Olecranon	Posterior	HCS. BP	24	100
19	61	F	Low energy	2A	Lateral condyle, Olecranon	Lateral. Posterior	HCS	9	100
20	67	F	Low energy	3B (group B)	Radial head	Posterior	HCS	32	80
21	66	F	Low energy	IB	Lateral condyle	Lateral	HCS. Lateral LCP	9	95
22	73	F	Low energy	IB		Lateral	HCS	12	95
23	36	M	Low energy	1A		Anterolateral	HCS	12	100
24	54	F	Low energy	2B	Lateral condyle	Posterior	HCS. BP. TBW	12	100
25	44	M	Low energy	1A		Lateral	HCS	4	100

BP, bioabsorbable pin; *HCS*, headless compression screw; *LCP*, locking compression plate; *TBW*, tension band wiring.
Low energy, fall from standing; High energy, fall from height.

trauma in 4 cases and included vehicular collisions. All patients underwent anteroposterior and lateral radiographs and computed tomography scans.

Fractures were retrospectively classified as per the Dubberley classification. Six fractures were type 1A, 3 were type 1B, 4 were type 2A, 2 were type 2B, 2 were type 3A, and 8 were type 3B. Fifteen patients (60%) had concomitant fractures, including 12 lateral epicondylar fractures, 3 olecranon fractures, 2 radial head fractures, and 1 medial epicondylar fracture (some overlapping). One patient had a medial collateral ligament tear that needed repair.

In the type 3B fractures, 4 patients had two trochlea fragments or less (group A) and 4 patients had three fragments or more (group B). Epidemiologic data of the 25 patients are summarized in Table I.

Surgical treatment

Approaches

In most type 1A, 1B, and 2A cases, a lateral approach was used; an anteromedial approach was used in only 1 case of type 1A and a combination of lateral and posterior approach in the 1 case of type 2A. In the type 3B cases, all cases used a posterior approach with an olecranon osteotomy, 2 cases were in combination with a lateral approach, and 1 case was in combination with an anteromedial approach. Dual incision was performed in the judgment of surgeons if it was difficult to reduce the capitellum and trochlea fragments and fix them from anterior to posterior. In the type 3A cases, a posterior approach was performed in one case and a lateral approach in another. In the type 2B cases, a posterior approach was used.

Internal fixation

In 24 of 25 cases, headless compression screws were used for the fixation of major articular fragments: double-threaded Japan screws (Meira, Japan) in 15 cases, Acutrak headless screws (Acumed, Hillsboro, OR, USA) in 7 cases, and Herbert screws (Zimmer, Warsaw, IN, USA) in 2 cases. In 10 cases, bioabsorbable pins were used in combination for supplemental fixation of small articular fragments that could not be fixed by using headless compression screws. Supplemental fixation with locking plates were used in 6 cases (lateral side in 4 cases, medial side in 2 cases) and figure-of-8 tension band wiring was used in 7 cases, specifically for lateral epicondylar fractures.

Postoperative management

All elbows were immobilized postoperatively at 90° of flexion for a mean of 16.7 days (range, 3-28 days). Active and active-assisted range-of-motion (ROM) exercises were performed after immobilization, and passive stretching and strengthening exercises were started 6 weeks postoperatively. If the range of flexion was $\leq$100° after bone union, hardware removal and contracture release was performed.

Postoperative assessments

All patients were identified prospectively and were independently assessed using radiographic assessment (Xp and computed tomography), the Mayo Elbow Performance score (MEPS), and ROM as functional assessments. Subsequent surgical procedures and complications were also considered. Radiographs were assessed for bone union, avascular necrosis, post-traumatic arthritis, heterotopic ossification, and hardware failure.

Statistical analysis

Descriptive methods used to evaluate the data were the median and interquartile range. Analytic methods were the Kruskal-Wallis test for the comparison of groups and the Mann-Whitney U test for comparisons between the 2 groups. The level of significance was set at $P < .05$.

Table II
Functional outcomes in relation to Dubberley classification.

Variable	1A (n = 6)	1B (n = 3)	2A (n = 4)	2B (n = 2)	3A (n = 2)	3B (n = 8)	Average	*P* value
Extension, deg	−5	−15	−5	−2.5	−10	−16.3	−10	.02
Flexion, deg	138.3	121.7	136.3	127.5	137.5	123.1	130	.04
Arc, deg	133.3	106.7	131.3	125	127.5	106.9	120.2	.006
Average MEPS score	99.2	96.7	95	100	100	85	96.3	.01

MEPS, Mayo Elbow Performance scale.

Results

Radiographic evaluation

All fractures in group A resulted in union. Two patients with type 3B fractures in group B experienced nonunion, and two patients with type 3B fractures in group A and 1 type 1B fracture demonstrated avascular necrosis on radiographs. Seven patients developed post-traumatic arthritis. Five patients showed slight joint-space narrowing with minimal osteophyte formation (grade 1: Broberg and Morrey classification), and two had moderate joint space narrowing with osteophyte formation (grade 2). No patients developed severe joint space narrowing with gross destruction (grade 3). Heterotopic ossification was present in two patients. All patients had minor periarticular calcifications. No patients experienced hardware failure.

Functional outcome

The average MEPS score was 96.3 points (range, 70-100), with 18 excellent, 5 good, and 1 fair result.

The average extension range was -10° (range, -30° to 5°), flexion range was 130° (range, 100°-145°), and the average flexion-extension arc was 120.2° (range, 80°-45°). The Dubberley classification types were compared statistically (Table II, Fig. 3a). Analysis showed a significant difference between the groups with respect to MEPS score ($P = .01$), extension degrees ($P = .02$), flexion degrees ($P = .04$), and flexion-extension arc degrees ($P = .006$). The MEPS score, extension range, flexion range, and flexion-extension arc of type 3B fractures were significantly lower than those of type 1A fractures ($P = .018$, .026, .029, and .013, respectively).

In comparison between type 1 and type 3 in the Dubberley classification (Table III, Fig. 3b), there was a significant difference with regard to MEPS score ($P = .01$), extension range ($P = .02$), and flexion-extension arc ($P = .03$). It was not clear which group achieved grater outcomes owing to the small sample size; however, the MEPS score worsened as Dubberley classification progressed from type 1 to type 3.

In comparing between subtype A and subtype B of the Dubberley classification (Table IV, Fig. 3c), subtype B fared significantly worse compared with subtype A regarding MEPS score ($P = .009$), extension range ($P = .007$), flexion range ($P = .001$), and flexion-extension arc ($P = .03$).

In comparison with and without concomitant fractures, concomitant fractures group was significantly worse regarding MEPS score ($P = .007$), extension range ($P = .03$), and flexion-extension arc ($P = .02$).

In 8 cases of type 3B fracture, the average MEPS score was 88 points (range, 70-100), with 4 excellent results and 4 good results. The average extension range was -15° (range, -30° to 0°), flexion range was 126° (range, 100°-140°), and the flexion-extension arc was 111° (range, 80°-140°). In comparison, in the two trochlea fragments or less group (group A) and three fragments or more group (group B) (Table V), the MEPS score was significantly worse in group B (93.8 vs. 76.3, $P = .006$) (Fig. 4). The flexion-extension arc was significantly smaller in group B (118.7° vs. 95°, $P = .03$), although the extension and flexion showed no statistically significant differences (−11.3° vs. −21.3°, $P = .05$ and 130° vs. 116.3°, $P = .07$).

Subsequent surgical procedure and complications

Subsequent surgical procedures were required in 12 patients. One patient had a delayed union of an olecranon osteotomy site, which required refixation. Eleven patients with type 2 and type 3 fractures required contracture releases and hardware removal for flexion ROM restriction. The average time from primary surgery to contracture release and hardware removal was 6.2 ± 1.9 months (range, 4-11 months). One patient with ulnar nerve palsy improved after removal of fixation and neurolysis. No patients required total elbow arthroplasty. One patient developed transient radial nerve palsy.

Discussion

Coronal shear fracture (CSF) is one of the most difficult elbow fractures to treat and various treatment options, including manual reduction,[3,14,17,21] fragment excision,[1,6] ORIF,[2–5,9,13,16,17,19,23,24] and TEA[10,20] have been reported. Few authors recommended manual reduction and immobilization, as it is difficult to achieve and maintain the reduction. Another disadvantage of this treatment is prolonged immobilization and rehabilitation. Fragment excision leads to articular incongruity, valgus instability, and radiohumeral osteoarthritis and is also known to be associated with poor outcomes.[15,26] ORIF, however, is currently recommended as a treatment for CSF because it allows early ROM exercise owing to anatomic reduction and internal fixation.[2–5,9,12,13,16,19,22,24,25,27]

It has been reported that good to excellent outcomes with ORIF are expected in most patients.[4,11] In this study, we obtained similar results: the average MEPS score was 96.3 points with 18 excellent, 5 good, and 1 fair result.

TEA has been recognized as a safe and effective alternative to ORIF for the treatment of comminuted intra-articular distal humerus fractures in the elderly. Several studies comparing the functional outcomes of ORIF and TEA for these fractures reported similar MEPS scores and ROM.[7,18] Although the potential advantages of TEA over ORIF include faster rehabilitation with earlier motion and improved short-term outcomes,[7,18] disadvantages include a lifetime weight-bearing restriction and the unique problems of component wear and loosening and the potential need for revision arthroplasty. TEA may most indicated for irreparable CSF in the elderly, but owing to the small numbers of cases, surgical indications, and treatment outcomes have not been fully evaluated.

Dubberley et al[4] and several other reports[2,5] have shown that CSF with medial extension and posterior comminution resulted in worse outcomes. In our study, the concomitant fractures group was also worse in functional outcomes. In addition, as with these reports, functional outcomes worsened as Dubberley classification

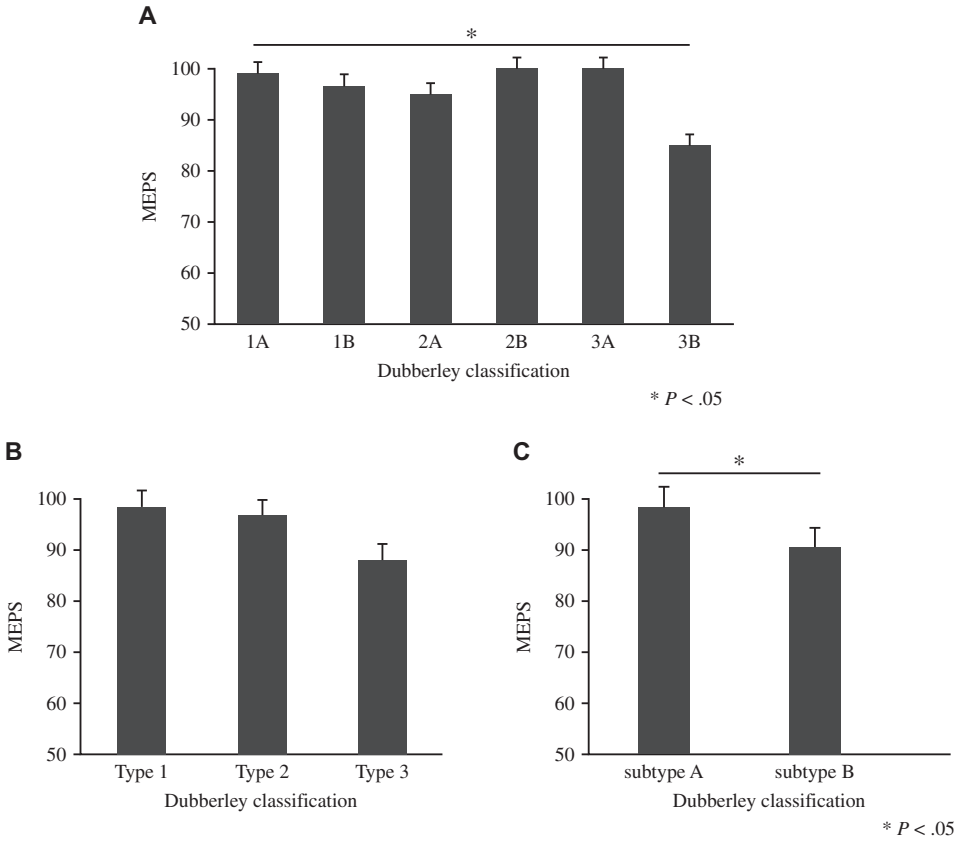

Figure 3 (**A**) MEPS score in relation to Dubberley classification. Type 3B fractures result in significantly lower scores than type 1A. (**B**) MEPS score in relation to Dubberley classification Type. MEPS score decreases further as Dubberley classification progresses from Type 1 to Type 3, respectively. (**C**) MEPS score in relation to Dubberley classification subtype. Scores are significantly worse in subtype B. *MEPS*, Mayo Elbow Performance scale.

Table III
Functional outcomes in relation to Dubberley classification type.

Variable	Type 1 (n = 9)	Type 2 (n = 6)	Type 3 (n = 10)	Average	*P* value
Extension, deg	−8.3	−4.17	−15	−10	.02
Flexion, deg	132.8	133.3	126	130	.48
Arc, deg	124.4	129.2	111	120.2	.03
Average MEPS score	98.3	96.7	88	96.3	.01

MEPS, Mayo Elbow Performance Scale.

Table IV
Functional outcomes in relation to Dubberley classification subtype.

Variable	subtype A (n = 12)	subtype B (n = 13)	Average	*P* value
Extension, deg	−5.83	−13.85	−10	.007
Flexion, deg	137.5	123.5	130	.001
Arc, deg	131.7	116.2	120.2	.03
Average MEPS score	98	90	96.3	.009

MEPS, Mayo Elbow Performance scale.

progressed from type 1 to type 3 and subtype A to B. Based on these results, this classification seemed to be useful in terms of prognosis prediction. In fact, the surgical method and treatment results for type 1A are good, and there are few clinical problems. However, type 3B is still one of the most difficult elbow traumas, and the optimal treatment method, including whether to select ORIF or TEA, has not been fully established.

There are some reports that bone union rate is relatively high and Avascular necrosis (AVN) is low, although CSF is considered to have a high risk of AVN and nonunion after ORIF owing to its anatomic properties.[23,27] In addition, some authors reported that even if AVN occurred, there was no significant effect on the treatment results.[8,11,12] Similarly, in this study, most cases achieved bone union and AVN occurred in only two cases with type 1B and type 3B fractures (group A); however, the functional outcome was still relatively good. Considering this, it can be inferred that if capitellum fragments can be reduced and fixed to an anatomic position to some extent in ORIF, the treatment result will not be significantly

Table V
Functional outcomes in relation to type 3B with two trochlea fragments or less group (group A) and three or more fragments (group B).

Variable	Group A (n = 4)	Group B (n = 4)	Average	*P* value
Extension, deg	−11.25	−21.25	−15	.05
Flexion, deg	130	116.25	126	.07
Arc, deg	118.75	95	111	.03
Average MEPS score	93.75	76.25	88	.005

MEPS, Mayo Elbow Performance scale.

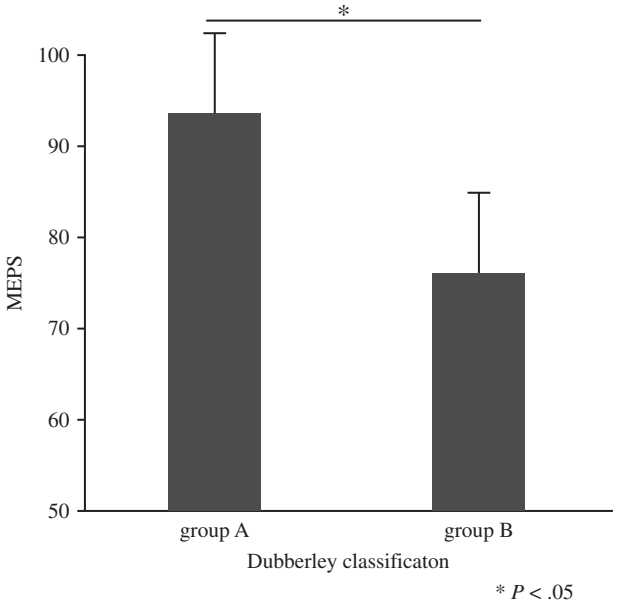

Figure 4 MEPS score in relation to Type 3B with two trochlear fragments or less (group A) and three or more fragments (group B). MEPS scores are significantly lower in group B. *MEPS*, Mayo Elbow Performance scale.

affected even if AVN occurs. Therefore, we believe that the medial side, which is the trochlear component, influences the treatment results of type 3B fractures, and whether the medial side can be reconstructed or not is important. In this study, we investigated type 3B in more detail and focused on the number of trochlear bone fragments. We found treatment result outcomes significantly worse in cases where the number of bone fragments in the trochlear region was three or more, and conversely, relatively good results were obtained in cases with two or fewer fragments. From this, type 3B cases with three or more trochlea fragments were more difficult to treat with ORIF. Previous reports have found the mean MEPS score after TEA for comminuted intraarticular distal humerus fractures in the elderly was 90.0,[7] higher than after ORIF for type 3B cases with three or more trochlear fragments, as in our series. Therefore, it may be possible to consider 1-term TEA for these cases in the elderly with low activity.

This study has some limitations. This was a retrospective study and the number of cases was small. We have not been able to compare the outcomes of ORIF and TEA. In addition, the results of this study are short-term results, and long-term outcomes are still unknown. In some cases, the follow-up period was less than half a year, and two cases were teenagers. However, most of these cases were Dubberley type 1A or 2A cases, and all these cases got good bone union and perfect MEPS score. It has been reported that AVN and post-traumatic arthritis were unlikely to occur in type 1A and 2A cases,[4,12] and the treatment results of these cases were extremely good. It was considered to have been effective data for evaluating the short-term treatment results by Dubberley classification, therefore these cases were included. The other limitation was high rate of contracture release. In this study, tension band wiring was used in many cases, and immobilization period tended to be long. It may be prevented by rigid internal fixation with locking plate and early range of motion exercise.

However, to the best of our knowledge, this is the first study to have examined the medial aspect of coronal shear fractures in detail, and we believe that it will be helpful for treatment selection.

Conclusion

We retrospectively evaluated the outcome of patients with coronal shear fractures of the distal humerus treated with ORIF. Functional outcomes worsened as the Dubberley classification progressed from type 1 to type 3 and from A to B; however, we largely obtained good functional outcomes after ORIF. Type 3B fractures with three or more trochlear fragments in the elderly are challenging surgical cases, and consideration of 1-term TEA may be effective.

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References

1. Alvarez E, Patel MR, Nimberg G, Pearlman HS. Fracture of the capitulum humeri. J Bone Joint Surg Am 1975;57:1093-6.
2. Ashwood N, Verma M, Hamlet M, Garlapati A, Fogg Q. Transarticular shear fractures of the distal humerus. J Shoulder Elbow Surg 2010;19:46-52. https://doi.org/10.1016/j.jse.2009.07.061.
3. Christopher F, Bushnell LF. Conservative treatment of fractures of the capitellum. J Bone Joint Surg 1935;17:489-92.
4. Dubberley JH, Faber KJ, MacDermid JC, Patterson SD, King GJW. Outcome after open reduction and internal fixation of capitellar and trochlear Fractures. J Bone Joint Surg Am 2006;88:46-54. https://doi.org/10.2106/JBJS.D.02954.
5. Durakbasa MO, Gumussuyu G, Gungor M, Ermis MN. Distal humeral coronal plane fractures: management, complications and outcome. J Shoulder Elbow Surg 2013;22:560-6. https://doi.org/10.1016/j.jse.2012.07.011.
6. Fowles JV, Kassab MT. Fractures of the capitulum humeri: treatment by excision. J Bone Joint Surg Am 1974;56:794-8.
7. Githens M, Yao J, Sox AH, Bishop J. Open reduction and internal fixation versus total elbow arthroplasty for treatment of Geriatric distal humerus fractures: a systematic review and meta-analysis. J Orthop Trauma 2014;28:481-8. https://doi.org/10.1097/BOT.0000000000000050.
8. Grantham SA, Norris TR, Bush DC. Isolated fractures of the humeral capitellum. Clin Orthop Relat Res 1981;161:262-9.
9. Jupiter JB, Neff U, Ragazzoni P, Allgower M. Unicondylar fractures of the distal humerus: an operative approach. J Orthop Trauma 1988;2:102-9.
10. Lapner M, King GJ. Elbow arthroplasty for distal humeral fractures. Instr Course Lect 2014;63:15-26.
11. Lasinger O, Mare K. Fracture of the capitellum humeri. Acta Orthop Scand 1981;52:39-44.
12. Lee JJ, Lawton JN. Coronal shear fractures of the distal humerus. J Hand Surg Am 2012;37:2412-7. https://doi.org/10.1016/j.jhsa.2012.09.001.
13. Lopiz Y, Rodriguez-Gonzalez A, Garcia-Fernandez C, Marco F. Open reduction and internal fixation of coronal fractures of the capitellum in patients older than 65 years. J Shoulder Elbow Surg 2016;25:369-75. https://doi.org/10.1016/j.jse.2015.12.004.
14. Ma YZ, Zheng CB, Zhou TL, Yeh YC. Percutaneous probe reduction of frontal fractures of humeral capitellum. Clin Orthop Relat Res 1984;183:17-21.
15. Mahirogullari M, Kiral A, Solakoglu C, Pehlivan O, Akmaz I, Rodop O. Treatment of fractures of the humeral capitellum using Herbert screws.

J Hand Surg Br 2006;31:320-5. https://doi.org/10.1016/j.jhsb.2006.02.002.
16. McKee MD, Jupiter JB. A contemporary approach to the management of complex fractures of the distal humerus and their sequelae. Hand Clin 1994;10:479-94.
17. Mckee MD, Jupiter JB, Bamberger HB. Coronal shear fractures of the distal end of the humerus. J Bone Joint Surg Am 1996;78:49-54.
18. McKee MD, Veillette CJ, Hall JA, Schemitsh EH, Wild LM, McCormack R, et al. A multicenter, prospective, randomized, controlled trial of open reduction—internal fixation versus total elbow arthroplasty for displaced intra-articular distal humeral fractures in elderly patients. J Shoulder Elbow Surg 2009;18:3-12. https://doi.org/10.1016/j.jse.2008.06.005.
19. Mighell M, Virani NA, Shannon R, Echols EL Jr, Badman BL, Keating CJ. Large coronal shear fractures of the capitellum and trochlea treated with headless compression screws. J Shoulder Elbow Surg 2010;19:3845. https://doi.org/10.1016/j.jse.2009.05.012.
20. Nauth A, McKee MD, Ristevski B, Hall J, Schemitsch EH. Distal humeral fractures in adults. J Bone Joint Surg Am 2011;93:686-700. https://doi.org/10.2106/JBJS.J.00845.
21. Ochner RS, Bloom H, Palumbo RC, Coyle MP. Closed reduction of coronal fractures of the capitellum. J Trauma 1996;40:199-203.
22. O'Driscoll SW, Morrey BF, Korinek S, An KN. Elbow subluxation and dislocation. A spectrum of instability. Clin Orthop Relat Res 1992;280:186-97.
23. Ring D. Open reduction and internal fixation of apparent capitellar fracture using an extended lateral exposure. J Hand Surg Am 2009;34:739-44. https://doi.org/10.1016/j.jhsa.2009.01.026.
24. Ring D, Jupiter JB, Gulotta L. Articular fractures of the distal part of the humerus. J Bone Joint Surg Am 2003;85-A:232-8. https://doi.org/10.2106/00004623-200302000-00008.
25. Ruchelsman DE, Tejwani NC, Kwon YW, Egol KA. Open reduction and internal fixation of capitellar fractures with headless screws. J Bone Joint Surg 2008;90A:1321-9. https://doi.org/10.2106/JBJS.H.01195.
26. Sabo MT, Fay K, McDonald CP, Ferreira LM, Johnson JA, King GJ. Effect of coronal shear fractures of the distal humerus on elbow kinematics and stability. J Shoulder Elbow Surg 2010;19:670-80. https://doi.org/10.1016/j.jse.2010.02.002.
27. Watts AC, Morris A, Robinson CM. Fractures of the distal humeral articular surface. J Bone Joint Surg Br 2007;89:510-5. https://doi.org/10.1302/0301-620X.89B4.18284.