



# Treatment of capitellar and trochlear fractures with posterior comminution: minimum 2-year follow-up

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**Hypothesis:** This study aimed to evaluate the safety and efficacy of the fixation of Dubberley type B capitellar and trochlear fractures using dorsolateral anatomic plates with support of the distal humerus (DAPSDHs).  
**Methods:** Fifteen patients with Dubberley type B capitellar and trochlear fractures (two type 1B, five type 2B, and eight type 3B) were treated through the extended lateral approach, and fixation was achieved with DAPSDHs. Radiographic evaluation was performed, and range of motion of the elbow and forearm was recorded. Functional outcomes were assessed using the Mayo Elbow Performance Score and Disabilities of the Arm, Shoulder and Hand score.

**Results:** The mean follow-up period was 32.5 months (range, 24–54 months). Fracture union was achieved in all cases. At the final follow-up, range of motion was as follows: flexion,  $123.7^\circ \pm 8.1^\circ$  (range,  $110^\circ$ – $135^\circ$ ); lack of extension,  $11.0^\circ \pm 7.1^\circ$  (range,  $5^\circ$ – $30^\circ$ ); pronation,  $81.7^\circ \pm 5.6^\circ$  (range,  $70^\circ$ – $90^\circ$ ); and supination,  $78.7^\circ \pm 5.2^\circ$  (range,  $70^\circ$ – $85^\circ$ ). At the final follow-up, the mean Disabilities of the Arm, Shoulder and Hand score was  $11.9 \pm 4.0$  (range, 4.2–20.8) and the mean Mayo Elbow Performance Score was  $89.0 \pm 7.1$  (range, 70–95). The outcome was rated as excellent in 12 patients (80.0%), good in 2 (13.3%), and fair in 1 (6.7%). Avascular necrosis of the capitellum developed in 1 patient. One patient had implant irritation. Heterotopic ossification developed in 1 patient. Ten patients returned to their previous activity levels.

**Conclusion:** Capitellar and trochlear fractures with posterior comminution are safely and effectively treated through the extended lateral approach using DAPSDHs, resulting in good radiographic and functional outcomes.

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

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**Keywords:** Capitellum; trochlea; elbow; fracture; distal humerus; open reduction and internal fixation

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Coronal fractures of the distal humerus may involve the capitellum and/or trochlea. These fractures are rare and challenging to manage. The mechanism of injury usually involves falling on an outstretched arm, which causes direct axial compression that is transmitted across the joint, resulting in coronal

shear fracture of the capitellum and trochlea.<sup>22</sup> Several classification systems have been described for capitellar and trochlear fractures.<sup>5,7,21,22,31</sup> The most commonly used classification is the Bryan and Morrey classification<sup>5</sup> expanded by McKee et al<sup>20</sup> with the addition of type IV (coronal shear fracture of the capitellum and trochlea as a single fragment). Recently, Dubberley et al<sup>7</sup> characterized the fracture patterns to guide surgical management and predict the outcome of these injuries. They classified capitellar and trochlear fractures according to the location of the fracture lines into 3 types. Each fracture type was further classified regarding the absence (A) or presence (B) of posterior condylar comminution.

In their study, Dubberley et al<sup>7</sup> reported an association between posterior comminution and prognosis. They recommended that fractures with posterior comminution of the distal humeral columns require bone grafting or additional fixation with pelvic reconstruction plates—or a combination thereof. The suggested fixation technique has some disadvantages: The 3.5-mm reconstruction plates provide limited points of fixation, the screws are not fixed-angle screws, the larger size of the screws may cause splitting of the capitellar and trochlear fragment, and the thickness and shape of the plate may result in irritation.<sup>1</sup> These disadvantages can be avoided by the use of lower-profile dorsolateral anatomic locking plates. Although several surgical approaches have been described for capitellar and trochlear fractures, the best approach is controversial.

The aim of this study was to evaluate the safety and efficacy of the fixation of Dubberley type B capitellar and trochlear fractures with dorsolateral anatomic plates with support of the distal humerus (DAPSDHs). We hypothesized that fixation with DAPSDHs through the Kocher extended lateral approach would be safe and effective and would result in good functional and radiographic outcomes.

## Methods

The study cohort included all patients treated at our center between 2011 and 2015. The patients were included in a prospectively collected database of all trauma patients. The inclusion criteria were Dubberley type B capitellar and trochlear fractures and fixation with a DAPSDH. The exclusion criteria were patients younger than 18 years and Dubberley type A fractures. Plain radiographs and computed tomography scans were obtained preoperatively to assess the fracture pattern according to the classification system described by Dubberley et al.<sup>7</sup> A long arm splint was placed in the emergency department. Patient demographic characteristics are shown in Table I.

## Surgical technique

All operations were performed by the same surgeon (Y.Z.). The patient was placed in the supine position, and the arm was positioned on a radiolucent arm table. A tourniquet was applied. The Kocher extended lateral approach<sup>34</sup> was used in all cases. The reduction was confirmed visually and radiographically. Provisional fixation was achieved with Kirschner wires. DAPSDHs (Synthes, Solothurn, Switzerland) were used in all patients for definitive fixation. Additional fully threaded tapered headless compression screws with variable pitch were used in 3 patients. The plate was positioned on the dorsolateral aspect of the distal humerus, with the distal spoon-shaped portion covering the nonarticulating part of the posterolateral condyle and with the lateral support reaching over the lateral epicondyle, just proximal to the lateral collateral ligament insertion. In the distal portion of the plate, to avoid joint penetration, fluoroscopy was used during drilling of screw holes (posterior to anterior) and confirmation of extra-articular placement of screws. For the thinner anterior part of the trochlea, 1 or 2 headless compression screws were added to increase the stability. A concomitant lateral collateral ligament injury was repaired with nonabsorbable sutures in 1 patient with associated dislocation. In 9 cases in which the origin of the lateral ulnar collateral ligament was involved, bony fixation

**Table I** Summary of cases

Patient No.	Age, yr	Sex	Side	Injury mechanism	Type of fracture	Associated injury
1	41	F	R/D	Traffic accident	2B	None
2	28	M	R/D	Sport	2B	None
3	22	F	L/ND	Traffic accident	3B	None
4	53	F	R/D	Fall	1B	None
5	71	F	L/ND	Traffic accident	3B	None
6	47	M	R/D	Fall	2B	Radial head fracture
7	39	F	R/D	Fall	2B	None
8	58	F	L/D	Traffic accident	3B	None
9	66	M	R/D	Fall	1B	Dislocation
10	51	F	L/D	Traffic accident	3B	None
11	49	F	R/D	Traffic accident	3B	None
12	45	F	R/D	Traffic accident	3B	None
13	28	M	L/D	Sport	2B	Radial head fracture
14	39	F	R/D	Traffic accident	3B	None
15	28	M	R/D	Sport	3B	None

F, female; R, right; D, dominant; M, male; L, left; ND, nondominant.

of the fracture was performed, and augmentation with nonabsorbable sutures was performed in all cases. Finally, the wound was irrigated and closed in layers.

## Postoperative management

A prophylactic antibiotic (cefazolin) was given preoperatively and 24 hours postoperatively. Patients were prescribed 25 mg of indomethacin 3 times daily for 6 weeks after the operation to prevent heterotopic ossification (HO). Postoperatively, the arm was immobilized with a long arm splint with the elbow in 90° of flexion and neutral forearm rotation for 1 week. At 1 week postoperatively, the splint was removed, and active and active-assisted range of motion of the elbow and forearm pronation-supination were started. Strengthening exercises were started at 3 months postoperatively.<sup>32</sup>

## Data collection

Follow-up evaluations were performed at 4, 8, and 12 weeks and then every 6 months. Radiographs were obtained at each follow-up. The range of motion of the elbow and forearm, the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire score, and the Mayo Elbow Performance Score (MEPS)<sup>15,24</sup> were recorded for each patient at the final follow-up. Radiographs were assessed for healing, osteonecrosis, HO, and post-traumatic arthritis. Arthritis was graded as described by Broberg and Morrey.<sup>3</sup> An orthopedic trauma surgeon with 18 years of experience who was not involved in the initial management or surgical treatment collected the data.

## Statistical analysis

The Statistical Package for the Social Sciences (SPSS, version 19; IBM, Armonk, NY, USA) was used for analysis. Data were presented as mean and standard deviation. Comparisons between groups were performed using the Student *t* test for continuous variables when normally distributed and the Mann-Whitney *U* test otherwise. Statistical significance was defined as  $P < .05$ .

## Results

The study included 15 patients with a mean age of 44.3 years (range, 22-71 years). On the basis of the Dubberley classification, the fractures were classified as type 1B in 2 patients, type 2B in 5, and type 3B in 8. None of the patients sustained neurovascular injuries. The average time from injury to surgery was  $5.7 \pm 3.3$  days.

The patients were evaluated at a mean follow-up of 32.5 months (range, 24-54 months). All fractures were healed. None of the patients had loss of reduction at the final follow-up. At the final follow-up, range of motion was as follows: flexion,  $123.7^\circ \pm 8.1^\circ$  (range, 110°-135°); lack of extension,  $11.0^\circ \pm 7.1^\circ$  (range, 5°-30°); pronation,  $81.7^\circ \pm 5.6^\circ$  (range, 70°-90°); and supination,  $78.7^\circ \pm 5.2^\circ$  (range, 70°-85°). The mean MEPS was  $89.0 \pm 7.1$  (range, 70-95). The outcome was rated as excellent in 12 patients (80.0%), good in 2 (13.3%), and fair in 1 (6.7%). The mean DASH score was  $11.2 \pm 4.0$  (range, 4.2-20.8). One patient had avascular necrosis (AVN)

of the capitellum. One patient had implant irritation. One patient had HO. One patient had grade 1 arthritic changes as described by Broberg and Morrey.<sup>3</sup> Ten patients returned to their previous activity level (Table II). Five patients did not return to their previous activity level. Patient 2, who was an amateur table tennis player, felt limited regarding the range of motion and strength. In patient 5, who was a retired worker, AVN developed, and this patient was complaining of intermittent moderate pain requiring occasional oral nonsteroidal anti-inflammatory medication. Patient 9 had implant irritation, sustained a wound infection after implant removal in a local hospital, and had decreased range of motion. Patients 6 and 14 changed their previous physical jobs to nonphysical work. The preoperative and postoperative radiographic evaluation findings and clinical photographs of range of motion in a patient are shown in Figures 1-4.

When patients with type 3B were compared with patients with types 1B and 2B combined, elbow flexion was significantly less in the type 3B group (Table III). The patients without AVN, HO, implant irritation, and arthritis had significantly better outcomes on evaluation with the DASH score and MEPS than those with these complications (Table IV). Patients who underwent surgery within 7 days of injury had significantly better outcomes (DASH score and MEPS) than patients operated on more than 7 days after injury (Table V).

## Discussion

Partial articular fractures in the coronal plane of the distal humerus involving the capitellum and trochlea account for 1% of all elbow fractures and 6% of distal humeral fractures.<sup>16</sup> The mechanism of injury is usually a fall on the outstretched hand, with the radius imparting a shearing force.<sup>22</sup> Maximum force transmission through the radial head occurs at 0° to 30° of elbow flexion.<sup>25</sup> Greater than 80% of capitellar and trochlear fractures occur in women, which has been attributed to increased cubitus valgus, recurvatum, and osteoporosis.<sup>7,8,33</sup> Although several classifications have been described for capitellar and trochlear fractures, none has been universally accepted<sup>6,8,9,31</sup>; the Bryan and Morrey classification has been most commonly used.<sup>6</sup> Yet, it does not refer to posterior comminution, which influences the fixation method and outcome. The classification proposed by Dubberley et al<sup>7</sup> takes into account posterior condylar comminution and recognizes fractures splitting the trochlea and capitellum into different fragments as a separate entity. Type 1 injuries involve the capitellum with or without the lateral trochlear ridge; type 2 injuries involve the capitellum and trochlea as a single piece; type 3 injuries consist of fractures of both the capitellum and trochlea as separate fragments. Each fracture type is additionally subclassified as type A or type B based on the presence of posterior condylar comminution. Dubberley et al contended that this classification guides treatment and found that isolated capitellar and/or trochlear fractures without comminution (type A) had better results than those with comminution

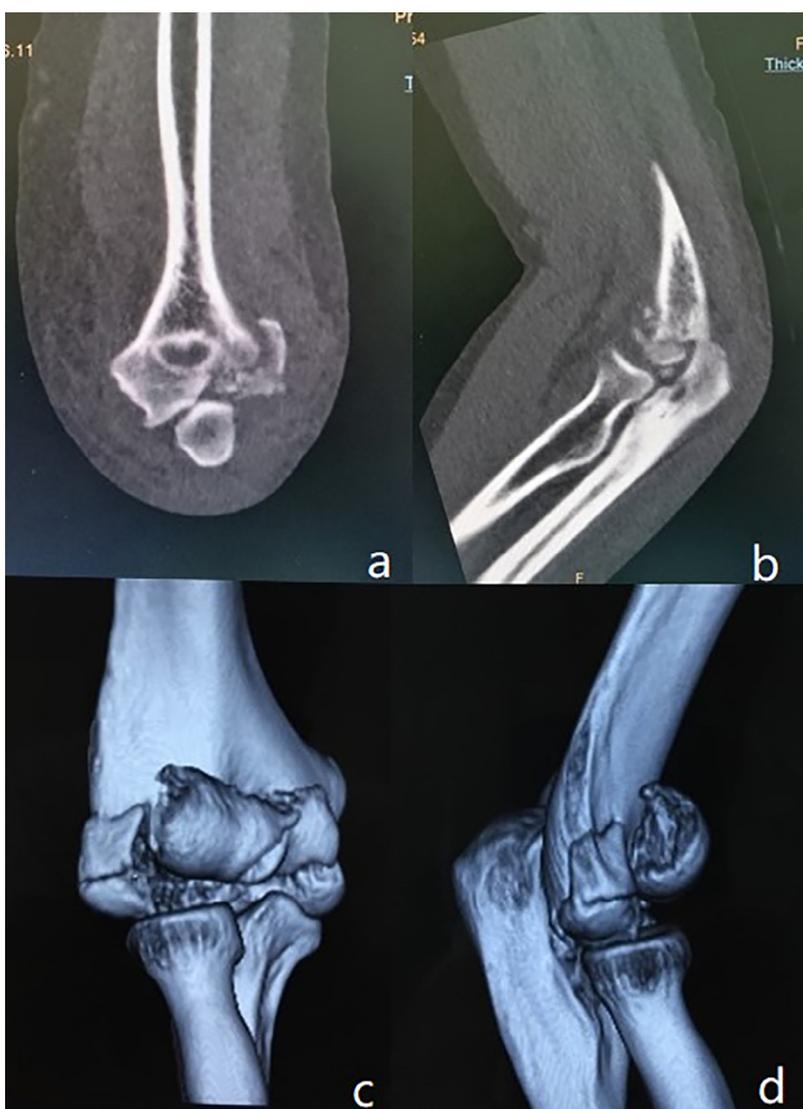
**Table II** Summary of results

	Age, yr	Sex	Ext, °	Flex, °	Pro, °	Sup, °	Time from injury to surgery, d	FU, mo	Complications	MEPS	DASH score
Patient No.											
1	41	F	5	135	85	80	3	32	None	90	8.3
2	28	M	5	125	80	75	12	24	None	90	12.5
3	22	F	10	115	85	80	6	29	None	95	10.0
4	53	F	15	135	75	85	5	30	None	95	8.3
5	71	F	30	115	75	70	7	54	AVN	70	20.8
6	47	M	5	125	85	85	5	30	Arthritis	90	15
7	39	F	5	130	90	80	2	30	None	90	11.7
8	58	F	5	110	85	80	5	48	None	90	10.7
9	66	M	20	120	85	75	14	36	Implant irritation	80	16.7
10	51	F	10	110	70	75	4	26	None	90	9.4
11	49	F	15	130	85	85	6	30	None	95	4.2
12	45	F	15	125	80	80	5	28	None	95	7.6
13	28	M	5	130	85	85	3	30	None	95	11.8
14	39	F	10	125	85	75	4	36	None	90	9.5
15	28	M	10	125	75	70	4	24	HO	80	11.4
Mean ± SD	44.3 ± 14.4		11.0 ± 7.1	123.7 ± 8.1	81.7 ± 5.6	78.7 ± 5.2	5.7 ± 3.3	32.5 ± 8.4		89.0 ± 7.1	11.2 ± 4.0

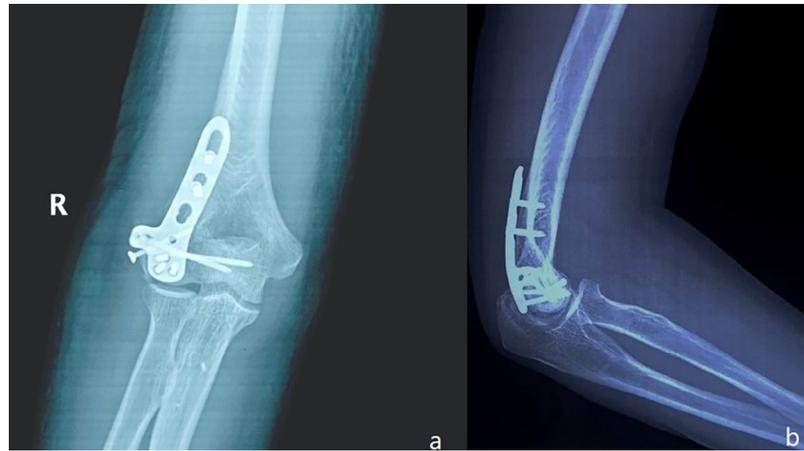
*Ext*, extension; *Flex*, flexion; *Pro*, pronation; *Sup*, supination; *FU*, follow-up; *MEPS*, Mayo Elbow Performance Score; *DASH*, Disabilities of the Arm, Shoulder and Hand; *F*, female; *M*, male; *AVN*, avascular necrosis; *HO*, heterotopic ossification; *SD*, standard deviation.



**Figure 1** Preoperative anteroposterior (a) and lateral (b) elbow radiographs of a 41-year-old patient. *R*, right.



**Figure 2** Coronal (a) and sagittal (b) computed tomography scans and 3-dimensional reconstructions of computed tomography scans (c, d) showing a comminuted fracture of the lateral condyle involving the posterior portion of the capitellum and trochlea.



**Figure 3** (a, b) Postoperative radiographs at 24 months after surgery. R, right.



**Figure 4** Range of motion at 24 months' follow-up: flexion (a), extension (b), pronation (c), and supination (d).

**Table III** Comparison of results of Dubberley types 1B and 2B and Dubberley type 3B

	Types 1B and 2B (n = 7)	Type 3B (n = 8)	P value
Age, yr	43.1 ± 13.6	45.4 ± 15.8	.78
Ext, °	8.6 ± 6.3	13.1 ± 7.5	.23
Flex, °	128.6 ± 5.6	119.4 ± 7.7	.02
Pro, °	83.6 ± 4.8	80.0 ± 6.0	.23
Sup, °	80.7 ± 4.5	76.9 ± 5.3	.16
FU, mo	30.3 ± 3.6	34.4 ± 11.0	.35
MEPS	90.0 ± 5.0	88.1 ± 8.8	.63
DASH score	12.0 ± 3.1	10.5 ± 4.8	.46

Ext, extension; Flex, flexion; Pro, pronation; Sup, supination; FU, follow-up; MEPS, Mayo Elbow Performance Score; DASH, Disabilities of the Arm, Shoulder and Hand.

(type B). Limited literature is available on capitellar and trochlear fractures with posterior comminution (Supplementary Table S1).<sup>1,4,7,9,10,17,28</sup>

The treatment of capitellar and trochlear fractures includes closed reduction,<sup>28</sup> excision,<sup>10</sup> and open reduction with or without internal fixation. Internal fixation can be performed

**Table IV** Comparison of outcomes (MEPS and DASH score) in patients with and without complications (avascular necrosis, heterotopic ossification, implant irritation, or arthritis)

	Complications	No complications	P value
MEPS	80.0 ± 8.2	92.3 ± 2.6	<.001
DASH score	16.0 ± 3.9	9.5 ± 2.4	<.001

MEPS, Mayo Elbow Performance Score; DASH, Disabilities of the Arm, Shoulder and Hand.

**Table V** Comparison of patients with and without complications (avascular necrosis, heterotopic ossification, implant irritation, or arthritis) and patients who underwent surgery within 7 days or at more than 7 days regarding outcomes (MEPS and DASH score)

	Complications			Time from injury to surgery		
	Yes	No	<i>P</i> value	≤7 d	>7d	<i>P</i> value
MEPS	80 (70-90)	90 (90-95)	.008	80 (70-90)	90 (90-95)	.036
DASH score	16.0 ± 3.9	9.5 ± 2.4	.013	9.8 ± 2.7	16.7 ± 4.2	.014

MEPS, Mayo Elbow Performance Score; DASH, Disabilities of the Arm, Shoulder and Hand.

with Kirschner wires,<sup>27</sup> cannulated screws,<sup>2,19</sup> or headless compression screws.<sup>23</sup> Considering Dubberley type B fractures involving posterior condylar comminution, fixation with Kirschner wires or with screws may have some limitations: First, fixation may not be achievable because of lack of an intact posterior cortex. Second, starting early range of motion may not be possible because of worry regarding loss of reduction and failure of fixation, which will result in stiffness. For type B fractures, Dubberley et al<sup>7</sup> recommended bone grafting or additional fixation with pelvic reconstruction plates—or a combination thereof. Fixation with a dorsally placed fixed-angle plate system (DAPSDH) can provide a more stable construct than screw-only fixation. The distal spoon shape of the plate supports the nonarticular part of the lateral condyle. Two lateral-to-medial screws partially offset coronal shear stress. The distal 2.7-mm aperture and lower-profile design can reduce the impingement, which may be the main reason for poor function emphasized in the study by Ashwood et al.<sup>1</sup> For type 1B fractures, the most distal 3 locking screws from posterior to anterior achieve stable fixation of the capitellum. In type 2B and 3B fractures, 2 lateral-to-medial screws through the plate extension provide additional fixation.

In our study, Dubberley type B capitellar and trochlear fractures were safely and effectively treated with DAPSDHs. Fracture union was achieved in all patients without loss of reduction or failure of fixation. No wound complications or neurovascular injury occurred. One patient with a type 2B fracture had osteonecrosis of the capitellum. This may be because of the severity of the injury or the surgical dissection.<sup>13,17</sup> The implants were removed because of irritation in 1 patient after bony union. HO developed in 1 patient.

Compared with the group with types 1B and 2B combined, the type 3B group had worse flexion ( $P < .05$ ). In other words, the greater the fragmentation of the articular surface, the worse the outcome,<sup>12</sup> which is consistent with the results of previous studies.<sup>28</sup> As the blood supply to the capitellum and lateral trochlea comes mainly from the posterior condylar perforating vessels,<sup>13,17</sup> posterior comminution may result in at least partial devascularization of the lateral column, predisposing to nonunion. Brouwer et al<sup>4</sup> reported a 44% nonunion rate (8 of 18 patients) after fixation in type 3B fractures. The high nonunion rate may be partly related to the type of fixation. Fixation with DAPSDHs can be helpful for capitellar and trochlear fractures with severe posterior comminution (type B) to maintain the position of the anterior shear fragments and avoid nonunion.<sup>8</sup>

Surgical approaches described for the treatment of capitellar and trochlear fractures include the extended lateral approach, posterior transolecranon approach, anterolateral approach, and 2-incision approach.<sup>8,11,14,20,30,33</sup> The best approach is controversial. The anterolateral approach has the advantage of exposure of the capitellum and trochlea without disruption of the lateral collateral ligament complex or an olecranon osteotomy,<sup>14</sup> but its inherent weakness is that it is too difficult to expose the posterolateral surface. The potential risk of olecranon osteotomy is nonunion. The most commonly used approach is the Kocher extended lateral approach, which was used in our study. Although functional outcomes do not appear to depend on the approach used,<sup>18,32</sup> on the basis of the experience of the current series, we would suggest that the extended lateral approach is preferable for type B fractures, allowing visualization, reduction, and stable fixation.

As expected, the clinical outcomes evaluated by the MEPS and DASH score were better when no complications occurred. In addition, the outcomes were better when the patients underwent surgical treatment within a week. The good results of our study for these complex injuries may be related to multiple factors including the approach, fixation method, or timing of surgical treatment or a combination of these factors.

This study comprises one of the largest studies focusing on Dubberley type B fractures of the capitellum and trochlea with midterm follow-up (Supplementary Table S1). In most of the previous series, the surgical approach and/or fixation method was not consistent, whereas in this study, all patients were treated using the same surgical approach and with the same type of fixation. On the other hand, this study has several limitations owing to its retrospective design. A comparative cohort is also lacking; however, we believe that screw-only fixation in Dubberley type B fractures is inadequate. The number of patients in our study is small given the rare nature of the type of injury examined.

## Conclusion

Dubberley type B capitellar and trochlear fractures are rare injuries. Posterior comminution is the source of the challenge to achieve stable fixation and maintain it until bony union. These fractures are safely and effectively treated with DAPSDHs, resulting in good radiographic and functional outcomes.

## Disclaimer

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

## Supplementary data

Supplementary data to this article can be found online at <http://dx.doi.org/10.1016/j.jse.2018.09.004>.

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