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Large coronal shear fractures of the capitellum and trochlea treated with headless compression screws

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Background: The purpose of this study is to retrospectively evaluate the clinical outcomes of 18 patients with large coronal shear fractures of the capitellum and lateral trochlea that underwent open reduction and internal fixation with headless compression screws.
Methods: Eighteen patients were identified (16 women, 2 men) with an average age of 45 years and an average follow-up of 26 months. Fractures were classified according to the Dubberley classification as 11 type-1A injuries and 7 type-2A injuries.
Results: All patients, with the exception of 1, had good to excellent functional results by the Broberg-Morrey scale (mean score, 93.3). Average arc of motion was 128° in flexion/extension and 176° in pronation/supination. Radiographically, 3 patients had subsequent development of avascular necrosis and 5 developed arthrosis. No significant negative correlation was noted between the development of avascular necrosis and clinical outcome. Minor complications occurred in 2 patients, but there were no re-operations.
Conclusion: Headless compression screw fixation allows for stable fixation in patients with large coronal shear fractures of the distal humerus without posterior comminution.
Level of Evidence: 4.

Keywords: Capitellum; Fracture; Internal Fixation

Fractures of the humeral capitellum are rare injuries.[1,12,15,16] These fractures result from a direct force transmitted through the radial head that provides a shearing and/or compressive load to the capitellum and occasionally to the trochlea.[28] One proposed mechanism of injury is a fall on an outstretched hand, with the force transmitted through the radius as an individual attempt to break the fall.[11] Displaced capitellar and trochlear fractures invariably lead to poor clinical outcomes if left untreated.[1] The bony fragments usually displace superiorly and may unite to the

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anterior humerus. This can cause a mechanical block to elbow flexion by obstructing the radial and/or coronoid fossa. The articular step-off created by the displaced fragment also predisposes the joint to the subsequent development of post-traumatic arthrosis.[10]

The classification of capitellar fractures has evolved over the years with several systems proposed; however, no single classification has been universally accepted.[4,5,10,18,26] Bryan and Morrey were the first to classify these complex injuries into 3 subtypes: type 1 injuries consisted of coronal shear fractures of the capitellum that had little to no involvement of the trochlea; type 2 injuries were shear fracture of the capitellum with minimal attached subchondral bone; and type 3 injuries were essentially comminuted fractures of the capitellum.[4] McKee et al subsequently added a 4th type that involved a large coronal shear fracture of the distal humerus, where the capitellum and trochlea consisted as 1 single fragment.[10,18] Recognizing that capitellar fractures are part of a larger spectrum of injury to the distal humerus articular surface, Ring described 5 injury patterns (types 1-5) on the basis of radiographs and intraoperative findings.[26] Lastly, Dubberley et al most recently proposed a classification system that takes into account posterior condylar comminution and also recognizes fractures splitting the trochlea and capitellum into different fragments as a separate entity.[5] These authors contended that this classification was better at directing treatment, and found that isolated capitellar and/or trochlear fractures without comminution had better results than patients with more complex fracture patterns.

Treatment strategies for these injuries have evolved over time from conservative management to open surgical approaches. While favorable outcomes have been reported with cast immobilization, this treatment is not routinely advocated because of the inherent difficulties with maintenance of the reduction in a cast.[22] In effect, surgical intervention is typically regarded as the standard of management and has included both simple excision of the fragment and internal fixation. Although simple excision is straightforward and has been associated with favorable functional outcomes, excision of the capitellum can lead to contracture and instability.[1,7,9,19,33,34] Restricted mobility may occur as a result of the formation of intra-articular adhesions between the exposed cancellous bone and overlying soft tissues. Instability may develop when the injury is associated with collateral ligament insufficiency or when the fracture extends beyond the lateral trochlear ridge and results in disassociation between the ulno-humeral joint.[18,19,33] Currently, open reduction and internal fixation are regarded as the preferred method for treating these injuries. Given the rarity of these fractures, it has been difficult to formulate a universally accepted method of fixation. The purpose of this study is to report on the demographic characteristics and clinical and radiographic outcomes for 18 patients with large coronal shear fractures of the capitellum treated with headless compression screws with a minimum of 1-year follow-up.

Materials and methods

Eighteen consecutive large coronal shear fractures of the capitellum and lateral trochlea were treated with internal fixation, using headless compression screws between December 2001 and March 2008. The senior author did all 18 surgeries. Patients were consecutively enrolled into the IRB-approved study upon diagnosis of a capitellum fracture. They were subsequently followed clinically and radiographically with subjective and objective outcome measures obtained. No patients were excluded or withdrawn.

Sixteen patients were female and 2 were male. All patients were available for a minimum of 12 months of follow-up. The average age in the present series was 45 years (range, 20-68) and the average follow-up period was 25.5 months (range, 12-64). The mean time from presentation to internal fixation was 10 days (range, 2-22 days). All injuries were the result of trauma (fall), and the nondominant side was affected 89% (16/18) of the time. The most common mechanism of injury was a ground level fall (Table I).

Fractures in this study were classified according to the Dubberley classification: type-1 injuries involved primarily the capitellum with or without the lateral trochlear ridge; type-2 injuries involved the capitellum and trochlea as one piece; type-3 injuries consisted of fractures of both the capitellum and trochlea as separate fragments.[5] This classification further subclassifies the fractures as A or B based on the presence of posterior comminution. Injury films were reviewed by 3 fellowship-trained shoulder and elbow orthopedic surgeons. Fractures were classified based upon routine radiographs and the fracture type was confirmed intraoperatively. All fractures in the current series were large coronal shear fractures without posterior comminution with 11 type-1A (Figure 1) and 7 type-2A (Figure 2) fractures identified.

Surgical Technique

Headless screw fixation was used in all cases. Acutrak Mini headless compression screws (Acumed, Hillsboro, OR) were placed from anterior to posterior with the screws buried beneath the articular cartilage. An associated lateral collateral ligament (LCL) injury was observed at the time of surgery in 3 of 18 cases (17%). In these cases, the LCL was repaired to the bone with heavy suture passed through drill holes. Unless the LCL was already injured, it was protected during surgery and not released surgically for purposes of improving exposure.

Operative stabilization was performed through the lateral Kaplan approach utilizing a nonsterile tourniquet. After appropriate exposure was achieved, the lateral column was identified. The extensors, in conjunction with the anterior capsule, were then elevated off of the supracondylar ridge as a full thickness sleeve of tissue. The posterior flap containing the LCL was not disrupted, unless there was a LCL injury that required repair. The posterior flap provides vascular supply to the posterior aspect of the distal humerus and damage to this flap can disrupt the blood supply to the capitellum.

Table I Patient demographics

#	Gender	Age	Dominant	Injured	Mechanism	Class	LCL injury?	OR delay	f/u (m)
1	Female	56	Right	Right	Ground Level Fall	2A	Yes	12 d	64
2	Female	47	Right	Left	Fall down stairs	1A	No	5 d	57
3	Male	48	Right	Left	Ground Level Fall	1A	No	14 d	18
4	Female	60	Right	Left	Ground Level Fall	1A	No	4 d	50
5	Female	28	Right	Left	Ground Level Fall	2A	No	5 d	36
6	Female	58	Right	Left	Ground Level Fall	2A	No	8 d	43
7	Female	31	Right	Left	Ground Level Fall	1A	No	10 d	12
8	Male	41	Right	Left	Fell off Roof	2A	Yes	11 d	33
9	Female	65	Right	Left	Ground Level Fall	1A	No	18 d	12
10	Female	48	Right	Left	Fell off Bike	1A	No	5 d	23
11	Female	35	Right	Left	Ground Level Fall	1A	No	22 d	21
12	Female	40	Right	Left	Ground Level Fall	2A	No	10 d	14
13	Female	45	Right	Left	Ground Level Fall	1A	No	6 d	14
14	Female	20	Right	Left	Fell off Horse	2A	No	12 d	12
15	Female	27	Right	Left	Fall off Catwalk	1A	No	17 d	12
16	Female	68	Right	Right	Fall in Bathroom	1A	No	6 d	12
17	Female	27	Right	Left	Ground Level Fall	2A	Yes	2 d	14
18	Female	65	Right	Left	Ground Level Fall	1A	No	9 d	12

LCL, lateral collateral ligament; *OR*, operating room; *d*, days; *f/u*, follow-up; *m*, months.

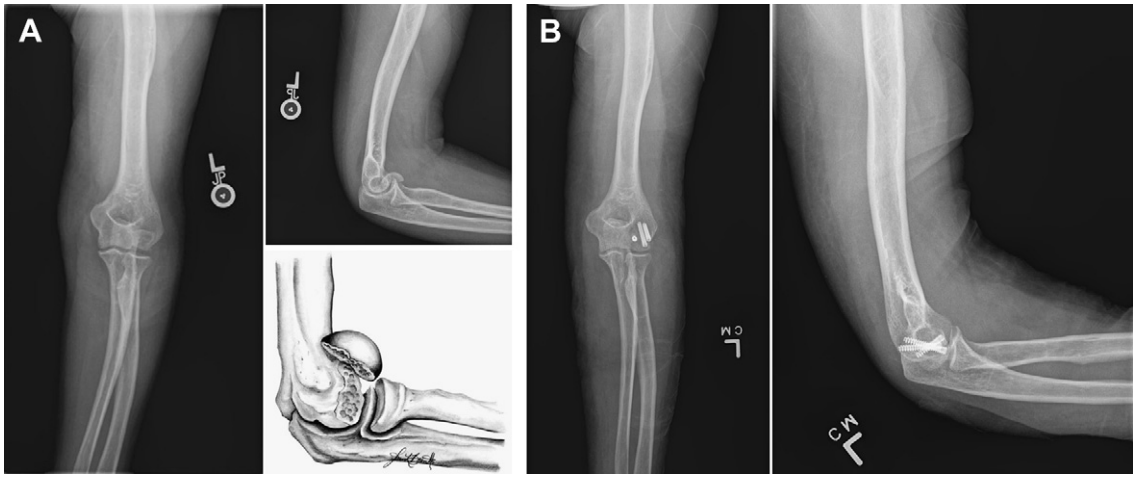

Figure 1 **A**, Antero-posterior x-ray view and lateral x-ray/diagrammatic views of a type-1A capitellum fracture. **B**, Antero-posterior and lateral views of the same patient 11 days after headless compression screw fixation.

The elbow was flexed 45° and a large blunt Hohmann retractor was placed beneath the anterior capsule and around the medial column of the humerus. This maneuver provided access to the capitellar fragment, metaphyseal fracture site, and anterior articular surface of the distal humerus. To minimize the risk of injury to the posterior interosseous nerve, anterior placement of retractors on the radial neck was avoided. Fibrous tissue and hematoma were curetted from the free capitellar fragment. The metaphyseal bed was then prepared to ensure that there was no posterior comminution and adequate bone stock remained to accept headless screw fixation.

To reduce the capitellar fragment anatomically, the proximal metaphyseal edge and trochlear articulation was visualized. Because of plastic deformation, perfect reduction was not always possible, but bone graft was not utilized in any case. The fragment was then reduced to the anterior surface of the humerus using a small bone tenaculum or dental pick. The capitellar fragment was provisionally fixed using Kirschner wires (K wires), which were placed along the fracture margin so as not to interfere with placement of headless screws (Figure 3). In our current series, there were no instances of iatrogenic fractures secondary to provisional K wire or headless screw placement.

Guide wires for the Acumed mini Acutrak headless screws were placed into the central portion of the articular surface of the capitellum and driven out the posterior cortex of the humerus distally. Two to 3 screws were placed to ensure

Figure 2 **A**, Lateral x-ray view and antero-posterior xray/diagrammatic views of a type-2A capitellum fracture. **B**, Ten-month postoperative antero-posterior and lateral views of a patient with a type-2A capitellum fracture fixed with headless compression screws.

rotational stability (Figure 1, *B*). When possible, a divergent screw pattern was preferred. Furthermore, attempts were made to assure adequate screw spread to avoid iatrogenic fragmentation of the capitellum. Each screw was placed over the guide wire and countersunk for at least 2 mm to avoid erosion of the articular surface of the proximal radius from prominent hardware. Intraoperative fluoroscopy was used to examine hardware position and fracture reduction in the antero-posterior (AP) and lateral planes.

Postoperatively, patients were held in a splint at 90° of flexion in neutral rotation for 5-7 days. Patients were then allowed to come out of the splint and perform a home exercise program for the ensuing 4 weeks. The program consisted of gravity-aided, active-assisted supine flexion and upright extension. Patients were instructed to perform these exercises a minimum of 3 times each day. Patients were evaluated 6 weeks postoperatively and radiographs were obtained during that visit. Range of motion and function were also evaluated and patients were placed into a supervised occupational therapy program if they lacked a 100° arc of flexion and extension.

Clinical outcomes were evaluated postoperatively at approximately 4 weeks, 8 weeks, 3 months, 6 months, and 1 year. After the 1-year visit, patients were called back for re-evaluation for the purposes of this study. At each follow-up clinic visit, range of motion (ROM) in flexion/extension and pronation/supination was recorded. The Broberg-Morrey (BM) scale, which is a functional rating based on a 100-point index, and the American Shoulder and Elbow Surgeons (ASES) scores were used.[2,13] Broberg-Morrey scores of 95-100 are considered excellent, 80-94 good, 60-79 fair, and 0-59 points considered a poor outcome.

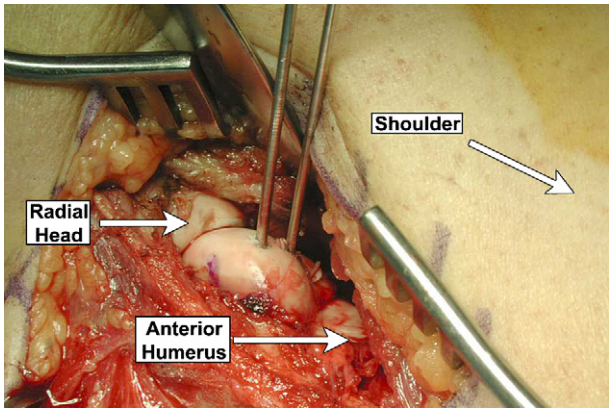

Figure 3 K wires are used for provisional fixation of the capitellar fragment.

Antero-posterior and lateral radiographs of the patient's elbow were taken at each follow-up clinic visit at the above-mentioned time periods. The latest available radiographs at a minimum of 1-year of follow-up were evaluated by 3 independent orthopaedic surgeon reviewers who were not involved in patient management. Radiographic outcomes evaluated included presence of union or nonunion (yes/no), avascular necrosis (present/absent), joint line step-off (none/≤1-mm/>1-mm), hardware failure (present/absent), and instability. Arthrosis was evaluated subjectively using the system described by Broberg and Morrey as: grade 0 if there was no signs of arthritis; grade 1 if there was slight joint-space narrowing and minimal osteophyte formation; grade 2 if there was moderate joint-space narrowing and osteophyte formation, or grade 3 if there was severe joint-space narrowing with gross destruction.[2] Finally, heterotopic ossification (HO) was classified using the Brooker classification applied to the elbow: class I was defined as islands of bone within the soft tissues; class II required the presence of ectopic bone from the humerus, radius, or ulna, leaving at least 1 cm between opposing surfaces; class III required ectopic bone from the humerus, radius, or ulna, reducing the space between opposing bone surfaces to less than 1 cm; and, lastly, class IV HO demonstrated apparent bone ankylosis of the elbow joint.[3]

Statistics

The Sign test was used to determine if the occurrence of capitellar fractures was significantly more common in females than males, and if nondominant extremities were more commonly involved than dominant extremities. The outcomes of fractures in terms of BM scores and ROM in flexion/extension were compared using independent samples *t* tests.

Based on the Kolmogorov-Smirnov test, all continuous data types were normally distributed. Age, time between injury and surgery, ROM in flexion/extension, and BM scores were compared using a correlation coefficient. Additionally, in order to determine if age was a confounding factor in the development of arthritis, the relationship of ages >45 or >50 and the presence of arthritis were evaluated using the Fisher exact test.

Finally, the presence or absence of avascular necrosis (AVN) was compared with the BM clinical result (excellent or not excellent), arthritis (present or absent), and age (>45 or >50) using the Fisher exact test. In all cases, statistical significance was set at $P < .05$.

Results

All fractures united by 1-year follow up. The average Broberg-Morrey score was 93.3 points (57-100) with 12 excellent, 5 good, and 1 poor rating (Table II). The average total ASES score was 83.1 (21.3-100). ROM in flexion/extension averaged 128° (83°-155°), while ROM in pronation/supination averaged 176° (120°-180°).

Radiographically, there were 5 patients with a minimum of grade 1 radio-capitellar arthrosis at their last follow-up, 3 patients with avascular necrosis, and 3 patients with class I heterotopic ossification. There were no instances of instability, nonunion, or hardware failure on the most recent radiographs (Table III).

Statistically, there were significantly more females (16/18 or 89%) than males ($P = .001$) and a greater number of nondominant extremity injuries (16/18 or 89%; $P = .001$). There were no significant differences in outcomes between types-IA and -IIA injuries in terms of BM scores ($P = .9$) and ROM ($P = .6$).

Age was not associated significantly with postoperative ROM ($R = -0.1$; $P = .6$), BM score ($R = -0.3$; $P = .3$), or the presence of arthritis ($P = 1.0$ when either 50 years or 45 years was used as the cut-off). Similarly, time from injury to surgical stabilization was not associated to clinical outcome in terms of ROM ($R = -0.2$; $P = .3$) and BM scores ($R = -0.008$; $P = 1.0$). The presence of AVN was significantly associated with the presence of arthritis ($P = .01$), as 3/3 patients in the AVN group had some evidence of arthritis on the last available radiographs compared to 2/15 patients in the non-AVN group. However, the presence of AVN was not associated significantly with BM clinical results of less than excellent (ie, BM score <95) with a P value of .2. Furthermore, the presence of AVN was not significantly associated with age >50 ($P = .2$) or age >45 ($P = .2$).

There were 2 patients with complications in this study and no re-operations (Table II). One patient had a stitch abscess with wound breakdown first noted 44 days after surgery. This patient was successfully managed with local wound care, oral antibiotics, and steri-strips. The other complication was in a patient that had persistent postoperative stiffness with a flexion contracture of 42° at the most recent post-operative visit (64 months). Several interventions were attempted in this patient, including therapy, extension splinting, and indomethacin. The patient had a BM clinical result of good and reported that she was satisfied because she had the ability

Table II Clinical outcomes

#	Broberg-Morrey	Total ASES	ROM- flex/ext	ROM- pron/sup	Complication
1	83- good	96.7	83	180	Persistent stiffness
2	100- excellent	94	140	180	Wound breakdown
3	100- excellent	100	150	180	None
4	100- excellent	98.3	150	180	None
5	100- excellent	98.3	135	180	None
6	100- excellent	100	145	180	None
7	86- good	79	98	180	None
8	85- good	21.3	130	180	None
9	97- excellent	N/A	120	170	None
10	100- excellent	92.3	155	180	None
11	97- excellent	95.5	120	180	None
12	83- good	N/A	90	120	None
13	99- excellent	N/A	128	180	None
14	100- excellent	88	148	180	None
15	93- good	88.3	137	180	None
16	57- poor	97.3	97	180	None
17	100- excellent	95.3	146	180	None
18	100-excellent	100	140	180	None

ASES, American Shoulder and Elbow Surgeons; *N/A*, not available; *ROM*, range of motion; *flex*, flexion; *ext*, extension; *pron*, pronation; *sup*, supination.

to effectively perform her activities of daily living. This patient wanted no further intervention.

The patient with a poor BM clinical outcome (BM score = 57) was not considered a complication. Despite having the lowest BM score, this patient experienced no pain and could perform routine activities of daily living. At last x-ray follow-up of 12 months, this patient was noted to have mild arthritis, heterotopic ossification, and AVN.

Discussion

Several studies using headless compression screws have shown mostly good to excellent results (using varying rating systems) for all types of capitellum fractures over a wide range of follow-up (5 months to 9.3 years).[14,18,24,26,27,30] With the exception of Ruchelsman et al, all of the above studies are limited by the small patient size ranging from 4 to 6 patients.[27] Our study is unique in that it has a larger sample size than any other previously reported in the literature, allowing us to break our patients into subgroups for statistical comparison. For example, there was no difference in postoperative BM scores and ROM after headless compression screw fixation of Dubberley types-1 and -2 fractures. These findings support those reported by Dubberley, where types-1A and -2A fractures also faired well with regard to functional outcome and range of motion.[5] This is in contrast to Ruchelsman et al, who reported that Bryan and Morrey (McKee) type IV fractures resulted in greater flexion contractures, lower total flexion, and lower net ulno-humeral arc when compared to Bryan-Morrey type-I fractures.[27] This discrepancy can be better explained by looking closer at these different classification schemes. The Bryan and Morrey (McKee) type IV fracture correlates with the Dubberley type 2 classification where the capitellum and trochlea are 1 large fragment.[5,10,18] The difference between them is in regards to the recognition of associated comminution that is not accounted for with the Bryan and Morrey system but noted with the Dubberley classification. In Ruchelsman's series, 50% of the type IV fractures identified had associated posteroinferior metaphyseal comminution and 2 fractures had separate trochlear fracture fragments.[27] In accordance with the Dubberley classification, 4 of these would have qualified as 2B fractures, and 2 as type 3 fractures.[5] Evaluation of the fractures in this manner may have further supported the present findings and those demonstrated by Dubberley that better outcomes are to be expected in large coronal fractures lacking significant comminution.

Based on our experience, we have devised a treatment algorithm for capitellum fractures. Internal fixation of capitellum fractures requires near anatomic reduction and compression at the fracture site. We have elected to use headless screws placed from anterior to posterior to avoid further disruption of the remaining blood flow.[35] The authors feel that a headless screw is an ideal implant for fixation of articular fractures that allows adequate stability for early motion. The variable pitched screw placed from anterior to posterior provides maximal threads for compression at the fracture site with minimal damage to the articular cartilage of the joint. Bio-mechanical analysis conducted to evaluate the fixation strength of an Acutrak headless compression screw versus a 4-mm cancellous partially-threaded lag screw (placed both anterior to posterior and posterior to anterior) found that the Acutrak screw was the most stable construct.[6]

Our surgical approach for fixation of these injuries has been a lateral column exposure. In all types of injuries, an effort is made to leave the LCL intact. Release of the

Table III Radiographic outcomes

#	Arthritis	Nonunion	AVN	HO	Step-Off	Hardware Failure	Instability	Union
1	Grade 2	No	Present	Class I	None	Absent	None	Yes
2	Grade 1	No	Present	None	None	Absent	None	Yes
3	Grade 0	No	Absent	Class I	None	Absent	None	Yes
4	Grade 0	No	Absent	None	None	Absent	None	Yes
5	Grade 0	No	Absent	None	None	Absent	None	Yes
6	Grade 0	No	Absent	None	None	Absent	None	Yes
7	Grade 0	No	Absent	None	None	Absent	None	Yes
8	Grade 1	No	Absent	None	None	Absent	None	Yes
9	Grade 0	No	Absent	None	None	Absent	None	Yes
10	Grade 0	No	Absent	None	None	Absent	None	Yes
11	Grade 1	No	Absent	None	None	Absent	None	Yes
12	Grade 0	No	Absent	None	None	Absent	None	Yes
13	Grade 0	No	Absent	None	None	Absent	None	Yes
14	Grade 0	No	Absent	None	None	Absent	None	Yes
15	Grade 0	No	Absent	None	None	Absent	None	Yes
16	Grade 1	No	Present	Class I	None	Absent	None	Yes
17	Grade 0	No	Absent	None	None	Absent	None	Yes
18	Grade 0	No	Absent	None	None	Absent	None	Yes

AVN, avascular necrosis; *HO*, heterotopic ossification.

ligament would be recommended only if enhanced exposure is required to achieve an anatomic reduction of the articular surface, but this could potentially disrupt the blood flow to the capitellum. Attention should be directed to the integrity of the LCL with type-2 injuries, as it was torn in 43% of cases in the present series and required repair. No LCL injuries were demonstrated with type-1 injuries.

Similar to other studies, several patients in the present series developed AVN (17%), degenerative joint disease (28%), or heterotopic ossification (17%).[14,18,27,30] According to our statistical analysis, the presence of AVN did not prevent an excellent BM score, and 2 of our patients had good to excellent results despite the presence of AVN. These findings support those reported by Stamatis and Paxinos, in which their only patient with AVN also had an excellent BM score.[30] Although instability can be an inherent complication associated with this injury, it was not seen in the present series.[14] Finally, we did not see any incidence of nonunion, which further corroborates the other studies presently reviewed.[14,18,24-27,30]

There are 2 interesting trends noted in the fractures in this series. The first trend is that 16 of 18 of the fractures occurred in women ($P = .001$). Other studies have also shown a similar trend of more capitellum fractures in females compared to males, ranging from 60-100% female predominance.[5,9,18,21,24-27,30] This trend could be a result of post-traumatic insufficiency fractures secondary to lower bone mineral density seen in women, especially during the post-menopausal period.[8,9,15,29,31] Watts et al noted that the incidence of distal humerus periarticular fractures in females over the age of 60 was twice as common as that between females aged 20-59.[33] A second explanation of this trend could be attributable to the increased valgus carrying angle at the elbow of up to 5° in women as compared to men.[9,23,32,36] This increased carrying angle could result in a greater contact force imparted to the lateral column during a fall with the elbow in an extended position.

The second interesting trend in this series is that 16 of 18 capitellar fractures occurred in the nondominant extremity ($P = .001$). The reason for this trend is unclear, but it could be due to decreased bone mineral density observed in the nondominant extremity compared to the dominant extremity.[17,20,31] A review of available literature does not bear out a similar trend in studies of capitellum fractures, where hand dominance was reported.[9,18,26,27,30] It must be noted that either a greater sample size or a meta-analysis of several capitellum studies is needed to establish a true association between hand dominance and the incidence of capitellum fractures.

Conclusion

Open reduction and internal fixation using headless screw compression via a lateral approach is a reliable treatment for large coronal shear fractures of capitellum and lateral trochlea, and results in stable fixation and restoration of a functional arc of motion. Statistical analysis of our study population demonstrated that the majority of capitellum fractures occur in female patients and involve the nondominant extremity. Although our study had a larger sample size than any other previously reported in the literature, an even larger sample size would be beneficial to completely rule out the possibility of a type-II statistical error. The authors acknowledge that the short-term follow-up period is one of the main weaknesses of the present study and understand that

a longer follow-up period is necessary to determine the true incidence of post traumatic arthritis of the elbow. The classification system utilized is a subject of debate; however, the Dubberley system takes into account the complexity of these fractures and helps us predict which fracture patterns are best treated through a lateral approach. Our clinical results are similar to the findings of Dubberley, that good results can be expected of coronal shear fractures of the distal humerus without associated posterior comminution.[5]

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