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Clinical outcome of AO/OTA type C fracture of the distal humerus using the expanded paratricipital approach and cadaveric comparison of the exposure of the paratricipital and expanded paratricipital approaches to the distal humerus

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Background: We investigated the overall clinical outcome of the expanded paratricipital approach in complex articular fractures of the distal humerus and the effect of lack of visualization in the surgical field. In addition, we performed a cadaveric study to investigate the expansion or limitation of articular access in the expanded paratricipital approach.
Methods: Forty-one AO/OTA type 13C fracture cases treated using the expanded paratricipital approach at a single trauma center from 2013 to 2017 were enrolled in this study. We evaluated the overall clinical outcome and analyzed the effect of lack of visualization in the surgical field with the expanded paratricipital approach by comparing outcomes between 2 groups classified by the location of the main articular fracture (group 1, limited visualization; group 2, without limited visualization). The length of inaccessible and accessible articular segments were analyzed using 40 matched-pair elbows.
Results: The average duration of follow-up was 15.1 months. All fractures (type C1 in 11 cases, type C2 in 21, and type C3 in 9) were radiologically healed at 3.2 months after surgery. No cases required additional surgery because of implant irritation. The average Mayo Elbow Performance Score was 90.5. The mean Disabilities of the Arm, Shoulder and Hand score was 18.5. Among the 41 cases, the

Approval for this study was received from Korea University Guro Hospital Institutional Review Board.

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limited visualization group (group 1, n = 21) had a longer surgical time and higher percentage of nonanatomic reduction than group 2. Although the expanded paratricipital approach allowed more articular exposure than the conventional approach, there was still a 20mm inaccessible articular segment (30% of transepicondylar width) in cadaveric dissection.
Conclusions: The expanded paratricipital approach can be used in type C1, type C2, and selective type C3 articular fractures of the distal humerus with favorable results. Relative to surgical times and achieving anatomic reduction, it is more successful in a fracture with a main articular fragment and with good visualization.
Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Distal humerus; complex articular fracture; surgical approach; expanded paratricipital; fracture fixation; outcome

Anatomic reduction of articular fracture components, restoration of bone alignment between the shaft and metaphysis, and stable fixation that allows early ranges of motion are necessary to achieve better functional outcomes in patients with intra-articular distal humeral fractures.[11,13,22,24,26,28] Achieving these goals requires good visualization of the articular surfaces in advance.[27] The trans-olecranon approach can provide wide exposure of the articular surfaces and remains the standard approach for the treatment of intra-articular distal humeral fractures.[9,15,16,21,25] However, complications associated with osteotomy, such as nonunion, delayed union, fixative failure, and symptomatic implants, have been reported.[12,18,21,25] Thus, additional olecranon repair surgery has to be performed with careful consideration even after achieving the main fracture repair.

To eliminate complications related to osteotomy, various approaches have been introduced. These include the triceps-reflecting anconeus pedicle (TRAP), anconeus flap, triceps-reflecting, and triceps-splitting approach, as well as the combination of triceps-splitting and -reflecting approaches.[3,4,6-8,18-20,31,32] All of these approaches involve a detaching or splitting extensor mechanism; thus, they may still damage the extensor mechanism.[17] The triceps-preserving approach, which is also called the ‘‘paratricipital approach,’’ was introduced by Alonso-Llames.[2] The triceps tendon insertion is not disrupted by this approach, thereby allowing early active range of motion.[14] However, the limited visualization of the articular surface of the distal humerus renders this approach inadequate for the fixation of type C fractures. Schildhauer et al[23] introduced the ‘‘extensor mechanism-sparing paratricipital approach,’’ which is a further expansion of the paratricipital approach with the Kocher interval. Although successful outcomes were reported even in type C1 and C2 fractures without olecranon osteotomy,[1,10] the limited visualization of the articular surface owing to its primary nature of preserving the triceps muscle and olecranon process still causes the surgeon to hesitate in the application of this approach in complex articular fractures. This may be because of the lack of a cadaveric study that proves the expansion of the articular access in this expanded approach. Moreover, there is still limited research about how this limited visualization of the articular surface of the distal humerus impacts the clinical outcomes according to the location of the fracture.

Thus, we conducted a 2-phase study: In the first phase, we performed a retrospective analysis of a clinical case series treated by the expanded paratricipital approach to investigate the overall clinical outcome and understand the effect of lack of visualization in the surgical field. In the second, we performed a cadaveric study to investigate the expansion or limitation of articular access in the expanded paratricipital approach.

Materials and methods

Clinical case series

We searched our trauma database for all acute distal humeral fractures surgically treated between January 2013 and December 2017 (N = 121). AO/Orthopaedic Trauma Association (OTA) type C fractures were identified in 57 patients (47%). The exclusion criteria were as follows: (1) no history of treatment with the expanded paratricipital approach, (2) skeletal immaturity or age <18 years, and (3) <12 months of follow-up.

The selection of approach was based on the presence and location of comminution in the trochlear region. When comminution was present in the center of the trochlear region, trans-olecranon osteotomy was primarily selected. Except for this indication, simple or comminuted articular fractures not confined within the trochlear region were treated using the expanded paratricipital approach.

Patient data, including demographic characteristics, medical comorbidity, mode of injury, and associated injury, were collected from medical chart review. The type and location of the articular fracture, presence of free articular fragments, and marginal impaction were assessed by preoperative 3-dimensional computed tomography (CT) scans. To determine the specific distribution of the articular fracture, the location of the main articular fracture line (or lines) was classified according to the zone (or zones), which was divided by anatomic landmarks on the posterior aspect of the articular surface from the medial margin of the trochlea to the lateral margin of the capitellum. To evaluate whether lack of visualization in the surgical field may affect the clinical outcome, cases in which any main articular fracture line was located in zone 1 or 2 comprised the ‘‘limited visualization group’’ (group 1)

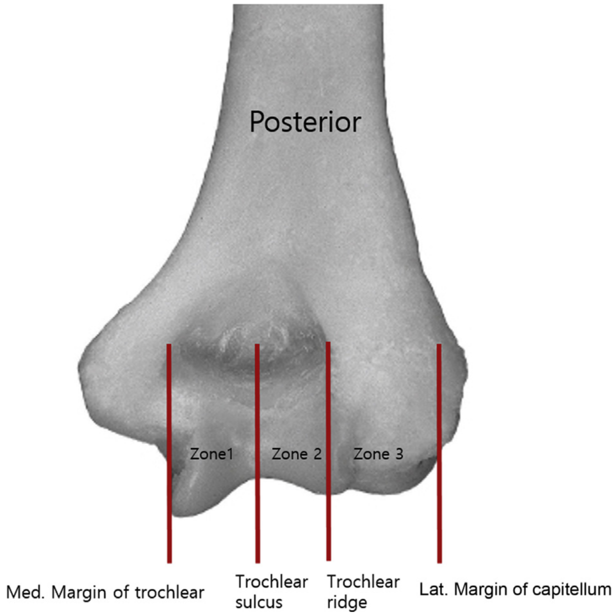

Figure 1 The location of the main articular fracture line (or lines) was classified according to the zone (or zones), which was divided by anatomic landmarks on the posterior aspect of the articular surface from the medial *(Med)* margin of the trochlea to the lateral *(Lat)* margin of the capitellum.

because the olecranon process is located along the trochlear groove. In contrast, cases in which the articular fracture was in zone 3 were classified as group 2 (Fig. 1).

Surgical details, such as surgical time, fixation construct, quality of reduction, and any complications, including the presence of screw penetration to the joint, were evaluated by postoperative radiographs and CT scans. The quality of reduction was measured on CT scans and was classified as anatomic or nonanatomic. When there was a step-off or articular gap >1 mm, the reduction was classified as nonanatomic.

All patients were followed up postoperatively at regular intervals (2 weeks and 1, 2, 3, 6, and 12 months) for a minimum of 12 months. Patients were instructed to follow the established rehabilitation program at each visit. Fracture union, defined as loss of the fracture lines in the articular or metaphyseal area, was evaluated by plain radiographs. Any complications, including postoperative infection, nonunion, loss of reduction, fixative failure, heterotopic ossification, ligamentous instability, or early posttraumatic arthritis, were also evaluated. The functional assessment included evaluation of pain and range-of-motion recovery of the elbow. Functional outcomes were evaluated using the Mayo Elbow Performance Score (MEPS) and Disabilities of the Arm, Shoulder and Hand (DASH) score at final follow-up.

Surgical approach (expanded paratricipital approach)

The patient was placed on the surgical table in the lateral position (Fig. 2). The injured arm was placed on a U-shaped support allowing 90° of elbow flexion. An intraoperative pneumatic tourniquet was not applied to allow easier mobilization of the triceps muscle during the entire procedure. A posterior midline incision was created, curving laterally around the olecranon and extending distally approximately 5-7 cm from the olecranon tip. The fascia overlying the triceps muscle was divided and elevated, creating a full-thickness subcutaneous tissue flap. Dissection was continued between the medial and lateral borders of the triceps muscle up to the posterior aspect of the intermuscular septum. The triceps muscle was sharply divided from the intermuscular septum. The posterolateral humeral shaft was exposed by elevating the triceps muscle from the periosteum while retracting the muscle medially.

Dissection was continued distally, elevating the triceps muscle from the posterolateral aspect of the metaphysis. At the level of the lateral epicondyle, the origin of the anconeus had to be identified. At this point, the Kocher interval between the anconeus and extensor carpi ulnaris had to be developed. Along the lateral border of the anconeus, surgical dissection was performed, elevating the anconeus partially from the posterior surface of the lateral column; the dissection can be continued distally, preserving its innervation and blood supply. During deep dissection of the anconeus and capsule, arthrotomy of the elbow can be performed at the posterolateral aspect of the elbow joint. In our experience, partial incision of the lateral ligamentous complex including the lateral ulnar collateral ligament and annular ligament can yield surgical exposure to the radiocapitellar joint if surgical manipulation on the articular surface of the trochlea and capitellum is needed.

Medially, the ulnar nerve was identified along the medial border of the triceps muscle and exposed proximally in the posterior compartment. The triceps muscle and ulnar nerve were dissected from the intermuscular septum, without separating from each other. Distally, the cubital tunnel was slightly incised on the medial insertion to release the ulnar nerve and mobilize the triceps muscle and ulnar nerve from the elbow capsule. The fat pad of the olecranon fossa was elevated from the posterior surface. Subsequently, arthrotomy on the posteromedial side of the trochlear region was performed. Connection of the medial and lateral dissections was completed via mobilization and elevation of the triceps muscle and ulnar nerve from the fracture and posterior humeral periosteum. This allowed visualization of the entire posterior aspect of the distal humerus via the medial and lateral windows (Fig. 2). After completion of surgical fixation, the incised lateral ligamentous complex was repaired layer by layer.

Cadaveric study

We studied 40 elbows with no history of upper-extremity pathology or trauma from 20 fresh-frozen cadavers. A single surgeon performed separate approaches on each elbow in a single day. The conventional paratricipital approach was applied on 1 side, whereas the expanded paratricipital approach was applied on the contralateral side. After completion of the surgical approach, the boundary of the surgical field given by the approach was marked with a dent on the articular surface by a 0.5-mm osteotome. The osteotomy markings were created on the articular surface from the medial and lateral sides with a 90° flexed elbow position.

After osteotomy marking, the entire distal humerus was dissected to investigate the accessible extent or inaccessible extent of the approach. To reduce the variability of measurement, the consistent point along the transepicondylar axis from both osteotomy markings was measured by a electronic goniometer. The average value from 2 repeated measurements was used. By dividing the length of inaccessible articular segment by the

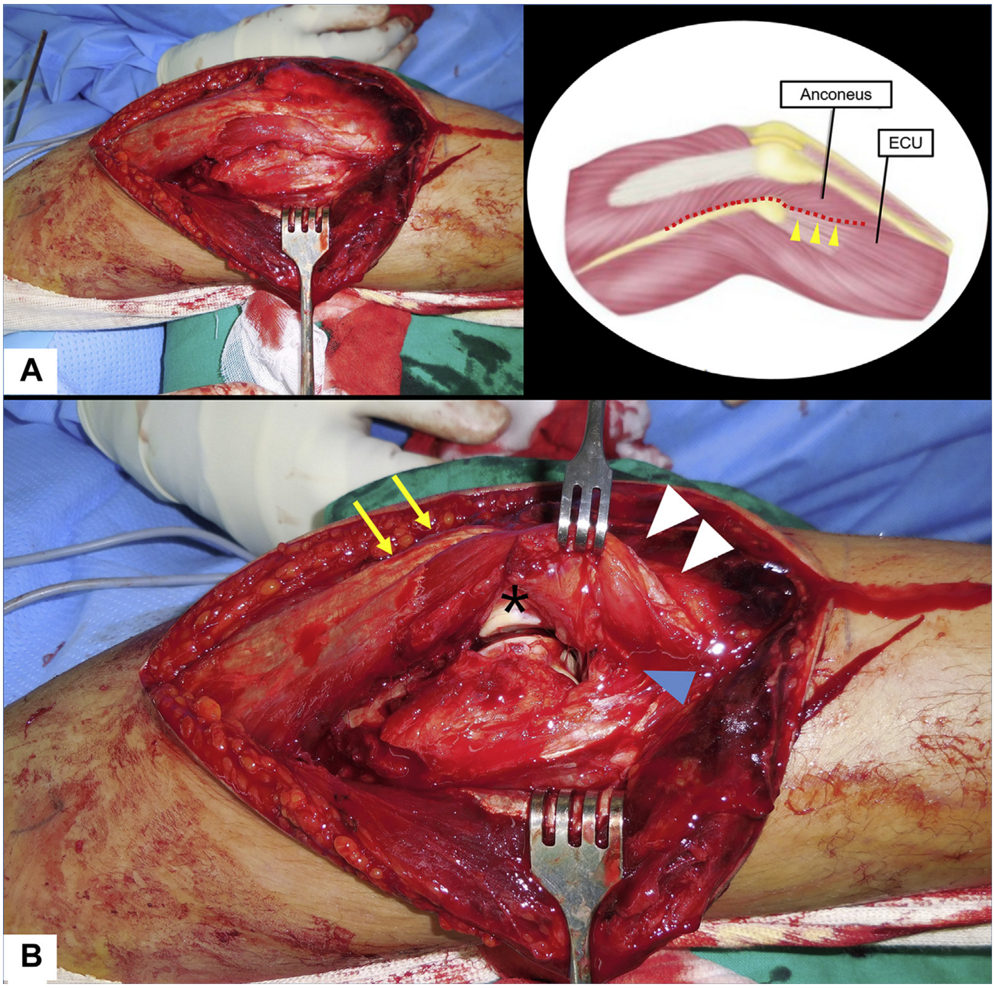

Figure 2 Lateral aspect of expanded paratricipital approach. (**A**) After the conventional paratricipital approach, the Kocher interval (*yellow arrowheads*, Tricpes brahii) is developed between the anconeus and extensor carpi ulnaris *(ECU, dashed red line)*. (**B**) The anconeus (*white arrowheads*) can be elevated from the posterior surface of the capitellum. After partial incision of the lateral ligamentous complex (*blue arrowhead*, Boundary of osteotomy marking), the olecranon process *(*)* and humeral articulation can be identified.

transepicondylar width, the proportion of the inaccessible articular segment was calculated and compared (Fig. 3).

Statistical analysis

Statistical analysis was performed using SPSS software (version 21.0; IBM, Armonk, NY, USA). Continuous variables were presented as mean ± standard deviation and categorical variables, as number (percentage). Comparisons between 2 groups of continuous variables were conducted using the Student t test. Comparisons of categorical variables were conducted using the χ^2 test. The level of significance was set at $P < .05$.

Results

Clinical case series

The final cohort consisted of 41 patients (16 men and 25 women). The mean patient age was 54 years (range, 23-90 years). The mean body mass index was 22.9 kg/m^2 (range, 18.0-28.8 kg/m^2). High-energy injuries were sustained by 27 patients (motorbike traffic accident in 8 patients, car traffic accident in 10, and falls in 9). Closed fractures occurred in 33 patients, whereas 8 patients had open fractures (classified as grade I in 3, grade II in 2, and grade IIIa in 3). Among the 41 cases, 11 had type C1 fractures, 21 had type C2, and 9 had type C3 (Table I).

All patients underwent the surgical procedure via the expanded paratricipital approach in the lateral position. No case required conversion to another extensile approach, including olecranon osteotomy, intraoperatively. The mean surgical time was 151 minutes (range, 80-245 minutes). By use of the 2.7-mm elbow VA-LCP : Variable angle locking compression plate or 3.5-mm distal elbow LCP: locking compression plate (Synthes, West Chester, PA, USA), parallel plating was applied in 18 cases and orthogonal plating, in 23. Anatomic reduction was achieved in 33 cases (80%). Fracture union was achieved in all cases an average of 3.2 months after surgery (Fig. 4).

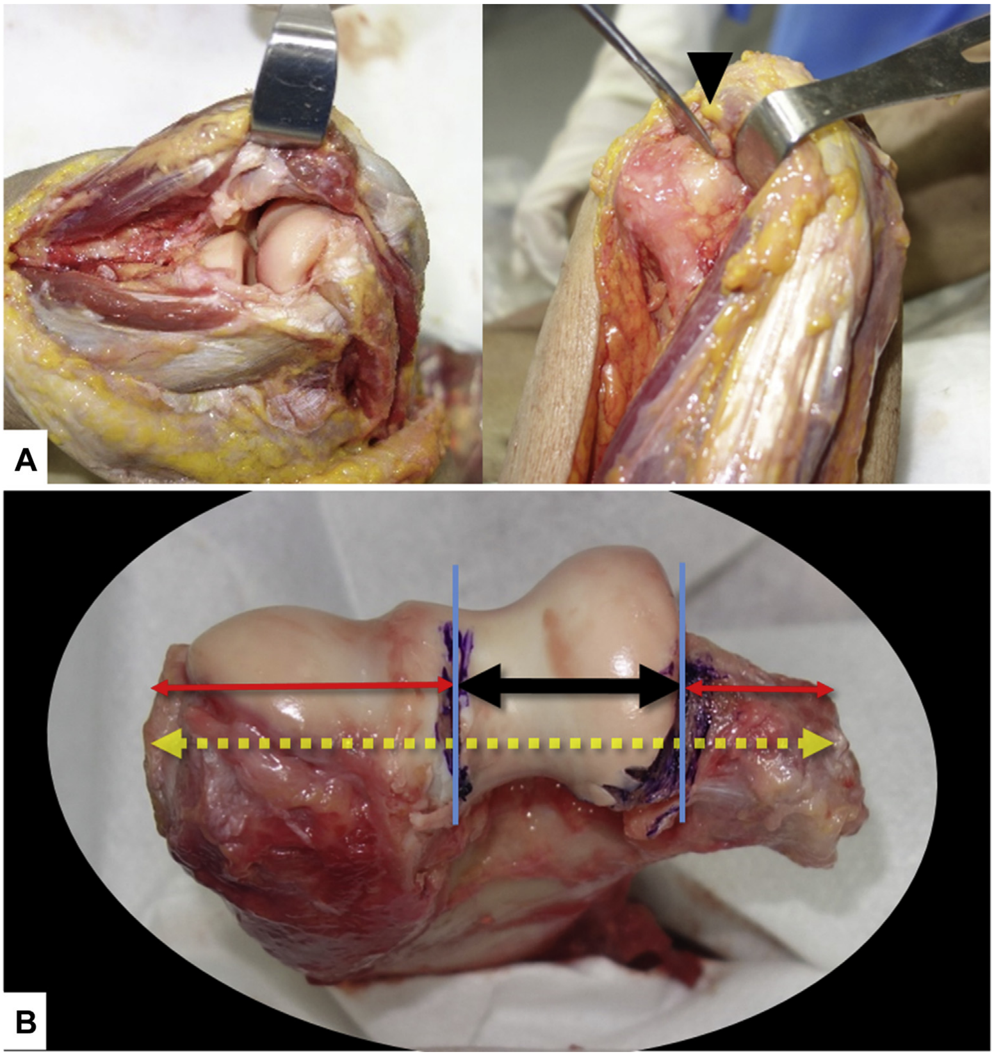

Figure 3 Cadaveric dissection. (**A**) After completion of the surgical approach, osteotomy markings (◀) are created on the articular surface from the medial and lateral sides. (**B**) The transepicondylar width (*yellow dashed arrow*), length of inaccessible articular segment (⟷), and length of accessible articular segment (⟷) are measured.

There were 2 cases of postoperative infection, 1 case of superficial wound necrosis, and 1 case of ulnar nerve neuropathy. Both cases of postoperative infection were successfully treated with implant-retained infection control surgery, without further recurrence. The case of superficial wound necrosis was managed via débridement and Vacuum assisted closure (KCI, San Antonio, Texas, USA) delayed skin grafting. In the patient with ulnar nerve neuropathy, full recovery occurred 16 months after surgery. No cases required additional surgery because of implant irritation.

The average MEPS was 90.5 (range, 85-100). The median arc of elbow motion was 127.5° (range, 110°-140°). The mean DASH score was 18.5 (range, 0-45). Of the patients, 33 (80%) were able to perform their preoperative activities and work duties fully (Table II).

Among the 32 main articular fracture lines of 32 type C1 or C2 fractures, 17 were located in the trochlear area (zones 1 and 2). Furthermore, 15 fracture lines were located lateral to the trochlear ridge in zone 3. Among the 9 type C3 fractures, 6 cases had 2 fracture lines in zone 1, 2, or 3 whereas 3 cases had 1 main articular fracture line in zone 2 or 3 with coronal split fragments.

To evaluate whether lack of visualization in the surgical field may affect the clinical outcome, group 1, defined as the limited visualization group (with any main fracture line located in zone 1 or 2), was compared with group 2. The union rate, union time, median arc of elbow motion, and functional scores including the MEPS and DASH score were not significantly different between the 2 groups. However, the mean surgical time (134 minutes vs. 166 minutes) and the percentage of nonanatomic reduction (5% vs. 33%) were statistically different between the 2 groups (Table II).

Table I Patient characteristics overall and by group

Demographic characteristic	Total	Group 1	Group 2	*P* value
Patients, n	41	21	20	
Average age (range), yr	54.0 (23-90)	51.3 (23-90)	57.8 (30-90)	.661
Sex: M/F	16/25	7/14	9/11	.663
BMI (range), kg/m^2	22.9 (18.0-28.8)	22.6	23.4	.601
ASA class: I/II/III/IV	31/7/3/0	16/3/2/0	15/4/1/0	.766
Mechanism of injury: high energy/low energy	27/14	11/10	16/4	.070
Associated injury, n (%)	5 (12)	4	1	.578
Fracture AO classification: C1/C2/C3	11/21/9	5/11/5	6/10/4	.626
Open fracture, n (%)	8 (20)	6	2	.406
Time to definite fixation (range), d	3.2 (0-10)	3.4	3.0	.846
Follow-up duration (range), mo	15.1 (12-36)	16.2	14.3	

M, male; *F*, female; *BMI*, body mass index; *ASA*, American Society of Anesthesiologists.
The final cohort (41 patients) was divided into 2 groups according to the presence of limited visualization based on the location of the main articular fracture: In group 1 (group with limited visualization), the main fracture line was located in zone 1 or 2. In group 2 (group without limited visualization), the main fracture line was located in zone 3.

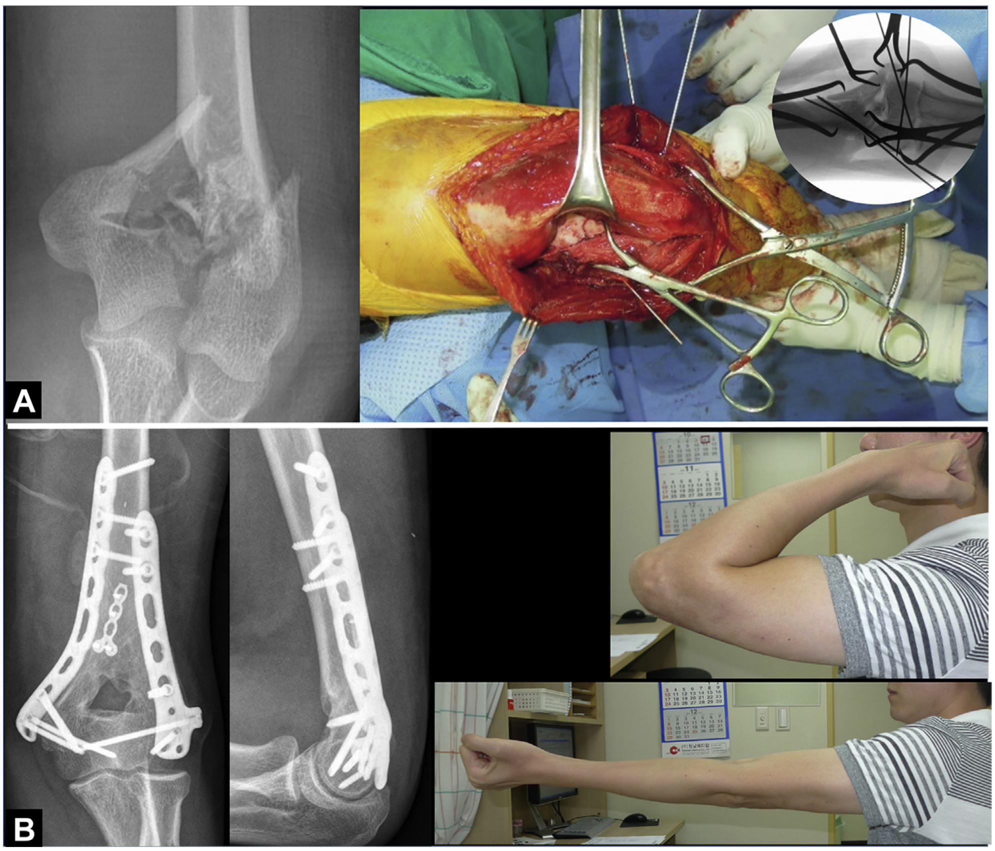

Figure 4 A 27-year-old male patient sustained an AO/Orthopaedic Trauma Association type 13C2 fracture. (**A**) A main intra-articular fracture (at zone 2) was reduced through the expanded paratricipital approach. (**B**) One-year follow-up radiographs demonstrate anatomic reduction of the articular surface without complications.

Cadaveric study

The average transepicondylar width between the conventional and expanded paratricipital approach groups was not significantly different (65.3 mm vs. 65.2 mm). The length of accessible articluar segment measured in the conventional paratricipital approach group was 34.4 mm, which was proportional to 52.7% of the transepicondylar width.

Table II Overall results and group comparison

	Total	Group 1 (n = 21)	Group 2 (n = 20)	*P* value
Characteristics of fracture lines				
1 main articular fracture	32	17	15	
2 main articular fracture	6	3	3	
1 main articular fracture with coronal split fragment	3	1	2	
Fixation construct, n				.807
Orthogonal dual plating	23	13	10	
Parallel dual plating	18	8	10	
Surgical time, min	151.5 ± 17.5	165.7 ± 20.2	133.6 ± 14.1	.035
Quality of reduction, n (%)				.042
Anatomic	33	14	19	
Nonanatomic*	8	7 (33.3)	1 (5.0)	
Fracture union, %	100			
Complications	4	2 cases of postoperative infection and 1 case of ulnar nerve neuropathy	1 case of superficial wound necrosis	
Arc of motion, °	127.5	125.2 (110-130)	130.0 (110-140)	.466
MEPS	90.5	88.7 ± 3.7	91.5 ± 4.2	.646
DASH score	18.5	18.9 ± 7.9	17.6 ± 3.9	.747

MEPS, Mayo Elbow Performance Score; *DASH*, Disabilities of the Arm, Shoulder and Hand.
The overall clinical results of the expanded paratricipital approach in patients with AO/OTA type 13C fractures are presented, in addition to a comparison of clinical parameters between the 2 groups.
* Nonanatomic was defined as a gap or step-off >1 mm on postoperative computed tomography.

Conversely, the length of accessible articular segment in the expanded paratricipital approach group was 45.2 mm, which was proportional to 69.5% of the transepicondylar width. An average of 10.8 mm (range, 6.6-20.2 mm) more of the articular segment was exposed in the expanded paratricipital approach group ($P < .05$). However, there was still a 20mm of inaccessible articular segment on the trochlear groove, which was proportional to 30.5% of the transepicondylar width. The differences in the length of inaccessible articular segment, length of accessible articular segment, and proportion between the 2 groups were statistically significant. The lateral osteotomy markings were located 6.9 mm medial to the capitello-trochlear sulcus in the expanded paratricipital approach group and 1.7 mm lateral to the capitello-trochlear sulcus in the conventional paratricipital approach group (Table III).

Discussion

An important finding of this study was that plate fixation through the expanded paratricipital approach treating AO/OTA type C1, type C2, or selective type C3 fractures resulted in comparable radiologic and functional outcomes. Overall complication and reoperation rates were acceptable. Furthermore, there was no additional surgery owing to prominent hardware of the olecranon osteotomy repair, which has been frequently reported with the trans-olecranon approach.[9,22,32] In addition, our clinical results are favorable to those of previously published studies regarding the expanded paratricipital approach. Erpelding et al[10] reported on 37 patients with distal humeral fractures managed with an "extensor mechanism-on approach." They reported a fracture union rate of 100%, median arc of motion of 126°, mean DASH score of 15.9, and mean MEPS of 91.5. However, only 17 cases of type C fractures were included in their study; therefore, this result was not warranted in cases of complex articular fracture. On the other hand, Singh et al[29] reported a union rate of 100%, median arc of motion of 111°, and mean MEPS of 82 in 27 complex articular distal humeral fractures (type C1 in 13, type C2 in 6, and type C3 in 6) through the expanded paratricipital approach. There were 2 cases of postoperative infection, 1 case of transient ulnar nerve palsy, and 1 case of heterotopic ossification.

Optimal selection of the surgical approach not only determines the adequate exposure of the fracture site but also influences the procedures of fracture reduction and fixation. The trans-olecranon approach or triceps-reflecting anconeus pedicle (TRAP) approach can provide excellent exposure of the articular surfaces; this was verified in a previous anatomic study.[30] Conversely, no study has verified how much the expanded paratricipital approach can expand the surgical field and assessed its limitations according to fracture morphology. Although recent studies have concluded that the type of surgical approach did not affect the final functional results, these results were simply based on the AO/OTA classification of the articular fracture

Table III Results of cadaveric study (20 paired elbows)

	Expanded paratricipital approach	Conventional paratricipital approach	*P* value
Average transepicondylar width, mm	65.2 ± 4.7	65.3 ± 4.4	.956
Average length of inaccessible articular segment, mm	19.9 ± 2.8	30.9 ± 3.6	.02*
Average length of accessible articular segment, mm	45.2 ± 3.3	34.4 ± 3.8	.02*
Mean proportion, %	69.5 ± 0.03	52.7 ± 0.04	.01*
Mean distance of medial osteotomy marking from medial epicondyle, mm	19.2 ± 1.4	18.2 ± 1.8	.879
Mean distance of lateral osteotomy marking from capitello-trochlear sulcus, mm	6.9 ± 1.2	−1.7 ± 2.1†	.026*

Data are reported as mean ± standard deviation.
* length of inaccessible and accessible articular segment, proportion, and location of lateral osteotomy marking were statistically different between the expanded and conventional paratricipital approaches.
† A negative value indicates a measurement lateral to the capitello-trochlear sulcus.

and failed to determine the clear indication of each approach according to the specific distribution of the fracture lines on the articular surface.[5,7] To overcome this limitation of current studies, we focused on the limited visualization of the expanded paratricipital approach and fracture anatomy in a 2-phase study. Our cadaveric study revealed that 10.8 mm more of the articular surface (17% of the articular length) could be exposed by this approach than by the conventional approach. These findings suggest that by expanding the approach with the Kocher interval in the elbow joint, there is more exposure of the intra-articular surfaces. However, our study also revealed that there remains 20-mm inaccessible articular segment (30% of transepicondylar width) that is located beyond the olecranon articulation hindered by the olecranon process. This lesion must be in a ''limited visualization area'' and located within zones 1 and 2 of the articular surface in our working definition of the clinical study.

It is interesting to note that when the fracture line was located in this limited visualization zone in our case series, there was a higher risk of a nonanatomic reduction and a longer surgical time compared with when the fracture line was directly visible in zone 3. Both cadaveric and clinical findings can serve as a guideline that can help to select the optimal surgical approach for simple articular fractures, as well as complex articular fractures, according to the location of the fracture lines. If the main articular fractures or comminuted fragments are confined within areas in zone 3, surgical access can allow direct visualization of the fracture site with the expanded paratricipital approach. Conversely, if comminuted fragments are located in zone 1 or 2, the fracture site can be manipulated in an indirect manner. Careful assessment of reduction is mandatory to avoid nonanatomic reduction. Unless the surgeon can achieve acceptable reduction in this manner, conversion to olecranon osteotomy must be considered intraoperatively.

Limited visualization failed to be correlated with poor clinical outcomes, including the union rate and arc of motion, and functional scores between the 2 groups. This result could be attributed that the case which has been classified as a nonanatomic reduction did not have serious articular malreduction which might be directly associated with arthritis and nonunion in our cohort (Fig. 5). In our experience, indirect reduction of an articular fracture under limited visualization could be facilitated by several technical tips, including achieving anatomic reduction directly on the simpler metaphyseal fracture in advance, before reducing the complex articular fracture (type C–to–type B strategy); free articular fragment reduction through fracture windows; and ''peeking inside'' the ulnohumeral joint via arthrotomy with a slightly subluxated elbow in further flexion. However, these indirect reduction procedures require more surgical time and a certain level of surgical experience to achieve successful results.

This study has several limitations. A cadaveric study is limited in providing information on accessible surface areas. In our cadaveric study, we measured the length of accessible articular segment; however, we could not obtain any information on the accessible articular surface area. This limits its application when there are anterior coronal-plane fracture patterns. Although this limits the understanding of the overall possible accessibility of this approach, the results of our 2-dimensional measurement can be simply applied to clinical cases using plain radiography. Another limitation is the possibility of selection bias in the clinical study. Although our cohort included 9 cases of type C3 articular fractures, cases that had confined comminution in the trochlear region were treated with the trans-olecranon approach and excluded primarily. As a result, the fracture configuration of type C3 articular fractures in our cohort was a configuration with a double articular fracture line with comminution in zone 3 or a configuration with a single articular fracture with 1 large coronal split articular fragment that C3 could be converted to a type C1 or C2 fracture with some manipulation of the articular fracture or fragment. Thus, our results have to be

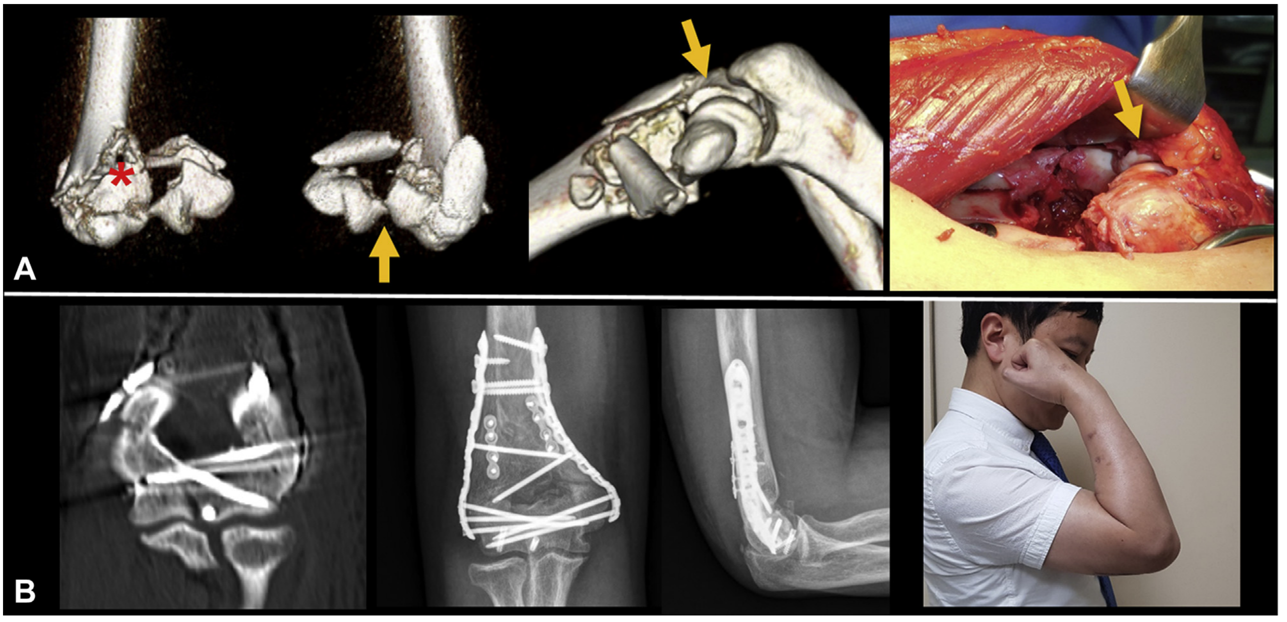

Figure 5 A 48-year-old male patient sustained an AO/OTA type C3 articular fracture of the distal humerus. (**A**) Three-dimensional computed tomography demonstrated that the articular fragment had a free coronal capitello-trochlear fragment (*) and the main articular fracture line was located in zone 2. Its visualization was hindered by the olecranon process (*arrows*). (**B**) After osteosynthesis through the expanded paratricipital approach, postoperative computed tomography showed a 1.7-mm articular gap, which was classified as a nonanatomic reduction. However, 1.5-year follow-up radiographs demonstrate complete fracture healing without any complications. Full recovery of final range of motion was observed.

interpreted carefully regarding AO/OTA type C1, type 2, and selective type C3 fractures, as we already described. Finally, the total number of clinical case series is relatively small to investigate the true impact of variables on final outcomes. A future well-structured randomized controlled study is needed.

Although the expanded paratricipital approach has been introduced, there has been no study on how much articular access is gained or limited. In this 2-phase study, we determined the accessibility of the articular surface in the expanded paratricipital approach and its clinical impact according to fracture morphology and location. The expanded paratricipital approach provides wider exposure of the articular surfaces of the distal humerus compared with the conventional approach. However, there is still a limitation of articular assessment of up to 30%.

Conclusion

The expanded paratricipital approach can be used in type C1, type C2, and selective type C3 articular fractures of the distal humerus with favorable results. Relative to surgical times and achieving anatomic reduction, it is more successful in a fracture with a main articular fragment and with good visualization.

Disclaimer

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