

Clinical Results of Supracondylar Dome Osteotomy for Cubitus Varus and Valgus Deformities in Adults

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Background: Cubitus varus and cubitus valgus deformities are common complications of distal humeral fractures in children. We evaluated the usefulness of supracondylar dome osteotomy as a treatment option for adults with cubitus varus or valgus deformity developed during childhood.

Methods: Ten patients who had received supracondylar dome osteotomy and stabilization with plates to treat cubitus varus or valgus deformity between July 2006 and August 2013 were included in this study. Their mean age at the time of surgery was 36.50 ± 10.22 years. The mean follow-up duration was 54.80 ± 32.50 months. We evaluated humerus-elbow-wrist angles (HEWA), improvements in the lateral prominence index (LPI) or medial prominence index (MPI), Mayo elbow performance scores (MEPS), and overall results in accordance with the Banerjee criteria.

Results: For the six patients with cubitus varus, the mean postoperative HEWA, mean correction angle, and mean improvement in LPI were $9.72^\circ \pm 3.95^\circ$, $27.67^\circ \pm 10.75^\circ$, and $6.92\% \pm 3.40\%$, respectively. For the four patients with cubitus valgus, the mean postoperative HEWA, mean correction angle, and mean improvement in MPI were $14.73^\circ \pm 2.97^\circ$, $11.55^\circ \pm 3.26^\circ$, and $11.33\% \pm 6.39\%$, respectively. There was no significant difference between postoperative and preoperative mean MEPS. The subjective ulnar nerve symptoms were alleviated in all patients. The overall results were excellent in six and good in four patients.

Conclusions: This study suggests that supracondylar dome osteotomy with secure fixation using double plates may be useful in correcting cubitus varus or cubitus valgus deformity, yielding good functional outcomes in adults.

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Key Words: Cubitus varus; Cubitus valgus; Supracondylar dome osteotomy; Distal humerus fracture; Adult

Introduction

Cubitus varus and cubitus valgus deformities are well-known late complications following distal humerus fractures during childhood. These deformities result from malunion of supracondylar fractures or nonunion of lateral condylar fractures in the distal humerus.¹⁻³⁾ The tardy ulnar nerve palsy induced by these deformities frequently requires operative management.^{2,4)} Posterior shoulder instability has been reported to be associated with cubitus varus deformity without functional limitation.⁵⁾ However,

the most common complaint is poorly tolerated cosmetic deformity without any functional impairment.⁶⁾

Several osteotomy methods have been proposed to improve the appearance or symptoms associated with these angular deformities, including open⁷⁾ or closed⁸⁾ wedge osteotomy, pentalateral osteotomy,⁹⁾ three dimension osteotomy,¹⁰⁾ oblique osteotomy,¹¹⁾ Pesamosca osteotomy,¹²⁾ step-cut osteotomy,¹³⁾ and supracondylar dome osteotomy.¹⁴⁾ However, to date, there has not been a general consensus on which technique is superior with respect to suitably correcting coronal or rotational defor-

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mities and preventing postoperative complications, including elbow stiffness or recurrence of the deformity.¹⁵ Supracondylar dome osteotomy was introduced to redeem the drawbacks of other kinds of osteotomy techniques that stem from the hinge of coronal rotation, difficulty in correcting the deformity, or prolonged immobilization.^{6,13} Dome osteotomy requires less rotation of the arc to correct the deformity since the center of rotation is in the midline of the humerus. Moreover, coronal and horizontal plane deformities can be corrected simultaneously after osteotomy with a single round of cutting, and it is easy to manage the correction angle using an image intensifier before firm fixation.¹⁶ Based on these features, several reports have previously been presented on dome-shaped osteotomies, which have all adopted some modifications on the original technique. However, most studies, except two, have reported results from children.^{8,14,16-19}

Given that some patients express concerns regarding their deformity in adulthood, we need surgical considerations. When surgery is performed on adults, delayed healing capacity at the osteotomy site and the possibility of postoperative elbow stiffness should be recognized. Supracondylar dome osteotomy has some merits in treating these problematic issues in adults. It has a center of rotation in the midline of the humerus, which enhances bone union by inducing a broad bony contact surface between the two fragments. However, there is limited information on whether this osteotomy method is useful for correcting cubitus varus or cubitus valgus deformity in adults. Therefore, the aim of this study was to evaluate the usefulness of supracondylar dome osteotomy as a treatment option for adults with cubitus varus or cubitus valgus deformity that developed during childhood.

Methods

Ten adults with angular deformities were treated at our institution with supracondylar dome osteotomy between July 2006 and August 2013. We retrospectively reviewed these 10 patients after institutional review board approval (GNUH 2015-06-022). The mean age at the time of injury was 8.20 ± 2.66 years, and the mean age at the time of surgery was 36.50 ± 10.22 years. Three males and three females comprised the cubitus varus group, with a mean age of 35.67 ± 12.19 years and a mean varus angle of $17.95^\circ \pm 10.79^\circ$, and all deformities resulted from malunion of supracondylar fractures of the humerus. Two males and two females comprised the cubitus valgus group, with a mean age of 35.75 ± 10.69 years and a mean valgus angle of $26.28^\circ \pm 1.20^\circ$, and three of the four patients had accompanying lateral condyle nonunion of the distal humerus. Seven patients (four cubitus valgus and three cubitus varus) had tardy ulnar nerve palsy preoperatively. Six of the seven patients underwent electrophysiological examination. Among them, four pa-

tients were confirmed as having ulnar neuropathy. Two elbows were on the right, and eight were on the left. The dominant elbow was involved in four of the ten cases.

The pre- and postoperative anteroposterior radiographs of both elbows were obtained, with the elbows fully extended and the forearms supinated to obtain the humerus-elbow-wrist angle (HEWA).³ The HEWA was measured using the angle of intersection between the humeral shaft line and the forearm line. The humeral shaft line connects the midpoints of the two transverse humeral lines, which connect the medial and lateral cortices of the humerus at the diaphysis and distal metaphysis levels. The forearm line connects the midpoints of the two transverse forearm lines, connecting the medial cortex of the ulna and the lateral cortex of the radius at the radial tuberosity and distal radius-ulnar diaphysis levels (Fig. 1A). The necessary corrective angle was estimated using the difference between the carrying angles of the normal and deformed elbows. The lateral prominence index (LPI) was measured on pre- and postoperative anteroposterior radiographs.²⁰ LPI was defined as the difference between the medial and lateral widths of the distal part of the humerus, from the longitudinal mid-humeral axis, and it was expressed as a percentage of the total width of the distal part of the humerus (Fig. 1B). The medial prominence index (MPI) was measured for cubitus valgus. MPI was calculated as the same as LPI. The existence of osteotomy site extension or flexion was confirmed



Fig. 1. (A) Measurement of the humerus-elbow-wrist angle, using the angle of intersection of the humeral shaft line and the forearm line. (B) Lateral prominence index (%), calculated as $(BC-AB)/AC \times 100$.

A: medial side of cortex, B: intersection point of longitudinal mid-humeral axis and intercondylar line, C: lateral side of cortex.

by measuring the distal humerus angulation index (DHAI), which was modified from Gartland classification.²¹⁾ The DHAI was defined as the distance from the anterior cortical line of the distal humerus to anterior the cortex of capitulum, and it was expressed as a percentage of the total width of capitulum using the radiographs of the lateral elbow (Fig. 2). Surgery was performed by one experienced senior author (HBP). Radiographic factors were measured by one orthopaedic fellow (JYG) and the mean



Fig. 2. Measurement of distal humerus angulation index (DHAI) is used to confirm the existence of osteotomy site extension or flexion. DHAI is defined as the distance from the anterior cortical line of the distal humerus (B) to the anterior cortex of capitulum (C), and is expressed as percentage of total width of capitulum from posterior cortex (A) to C ($BC/AC \times 100$).

value of three measurements were used in the current study.

Surgical Procedure

Patients were placed in a lateral decubitus position under general anesthesia. The triceps muscle was split in the midline to expose the distal humerus. After incising the periosteum, along the midline using a scalpel, a subperiosteal dissection was made. The intersection of the midline axis and the proximal margin of the olecranon fossa (point A) was designated as the center of the dome curvature. The AB line was added from point A to the nearest cortical surface of the distal humerus (point B). This radius of the semicircle (AB line), which was 2- to 3-cm long, was used to guide the correction (Fig. 3). Upon completion of osteotomy with a 1.6 mm drill bit and a one-eighth inch osteotome, the distal fragment was rotated radially to achieve the desired correction angle. These two realigned fragments were held by two plates and screws. In three cases of nonunion of the lateral condyle, we performed curettage between fragments and in situ screw fixation without broad soft tissue dissection (Fig. 4). The ulnar nerve was transpositioned anteriorly in whole cases. The elbow was kept at 90° flexion and immobilized with a long arm splint for at least 2 weeks followed by gentle range of motion (ROM) exercises.

Follow-up

All patients re-visited the hospital for clinical and radiographic evaluations. The mean follow-up duration was 54.80 ± 32.50 months. Physical examination was conducted for the ROM, postoperative scarring, and the presence of neurological symptoms. Subjective opinions regarding the gross appearance of the surgically treated elbow was recorded. The Mayo elbow performance scores (MEPS) were evaluated twice, once preoperatively

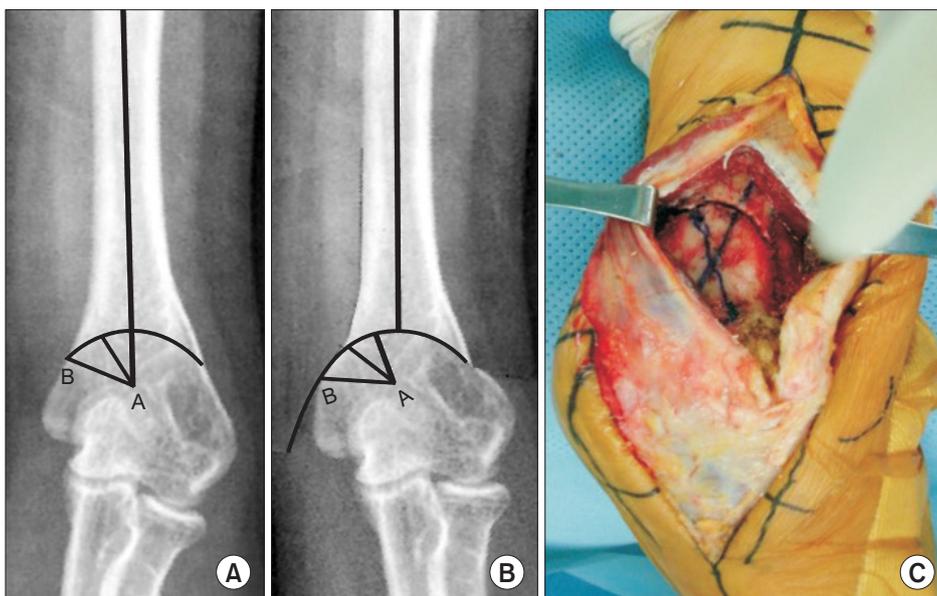


Fig. 3. Dome osteotomy was performed along the semicircle using the radius of AB line. (A) Point A is the center of the dome curvature. The intersection of the midline axis and the proximal margin of the olecranon fossa. (B) Distal fragment was rotated radially as previously measured correction angle. (C) Intraoperative gross picture showed dome shaped osteotomy of distal humerus.



Fig. 4. (A, B) A 42-year-old male with cubitus valgus deformity and nonunion of lateral condyle on his right elbow. (C, D) At postoperative 2 year, bone union of lateral condyle was confirmed following in situ screw fixation with minimal soft tissue dissection.

Table 1. Banerjee Criteria for Assessment of Outcomes Cited from the Article of Banerjee et al. (J Pediatr Orthop. 2012;32:385-93)¹⁹⁾

	Excellent	Good	Poor
Gap discrepancy in HEWA from the normal side (°)	≤5	6-10	>10
Decrease in range of motion from preoperative range (°)	≤10	>10, ≤20	>20
Increase in lateral or medial condylar prominence index (%)	No	≤2.5	>2.5

HEWA: humerus-elbow-wrist angle.

and another postoperatively. Anteroposterior and lateral radiographs of the elbow were obtained, and an overall clinical evaluation was carried out following the Banerjee criteria,¹⁹⁾ which graded the outcomes as being either excellent, good, or poor (Table 1). The overall pre- and postoperative clinical and radiographic data with normal distribution were statistically compared using a paired t-test, and those without normal distribution were compared statistically using a Wilcoxon signed-rank test. *p*-value was set at 0.05.

Results

Six patients with cubitus varus showed a mean postoperative

HEWA of $9.72^\circ \pm 3.95^\circ$, with a mean correction angle of $27.67^\circ \pm 10.75^\circ$ ($p=0.001$). The mean improvement of LPI was $6.92\% \pm 3.40\%$ ($p=0.004$). Four patients with cubitus valgus showed a mean postoperative carrying angle of $14.73^\circ \pm 2.97^\circ$, with a mean correction angle of $11.55^\circ \pm 3.26^\circ$ ($p=0.006$). The mean improvement of MPI was $11.33\% \pm 6.39\%$ ($p=0.038$).

The mean ROM for all patients was $133.00^\circ \pm 15.49^\circ$ preoperatively and $129.50^\circ \pm 15.71^\circ$ postoperatively ($p=0.173$). The mean ROM for the six cubitus varus patients was $131.67^\circ \pm 18.35^\circ$ preoperatively and $131.67^\circ \pm 16.33^\circ$ postoperatively ($p=1.000$). The mean ROM for the four cubitus valgus patients was $135.00^\circ \pm 12.25^\circ$ preoperatively and $126.25^\circ \pm 16.52^\circ$ postoperatively ($p=0.102$).

According to DHAI, five patients showed osteotomy site flexion and another five patients showed osteotomy site extension. Among the osteotomy site flexion patients, ROM decreased from $135.00^\circ \pm 7.68^\circ$ to $128.00^\circ \pm 4.18^\circ$ with decrements of $7.00^\circ \pm 9.08^\circ$ ($p=0.160$). Among those who showed osteotomy site extension, the mean change of ROM ranged from $131.00^\circ \pm 1.70^\circ$ to $131.00^\circ \pm 3.76^\circ$. There was no significant difference between the two time points ($p=1.000$). The overall results of pre- and postoperative evaluations are described in Table 2. Three patients, who were established as having lateral condylar nonunion in the humerus, underwent osteosynthesis during surgery.

Cosmetic unsightliness was the major concern for surgery in all patients, and ulnar nerve neuropathy was an additional issue for seven patients. There were no complaints of pain, stiffness, weakness, nonunion, or functional limitation of motion during postoperative evaluation. Correction of deformity without complications was maintained well throughout the healing stage and up until the final follow-up. Union from osteotomy was confirmed by a radiographic examination in all patients. Patients were satisfied with the cosmetic outcome, and none of them complained about scarring from the operation, except one woman who underwent scar revision after plate removal.

Ulnar nerve anterior transposition was performed in all subjects. Preoperative ulnar nerve symptoms were alleviated in seven patients. Three patients with cubitus varus who did not complain about ulnar nerve symptoms preoperatively also had nerve transposition due to tethering of the nerve after correction of the deformity; however, no ulnar nerve symptoms developed postoperatively. The postoperative mean MEPS was 98.50 ± 4.74 , which was not significantly different to the preoperative MEPS, which was 94.00 ± 7.75 . Among ten patients, six had excellent results and four had good results (Fig. 5).

Discussion

The current study reports optimistic results regarding supracondylar dome osteotomy for cubitus varus and valgus deformities in adults. The postoperative clinical and radiologic results from cubitus varus patients were satisfactory. The outcome of osteotomy in patients with cubitus valgus deformity were also satisfactory, although postoperative ROM slightly decreased. This study suggests that supracondylar dome osteotomy is a reliable option for adult patients with cubitus varus or cubitus valgus deformity. Most previous studies reported that corrective dome osteotomy with secure fixation can prevent lateral condyle prominence, allowing early rehabilitation that may result in satisfactory function and cosmetics. However, one report by Kumar et al.⁸⁾ comparing between French and dome osteotomies suggested that the latter can be technically more demanding and lead to a higher incidence of complications, such as nerve palsy,

Table 2. Demographic, Radiographic, and Clinical Data of Ten Patients Who Underwent Dome Osteotomy

Case No.	Sex	Age (yr)	Diagnosis	Follow-up (mo)	Range of motion (°)		Normal elbow	HEWA (°)		LPI or MPI (%)		DHAI (%)		MEPS		Results
					Pre-/postoperation	postoperation		Pre-/postoperation	postoperation	Pre-/postoperation	postoperation	Pre-/postoperation	postoperation	Pre-/postoperation	postoperation	
1	Male	45	Cubitus valgus, left	24	120/105		13.7	27.2/13.5	30.0/17.2	36/47	Flexion	85/100	Good			
2	Male	42	Cubitus valgus, right	24	130/125		18.6	27.3/17.1	25.0/9.9	45/32	Extension	85/85	Excellent			
3	Female	35	Cubitus valgus, left	25	145/130		15.0	24.8/17.2	12.9/11.0	50/62	Flexion	85/100	Good			
4	Female	21	Cubitus valgus, right	33	145/145		12.1	25.8/11.1	15.3/-0.2	52/29	Extension	100/100	Excellent			
5	Female	40	Cubitus varus, left	51	150/150		16.2	-13.6/10.8	12.0/7.8	30/33	Flexion	100/100	Good			
6	Male	21	Cubitus varus, left	48	150/140		5.7	-5.8/7.1	-2.2/-8.3	23/27	Flexion	100/100	Excellent			
7	Female	37	Cubitus varus, left	66	110/115		15.1	-24.7/12.0	8.5/2.3	-19/-11	Flexion	100/100	Excellent			
8	Male	45	Cubitus varus, left	97	110/110		16.8	-18.6/15.5	7.2/1.7	40/20	Extension	85/100	Excellent			
9	Female	50	Cubitus varus, left	120	130/130		8.7	-35.3/4.2	-3.7/-9.5	27/23	Extension	100/100	Excellent			
10	Male	21	Cubitus varus, left	60	140/145		13.6	-9.7/8.7	5.3/-8.4	35/25	Extension	100/100	Good			

HEWA: humerus-elbow-wrist angle, LPI: lateral prominence index, MPI: medial prominence index, DHAI: distal humeral angulation index, MEPS: Mayo elbow performance scores.



Fig. 5. (A, B) A 21-year-old male with cubitus varus deformity on his left elbow (humerus-elbow-wrist angle [HEWA]: varus 6.0°). (C, D) Four years after supracondylar dome osteotomy, HEWA is corrected to valgus 7.4° without any complications.

infection, inadequate correction, and vascular compromise. This current study differs from the study by Kumar et al.⁸⁾ as we used double plating instead of K-wire fixation as the fixation method and we did not observe any of the mentioned complications through the follow-up period. The postoperative ROM could be an important factor in determining the outcome of dome osteotomy. Kumar et al.⁸⁾ mentioned that after dome osteotomy, extension of osteotomy site can lead to postoperative limitation of flexion and less tolerable results. In the current study, the mean postoperative ROM of ten patients decreased from $133.00^\circ \pm 15.49^\circ$ to $129.50^\circ \pm 15.71^\circ$. However, decreased ROM did not compromise the outcome results. Moreover, postoperative extension of the osteotomy site was confirmed in five patients and they did not have the decrease in ROM, unlike those in Kumar et al.'s result.⁸⁾ As for the decrease of postoperative ROM in the current study, osteosynthesis of lateral epicondyle could be contributing factor. Kim et al.¹³⁾ and Masada et al.²²⁾ suggested that osteosynthesis of the lateral condyle could lead to complications, including decreased elbow ROM by extensive soft tissue dissection and mobilization of the lateral condyle fragment. In this study, we performed condyle osteosynthesis to three patients who have pain in the lateral condyle. Even though

our procedures were in situ fixation after curettage of fragments surface with mini soft tissue dissection and little mobilization of the condyle fragment, postoperative ROM showed decrease of $11.67^\circ \pm 5.77^\circ$ ($p=0.073$). However, it did not affect the clinical end results. After extraction the three patients who underwent osteosynthesis of the lateral condyle among the four patients of cubitus valgus, remaining one patient showed the same postoperative result as preoperative ROM.

In the current study, we performed ulnar nerve anterior transposition in whole patients to relieve symptoms of tardy ulnar nerve palsy (seven patients) or to prevent tethering of the ulnar nerve during correction of the deformity (three patients). Tardy ulnar nerve palsy is more common in cubitus valgus than in varus, but cubitus varus can induce the palsy due to nerve instability and internal rotational component of the deformity.^{23,24)} In regards to combined operations of bony correction with an anterior transposition of the ulnar nerve for tardy ulnar nerve palsy in cubitus valgus or cubitus varus, some reports performed combined operations and reported satisfactory improvement in terms of deformity correction and neurologic symptom.^{13,25,26)} We underwent the same procedures as previous studies for tardy ulnar nerve palsy patients with cubitus valgus or varus and

got promising clinical results. Three patients who showed no symptom related to the tardy ulnar nerve palsy in cubitus varus also received the same combined operations. In these patients, the main purpose of ulnar nerve anterior transposition was to reduce the tension on the ulnar nerve, and over-tensioning of the ulnar nerve was determined intra-operatively. No patients in our study complained of any ulnar nerve symptoms postoperatively.

A proper osteotomy method with rigid fixation and early motion of the elbow should be applied to achieve satisfactory results for adults who might have a more delayed bone healing potential than children and are prone to postoperative elbow stiffness. Fixation with two conventional reconstruction plates, or a combination of one-third tubular and reconstruction plate (Synthes, West Chester, PA, USA) after the dome osteotomy, achieved stable fixation, permitting early ROM exercises for the elbow and maintaining the range of elbow motion.

The current study has some limitations. This is a retrospective study with a small number of patients. We did not evaluate internal-rotation deformity, which is frequently associated with varus or valgus deformity. However, internal-rotation deformity is well tolerated as it is compensated for by the rotation of the shoulder, and persistent internal rotational deformity has been reported to have no effect on the results.^{27,28)} None of our patients had any complaints on the restriction of activities associated with internal rotational deformity in their daily lives.

Conclusion

This study suggests that supracondylar dome osteotomy with secure fixation using double plates may be useful in correcting cubitus varus or cubitus valgus deformity, yielding good functional outcomes in adults.

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