Relationship between Medial Humeral Epicondyle Fractures and Forearm Rotation: A Cadaveric Study

Todsaporn Sirithiantong MD[1], Patarawan Woratanarat MD, PhD[1],
Chanika Angsanuntsukh MD[1], Tanyawat Saisongcroh MD[1], Umaporn Udomsubpayakul MD[2]

[1] Pediatric Unit, Department of Orthopaedics, Faculty of Medicine Ramathibodi Hospital, Bangkok, Thailand
[2] Section of Clinical Epidemiology and Biostatistics, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Bangkok, Thailand

Objective: Forearm position for immobilizing an isolated medial humeral epicondyle fracture has not yet been established. This study aimed to investigate the relationship between forearm rotation and medial humeral epicondyle displacement.

Materials and Methods: A cadaveric study was performed in which a medial epicondyle fracture was simulated by performing an osteotomy. Fracture displacement was measured using a digital Vernier caliper from full pronation to full supination in 10-degree increments. Displacement was measured at the point of maximum distance. After that, the fragment was reduced and stabilized with K-wire. Intra-observer reliability and prediction of displacement based on forearm rotation was analyzed.

Results: Five cadavers (ten medial epicondyles) were involved in the study. The mean displacement ranged from 14.39 mm at full pronation to the most reducible 1.60 mm at full supination, a mean difference of 12.79 mm (SD 2.39, 95% confidence interval: 11.31, 14.27). There was a significant correlation between forearm rotation and actual medial epicondyle displacement (Pearson r = 0.91, p<0.001). Using a displacement of less than 5 mm as the criterion for conservative treatment, the best position for fracture stabilization was ≥20 degrees supination with a sensitivity, specificity, PPV, and NPV of 93.3%, 91.3%, 87.5%, and 95.5%, respectively (area under the curve 0.92; p<0.001). No fragment was displaced during forearm rotation following fixation with two K-wires.

Conclusion: Forearm rotation significantly affects actual medial humeral epicondyle displacement. The more the forearm supinates, the less the medial epicondyle is displaced. A forearm rotation of at least 20 degrees of supination confines the fragment to <5 mm of displacement.

Keywords: Medial epicondyle fracture; Immobilization; Forearm rotation

J Med Assoc Thai 2018; 101 [Suppl. 3]: S137-S142
Website: http://www.jmatonline.com

Medial humeral epicondyle fractures accounted for approximately 12% of pediatric elbow fractures; the fractures frequently occurred in individuals between the ages of 9 and 14 years[1,2]. There has been debate over the past few decades regarding the best treatment for this condition. Absolute indications for surgical fixation were intra-articular incarceration of a fragment in the elbow joint and open fracture. Relative indications include gross elbow instability, ulnar neuropathy, and fracture displacement. However, appropriate treatment of the displaced fragment is still controversial. Recommendations for internal fixation have ranged from 2 to 15 mm of displacement[2-4]. Although clinical results have been satisfactory, elbow stiffness, ulnar nerve symptoms, and radiographic abnormalities have been reported after open reduction and internal fixation[5-7].

Several recent studies[8-11] have reported that conservative treatment provides outcomes which are good to excellent while avoiding the operative risks of surgical treatment, e.g., painful scars, surgical site infections, and anesthetic risk. Even though

Correspondence to:
Woratanarat P, Department of Orthopaedics, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Bangkok 10400, Thailand.
Phone: +66-2-2011589, **Fax:** +66-2-2011599
E-mail: pataraw@yahoo.com

How to cite this article: Sirithiantong T, Woratanarat P, Angsanuntsukh C, Saisongcroh T, Udomsubpayakul U. Relationship between Medial Humeral Epicondyle Fractures and Forearm Rotation: A cadaveric study. J Med Assoc Thai 2018;101;Suppl.3: S136-S142.

conservative treatment has been demonstrated to provide good results, sequelae such as pseudarthrosis, malunion, nonunion, and elbow instability have occurred. Moreover, there has been no generally accepted recommendation regarding the proper forearm rotation for immobilization in this type of injury.

The medial humeral epicondyle apophysis is a posteromedial structure that serves as the site of origin of the flexor-pronator mass and the ulnar collateral ligament[12,13]. Three types of mechanisms have been proposed for acute injuries of the medial humeral epicondyle in children. The most commonly described is avulsion by the flexor-pronator mass which is described as a valgus stress on the elbow resulting from falling on an outstretched hand with the elbow in extension, supination of forearm, and extension of the wrist and hand. Another proposed mechanism is a sudden increase in tension in the flexor-pronator mass placing tension on the epicondyle itself[4]. Reduction or proper immobilization with a long arm cast with the forearm in pronation and flexion has also been suggested. Some studies recommend pronation immobilization[14], while others do not[15,16]. Starting from this point of controversy, we hypothesized that medial epicondyle displacement may depend on forearm rotation. This study was conducted to determine the effect of forearm rotation on the displacement of a medial epicondyle fragment.

Materials and Methods

This experimental study was performed with Institutional Review Board approval. Five fresh frozen adult cadavers with no history of elbow trauma were prepared. Demographic data recorded included age, gender, cause of death, forearm length (measured from medial epicondyle to the ulna styloid) and forearm circumference (measured at mid forearm). All measurements were performed two times by one orthopedic surgeon (TS) using a digital Vernier caliper. An L-shaped skin incision was made at the anteromedial side of the elbow. Subcutaneous tissue was dissected directly to the medial epicondyle. An osteotomy of the medial epicondyle was performed by an orthopedic surgeon (TS) using an osteotome at the site of the presumed medial epicondyle to simulate a medial epicondyle fracture[17] (Figure 1). The soft tissue around the osteotomy site was preserved as much as possible, especially the pronator teres and flexor-pronator muscles. The affected forearm was then placed in an upper-extremity rotation-evaluation frame at 90° of shoulder abduction, 90 degrees of elbow flexion, neutral wrist position, and with all fingers in their resting position (Figure 2). Medial epicondyle displacement was measured at 10 degree increments from full pronation to full supination. After that, the fragment was reduced, stabilized with two 1.8 mm Kirschner wires, then the displacement was measured. All displacements were measured two times by one orthopaedic surgeon (TS) using a digital Vernier caliper at the maximum distance between the displaced fragment and its origin.

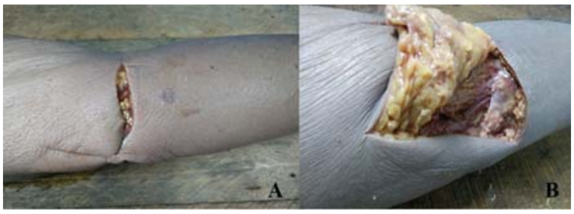

Figure 1. An L-shaped skin incision was made A) at the anteromedial side of the elbow, and B) the medial epicondyle was separated after osteotomy.

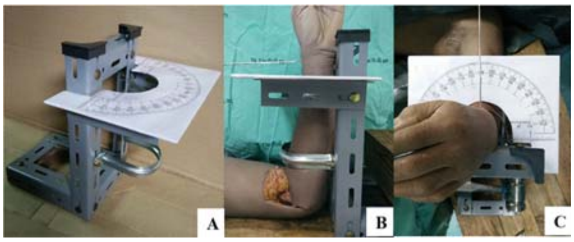

Figure 2. A) The 90-degree elbow flexion frame. The frame in B) forearm medial and C) top view.

Statistical analysis

Recorded characteristics of the cadaver included age, forearm length and circumference. Intra-observer reliability was performed using the Bland-Altman limits of agreement method (1986)[18]. Mean and standard deviation [SD] of medial epicondyle displacement were calculated. Student's t-test was used to evaluate the relationship of the displacement in full supination and full pronation. The correlation between forearm rotation and medial epicondyle displacement was determined using the Pearson correlation coefficient. Prediction of medial epicondyle displacement based on forearm rotation was estimated by R^2 using regression model analysis. With conservative treatment and a displacement not over 5 mm, the best cutoff point for forearm rotation was determined by the area under the receiver operating characteristics [ROC] curve, sensitivity, specificity, positive predictive value [PPV], and negative predictive value [NPV] with a 95% confidence interval [CI]. The Pearson Correlation Coefficient and ROC curve were evaluated using SPSS V 17.0 (SPSS Inc., Chicago, IL, USA). Sensitivity, specificity, PPV and NPV with a 95% confidence interval were evaluated by STATA V 12.0 (Stata corp., College Station, TX, USA). Sample size was determined by comparing two means two-sample, two-sided equality. Assuming an alpha error 0.05, power 80%, expected area under ROC curve 0.8, acceptable error 0.1, SD 0.1, the sample size was calculated to be 8 elbows.

Results

Ten elbows from five fresh frozen cadavers were included in this study. There were four males and one female with a median age of 74 years (range 62 to 84). All had died from medical conditions but without musculoskeletal problems. The median forearm length and circumference were 24 cm (range 24 to 26 cm) and 23 cm (range 20 to 24 cm), respectively. All of the medial epicondyles were displaced posteromedially after the osteotomy. The average displacement at the neutral position was 5.64$\pm$0.61 mm, and 5.52$\pm$0.58 mm for the right and left elbow, respectively (Table 1).

Measurements of medial epicondyle displacement and degree of forearm rotation are shown in Table 1. There was no significant difference in displacement between the right and the left sides. Displacement gradually decreased from 14.9 mm at 90 degrees pronation to 1.6 mm at 90 degrees supination. Limits of agreement showed intra-observer reliability ranged from 0.16 mm to 2.05 mm, with a lower limit of -0.93 mm and an upper limit of 3.47 mm (Table 1). No further displacement occurred after fixations with two Kirchner wires.

From analysis of the entire group, the mean displacement at full pronation was 14.39 mm which was reduced to 1.60 mm at full supination. The mean difference between full pronation and supination was 12.79 mm. (SD 2.39, 95% CI: 11.31, 14.27). There was a significant correlation between forearm rotation and actual medial epicondyle displacement (Pearson r = 0.91, p<0.001). Regression analysis was able to predict medial epicondyle displacement based on forearm rotation (R^2 from linear regression = 0.827, p<0.001). The equation for prediction was displacement in mm = 12.225 - 0.062 x degrees of forearm rotation (Figure 3).

Using less than 5 mm of displacement as an indication for conservative treatment, the cut-off for forearm rotation that provided the best performance was $\geq$20 degrees supination with a sensitivity, specificity, PPV, and NPV of 93.3%, 91.3%, 87.5%, and 95.5%, respectively, and an area under the curve of 0.92; p<0.001 (Figure 4). There was no fragment displacement after fixation with two Kirschner wires with any forearm rotation.

Discussion

This study showed that in isolated fractures of the medial humeral epicondyle, fragment displacement is the key to determining further management, an issue which up to now has been controversial. Previous studies have shown that conservative treatment provides good to excellent outcomes[8-11]. However, there has been no standard immobilization technique for this condition; different immobilization techniques can result in various outcomes and complications. We hypothesized that medial epicondyle displacement may depend on forearm rotation position. Our study demonstrated that the medial epicondyle is displaced more with forearm pronation, and is confined to within a 5 mm displacement by forearm supination of at least 20 degrees.

The medial humeral epicondyle serves as the site of origin of the flexor-pronator mass. It includes the pronator teres, flexor digitorum superficialis, flexor carpi radialis, palmaris longus, and flexor carpi ulnaris muscles, all of which are attached at the superomedial surface of the medial epicondyle[12,13]. The medial muscles apply a varus moment to the elbow and can resist valgus force of forearm rotation. Several authors[15,16] have studied the effect of forearm rotation on valgus laxity. Some reported that pronation of the forearm reduces valgus laxity, probably as a result of proximal migration of the radial head compressing the capitellum. Supination was also shown to reduce valgus laxity, most likely because of passive medial muscle tension in the flexor-pronator group. Moreover, when the forearm was supinated, the lacertus fibrosus was tightened, and tensed the flexor pronator fascia. This mechanism may pull the medial epicondyle back to its original position[19].

Our study found a strong correlation between forearm rotation and medial epicondyle fragment displacement: the more supination, the less fragment displacement. We found that forearm supination of more than 20 degrees resulted in more than 87% of fractures being displaced by less than 5 mm. Moreover, we

Table 1. Intra-observer reliability of medial epicondyle displacement of the elbows

Rotation (degrees)	Displacement measurement (mm), mean (SD)						Limits of agreement (SD)		95% CI	
	First measurement		Second measurement		Average					
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
90 pronation	15.89 (1.62)	14.91 (2.70)	13.90 (1.44)	12.86 (2.49)	14.90 (1.49)	13.88 (2.59)	2.00 (0.75)	2.05 (0.55)	0.52, 3.47	0.98, 3.12
80	13.51 (0.90)	13.23 (3.18)	12.17 (2.14)	11.54 (2.95)	12.84 (2.04)	12.39 (3.06)	1.34 (0.64)	1.70 (0.72)	0.09, 2.60	0.28, 3.11
70	12.06 (0.62)	11.12 (2.97)	10.55 (1.01)	10.42 (3.00)	11.31 (1.18)	10.77 (2.98)	1.51(0.53)	0.71 (0.18)	0.47, 2.55	0.36, 1.06
60	10.62 (0.93)	10.57 (3.30)	9.43 (1.91)	9.76 (3.03)	10.02 (1.96)	10.16 (3.16)	1.20 (0.74)	0.81 (0.43)	-0.25, 2.64	-0.03, 1.66
50	9.90 (0.80)	9.45 (2.71)	8.90 (1.32)	8.68 (2.52)	9.40 (1.55)	9.07 (2.61)	1.00 (0.59)	0.77 (0.32)	-0.15, 2.15	0.15, 1.40
40	9.66 (1.26)	8.81 (2.83)	8.53 (1.04)	7.89 (2.30)	9.09 (1.09)	8.35 (2.56)	1.13 (0.79)	0.93 (0.60)	-0.42, 2.68	-0.25, 2.10
30	8.61 (1.09)	7.70 (1.94)	7.72 (0.99)	6.96 (1.62)	8.16 (0.97)	7.33 (1.74)	0.89 (0.79)	0.73 (0.85)	-0.65, 2.44	-0.93, 2.39
20	7.73 (1.45)	6.84 (1.47)	6.74 (1.15)	6.24 (1.43)	7.24 (1.28)	6.54 (1.44)	1.00 (0.85)	0.60 (0.35)	-0.66, 2.66	-0.08, 1.29
10	6.84 (1.17)	6.37 (0.87)	6.12 (1.08)	5.77 (0.71)	6.48 (1.11)	6.07 (0.78)	0.72 (0.25)	0.60 (0.27)	0.23, 1.21	0.08,1.12
Neutral	6.09 (0.73)	5.75 (0.65)	5.19 (0.68)	5.30 (0.52)	5.64 (0.61)	5.52 (0.58)	0.90 (0.72)	0.45 (0.16)	-0.51, 2.31	0.13, 0.76
10 supination	5.32 (0.71)	5.77 (0.45)	4.94 (0.66)	5.25 (0.60)	5.13 (0.68)	5.51 (0.50)	0.37 (0.18)	0.52 (0.35)	0.03, 0.72	-0.16. 1.20
20	5.39 (1.03)	5.25 (0.29)	4.73 (1.03)	4.73 (0.35)	5.06 (0.99)	5.00 (0.29)	0.66 (0.57)	0.52 (0.28)	-0.46, 1.78	-0.03, 1.08
30	5.01 (1.18)	4.83 (0.60)	4.48 (1.05)	4.40 (0.46)	4.74 (1.09)	4.62 (0.53)	0.54 (0.46)	0.44 (0.17)	-0.37, 1.44	0.10, 0.77
40	4.69 (0.82)	4.42 (0.62)	4.18 (0.86)	3.97 (0.78)	4.44 (0.81)	4.20 (0.69)	0.51 (0.41)	0.45 (0.26)	0.30, 1.32	-0.06, 0.96
50	4.03 (0.83)	3.89 (0.71)	3.45 (0.88)	3.41 (0.87)	3.74 (0.85)	3.65 (0.79)	0.58 (0.26)	0.47 (0.22)	0.07, 1.10	0.05, 0.90
60	3.63 (1.11)	3.76 (0.68)	3.11 (0.43)	3.28 (0.76)	3.37 (1.03)	3.52 (0.70)	0.52 (0.34)	0.47 (0.34)	0.06, 0.98	-0.19, 1.13
70	3.05 (0.47)	2.94 (0.85)	2.70 (0.83)	2.51 (0.73)	2.87 (0.93)	2.73 (0.79)	0.36 (0.25)	0.43 (0.15)	-0.13, 0.83	0.14, 0.72
80	2.46 (0.95)	2.16 (0.29)	2.07 (0.89)	1.90 (0.35)	2.26 (0.91)	2.03 (0.32)	0.39 (0.20)	0.26 (0.09)	-0.01, 0.79	0.09, 0.43
90	1.83 (0.89)	1.65 (0.51)	1.44 (0.70)	1.48 (0.52)	1.63 (0.78)	1.57 (0.52)	0.39 (0.42)	0.16 (0.07)	-0.43, 1.21	0.02, 0.31

SD = standard deviation; CI = confidence interval

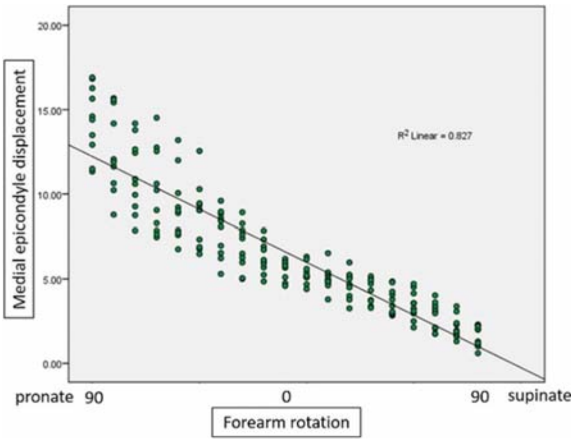

Figure 3. The relationship between forearm rotation and medial epicondyle displacement.

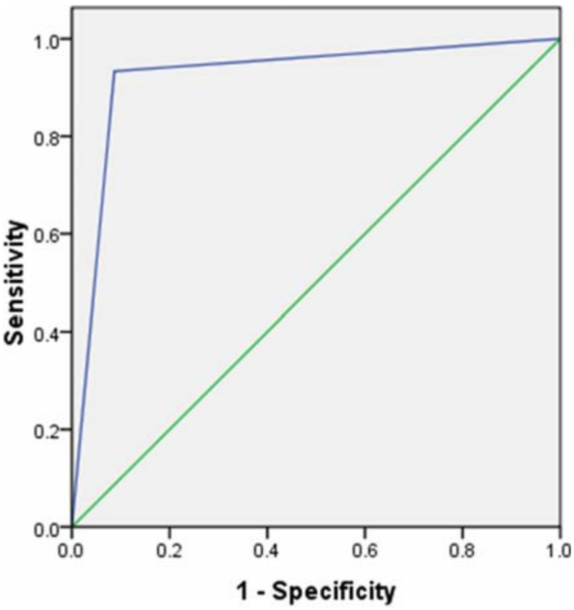

Figure 4. ROC curve of 20-degree forearm supination and acceptable displacement with a maximum of 5-mm of medial epicondyle displacement.

demonstrated that the direction of displacement was posteromedial to the humerus when the forearm was in the pronation position, a finding which contradicts a previous study(14). The supinated forearm increased medial muscle tension and moved the fragment in the anterolateral direction, closer to its original position. After fixation with two Kirschner wires, the fragment was stable in all forearm rotation positions.

This is the first study to described the relationship between changes in the displacement of the medial humeral epicondyle and forearm rotation. These findings may help identify the proper immobilization position and may serve as a foundation for future clinical studies. Limitations of this study include that the cadavers were elderly rather than being similar to adolescents or children. Also, the fragments created by osteotome in the cadavers could not imitate exact muscle tone or spasm, and may have over or under represented the injury condition. The strength of this study is the direct measurement of displacement at the osteotomy site which is more accurate than standard elbow images. In this study, intra-observer reliability was determined using limits of agreement.

Conclusion

Medial epicondyle fracture is significantly reduced in forearm supination when compared with pronation. That reduction results from increasing the flexor-pronator mass tension and brings the fragment close to its origin. Forearm rotation of at least 20 degrees- of supination largely confines the fragment to within 5 mm of displacement.

What is already know on this topic?

Conservative treatment provides good to excellent outcomes and avoids the operative risks in medial humeral epicondyle fracture treatment, but there has been no recommendation regarding the proper forearm rotation for immobilization in this type of injury.

What this study adds?

Forearm rotation is significantly related to actual medial humeral epicondyle displacement. Using a separation of less than 5 mm as a criterion for conservative treatment, the best position for fracture stabilization is ≥20 degrees of supination.

Potential conflicts of interest

The authors declare no conflict of interest.

References

1. Landin LA, Danielsson LG. Elbow fractures in children. An epidemiological analysis of 589 cases. Acta Orthop Scand 1986;57:309-12.
2. Pathy R, Dodwell ER. Medial epicondyle fractures in children. Curr Opin Pediatr 2015;27:58-66.
3. Duun PS, Ravn P, Hansen LB, Buron B. Osteosynthesis of medial humeral epicondyle fractures in children. 8-year follow-up of 33 cases. Acta Orthop Scand 1994;65:439-41.

4. Gottschalk HP, Eisner E, Hosalkar HS. Medial epicondyle fractures in the pediatric population. J Am Acad Orthop Surg 2012;20:223-32.
5. Lee HH, Shen HC, Chang JH, Lee CH, Wu SS. Operative treatment of displaced medial epicondyle fractures in children and adolescents. J Shoulder Elbow Surg 2005;14:178-85.
6. Louahem DM, Bourelle S, Buscayret F, Mazeau P, Kelly P, Dimeglio A, et al. Displaced medial epicondyle fractures of the humerus: surgical treatment and results. A report of 139 cases. Arch Orthop Trauma Surg 2010;130:649-55.
7. Skak SV, Grossmann E, Wagn P. Deformity after internal fixation of fracture separation of the medial epicondyle of the humerus. J Bone Joint Surg Br 1994;76:297-302.
8. Dias JJ, Johnson GV, Hoskinson J, Sulaiman K. Management of severely displaced medial epicondyle fractures. J Orthop Trauma 1987;1:59-62.
9. Farsetti P, Potenza V, Caterini R, Ippolito E. Long-term results of treatment of fractures of the medial humeral epicondyle in children. J Bone Joint Surg Am 2001;83-A:1299-305.
10. Lim KB, Woo CY, Chong XL, Ul-Alam S, Allen JC Jr. The isolated medial humeral epicondyle fracture treated nonoperatively: does fracture displacement change over time? J Pediatr Orthop B 2015;24:184-90.
11. Stepanovich M, Bastrom TP, Munch J 3rd, Roocroft JH, Edmonds EW, Pennock AT. Does operative fixation affect outcomes of displaced medial epicondyle fractures? J Child Orthop 2016;10:413-9.
12. Safran MR, Baillargeon D. Soft-tissue stabilizers of the elbow. J Shoulder Elbow Surg 2005;14:179S-85S.
13. Bryce CD, Armstrong AD. Anatomy and biomechanics of the elbow. Orthop Clin North Am 2008;39:141-54, v.
14. Edmonds EW. How displaced are “nondisplaced” fractures of the medial humeral epicondyle in children? Results of a three-dimensional computed tomography analysis. J Bone Joint Surg Am 2010;92:2785-91.
15. An KN, Hui FC, Morrey BF, Linscheid RL, Chao EY. Muscles across the elbow joint: a biomechanical analysis. J Biomech 1981;14:659-69.
16. Safran MR, McGarry MH, Lee TQ. Muscles and forearm rotation affect valgus laxity of the elbow. In: Transactions of the 19th Open Meeting of the American Shoulder and Elbow Surgeon, New Orleans, LA; 2003:17.
17. Hoppenfeld S, deBoer P. Surgical exposures in orthopaedics: The anatomic approach. 3rd ed. Philadelphia: Lippincott Williams & Wilkins; 2003.
18. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986;1:307-10.
19. Eames MH, Bain GI, Fogg QA, van Riet RP. Distal biceps tendon anatomy: a cadaveric study. J Bone Joint Surg Am 2007;89:1044-9.