

# Gartland Type 3 Supracondylar Humeral Fractures in Children: Which Open Reduction Approach Should Be Used After Failed Closed Reduction?

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**Objectives:** For displaced supracondylar humeral fractures in children, in the event of closed reduction failure, anatomic reduction is achieved via open reduction techniques; however, there are no confirmative reports among the published open reduction approaches that deliver the best functional and cosmetic results. Here, we compared long-term functional and cosmetic results of different surgical approaches.

**Design:** Retrospective cohort study.

**Setting:** Ankara Education and Research Hospital/Turkey. Secondary care hospital and trauma center.

**Patients/participants:** We evaluated 70 surgically treated Gartland type 3 supracondylar humeral fractures. Patients, with detailed history record, were divided into 5 groups with respect to surgery methods.

**Intervention:** All patients were treated surgically using closed reduction and percutaneous pinning or 4 different open reduction approaches and percutaneous pinning.

**Main Outcome Measures:** Flynn cosmetic and functional score results were compared between surgical groups.

**Results:** Posterior open reduction and triceps transection groups showed worst results, whereas medial and lateral open reduction groups showed good to excellent results similar to closed reduction group.

**Conclusion:** Medial and lateral approaches demonstrated better functional results than posterior and triceps transection approaches. Posterior approaches lead to restrictions in extension and poor functional results. In the posterior approach, transecting triceps from

olecranon does not benefit from fracture reduction but results in loss of triceps strength and should be avoided. In failed closed reduction, medial and lateral open reduction approaches lead to similar cosmetic outcomes and functional results that are only slightly worse compared with those in closed reduction.

**Key Words:** supracondylar humeral fractures in children, open reduction, elbow fractures in children, closed reduction

**Level of Evidence:** Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

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## INTRODUCTION

Supracondylar humeral fractures are the most prevalent elbow fractures in children.<sup>1</sup> Because of excellent functional results, closed reduction and percutaneous pinning is considered the “gold standard” method and treatment of choice for these fractures in the recent literature.<sup>2–4</sup> Unfortunately, anatomic reduction cannot always be achieved by closed techniques.<sup>4,5</sup> In the event of closed reduction failure, anatomic reduction should be achieved via open surgical approaches.

Failed closed reduction is the most common indication for open reduction in this type of fracture. Various approaches have been described with respect to open reduction in the literature. Usually, an anterior approach is the technique of choice in case of vascular injury. However, there is still no explicit evidence concerning which open reduction approach should be performed after failed closed reduction. In addition, there is no consensus regarding which open reduction approach delivers the best cosmetic and functional results.<sup>4–9</sup>

The aim of this study is to compare the functional and cosmetic results of various open reduction approaches with those of closed reduction.

## PATIENTS AND METHODS

### Patient Selection

One hundred four patients were referred to our clinic with Gartland type 3 supracondylar humeral fractures between 2007 and 2012. Seventy patients met our inclusion criteria and were included in the study. Patients between the ages of 1 and 14 years with surgically treated Gartland type 3 fractures via cross-pin configuration were included in our study. Patients with open

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fractures, pathologic fractures, intra-articular fractures, vascular injury, and Gartland type 1 or 2 fractures were excluded.

The patients were called from the patient records for a final control with a written consent from their parents. Patients were divided into 5 groups with reference to surgical technique or approach (Table 1). Nineteen patients were treated through closed reduction and percutaneous pinning. Fifty-one patients were treated via 4 different open reduction approaches and percutaneous pinning. All fractures were pinned with a cross-pin configuration. Medial, lateral, and posterior approaches were performed for open reduction purposes. Triceps tendon was transected from the olecranon insertion in a reverse “V” shape in the event that there was need for more fracture visualization when performing the posterior approach. Patients with triceps tendon transected were evaluated in a different group separate from the posterior approach without triceps transection.

### Clinical and Radiologic Evaluation

All parents signed written informed consent for the surgical procedures and the study. Patients meeting inclusion criteria were followed through their patient records. Anteroposterior and lateral view radiographs of the fractured and contralateral elbows were taken. Carrying angle, elbow range of motion, and triceps strength were evaluated clinically. Baumann angle, humeral capitellar angle, and the direction of displacement (posterolateral or posteromedial) were evaluated radiographically during the final control. Triceps strength was initially measured using Cybex dynamometry. However, younger patients were not able to adapt to this sophisticated device. Therefore, a simplified assembly was constructed by making use of a digital dynamometer with a reel and rope assembly as shown in **Supplemental Digital Content 1** (see **Figure**, <http://links.lww.com/BOT/A764>). Patients were asked to extend their elbows by pulling the rope with full strength with the elbow at 90 degrees flexion 3 times for both the fractured and contralateral sides. The mean triceps strength was recorded for both sides. The ratio between fractured side and contralateral side triceps strength was calculated. The clinical parameters such as triceps strength and ROM were evaluated in the final control. This time period was not equal for all the patients. The evaluation time after surgery was on average  $31.71 \pm 16.50$  months.

### Treatment Algorithm

The patients were treated in a similar algorithm. Initial reduction and long-arm splint were applied to all the fractures

in the emergency room. None of the patients were treated with conservative methods. Patients whose 6-hour fasting period ended before midnight and were without neurovascular injury were operated on the same day. Patients whose fasting period came to an end after midnight were operated early in the next morning.

In the operating room, closed reduction was attempted for all fractures under fluoroscopy (see **Figure, Supplemental Digital Content 2**, <http://links.lww.com/BOT/A765>). After achieving anatomic reduction in both anterior-posterior and lateral views, percutaneous pinning was applied via cross-pin technique. For the reason that cross-pin is the most stable pinning configuration biomechanically, this technique was used all the Gartland type 3 fractures (see **Figure, Supplemental Digital Content 3**, <http://links.lww.com/BOT/A766>). With the elbow in flexion, the first pin was introduced from the lateral epicondyle to the opposite cortex approximately 60 degrees with respect to humeral cortex. After fluoroscopic control of the first pin, the second pin was introduced from the medial epicondyle with elbow in extension to the opposite cortex with the same angle like the first pin. The ulnar nerve was manually displaced posteriorly with a finger gently to protect the nerve from pin insertion (see **Figure, Supplemental Digital Content 4**, <http://links.lww.com/BOT/A767>). All fractures types were Gartland type 3, and increase fracture stability, all were treated with the cross-pin technique. A third pin was applied from the lateral epicondyle when instability was noted at the fracture site.

We identified 3 criteria for “anatomic reduction” under fluoroscopy. The first was “anterior humeral line.” This line is drawn tangential to the anterior humeral cortex in the lateral fluoroscopic views. Normally, this line should cross the middle third part of the capitellum. The line crossing out of the third part of the capitellum was defined as nonanatomic reduction. Second any rotational malalignment in the lateral fluoroscopic view was accepted as a nonanatomic reduction. And third a resident measured the Baumann angle intraoperatively on anterior-posterior fluoroscopic images compared with the contralateral elbow on x-rays. Change in Baumann angle over 10 degrees was accepted as nonanatomic reduction (see **Figure, Supplemental Digital Content 5**, <http://links.lww.com/BOT/A768>). Open reduction was performed in case of nonanatomic fracture position after closed reduction (Fig. 1).

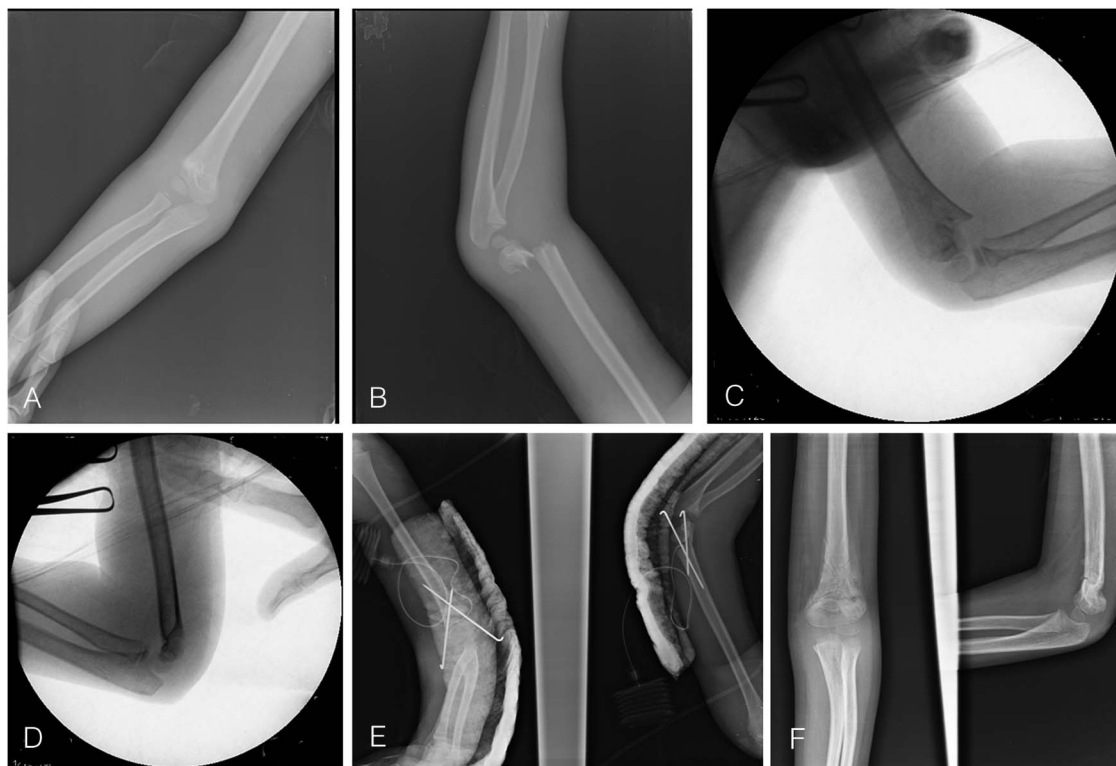
Various open reduction approaches (medial, lateral, posterior, posterior with triceps tendon transection) were performed. Each surgical approach was given preference according to 5 different surgeon’s experience. All the surgeons had at least 10 years of experience in a training and research hospital. In some cases, when using the posterior approach, the triceps tendon was transected from olecranon in a reverse “V” shape to improve fracture visualization. These patients with triceps tendon transected were evaluated in a different group apart from posterior approach (Table 1).

### Statistical Analysis

Patients were divided into 5 groups according to the surgical approach (Table 1). Variables [age, follow-up time (months), time until surgery (hours), immobilization time (weeks), pin removal time (weeks), and direction of displacement] were

**TABLE 1.** Patient Groups According to Different Surgical Procedures

	Patient Number
Closed reduction	19
Medial approach	11
Lateral approach	11
Posterior approach	11
Posterior approach + triceps tendon transection	18



**FIGURE 1.** A and B, The initial AP and lateral x-rays of the fractured elbow. C, Intraoperative lateral view under fluoroscopy. The anatomic reduction could not be achieved by closed reduction techniques. D, Anatomic reduction achieved after open reduction. E, Immediate postoperative x-rays. F, AP and lateral views after pin removal.

evaluated between the groups. Results (neurologic injury, change in carrying angle, change in Baumann angle, flexion loss, extension loss, range of motion loss, Flynn cosmetic score, functional scores, and triceps strength) were evaluated between groups statistically. Results were compared between groups by using Kruskal–Wallis test when the parameters match normal distribution and analysis of variance test when the parameters did not match normal distribution. Results were evaluated between 95% confidence interval, and  $P < 0.05$  was accepted as significant. SPSS (Statistical Package for Social Sciences for Windows ver.20; IBM Corporation, Somers, NY) software was used for all statistical analyses.

## RESULTS

### General Findings

In our study, the mean age was  $6.87 (\pm 2.81)$  years. Male–female ratio was 2:5. In all patients, 80% of the fractures ( $n = 56$ ) were observed on the left side and 20% ( $n = 14$ ) on the right side. Right-hand dominance was noted in 88.5% of the patients. According to these findings, fractures mostly occurred on the nondominant side ( $P < 0.05$ ). Mean immobilization time was  $4.02 (\pm 1.08)$  weeks, and mean pin removal time was  $6.15 (\pm 0.84)$  weeks. The mean follow-up time was  $31.71 (\pm 16.5)$  months. The average time until surgery was  $13.85 (\pm 7.7)$  hours. These variables were defined as “parameters that may affect study results.” According to the

results of Kruskal–Wallis and analysis of variance tests, no significant difference between surgical groups was noted between “parameters that could affect study results” (Table 2). These results have indicated that surgical groups were homogeneous. In addition, there was no significant difference between groups regarding the direction of displacement (posteromedial or posterolateral) ( $P > 0.05$ ).

### Clinical and Radiologic Results in Fracture Alignment

Elbow alignment was compared between groups clinically and radiographically during the final control. The differences in carrying angle, Baumann angle, and humeral capitellar angle between the fractured and contralateral elbows were compared between surgical groups. There was no significant difference between surgical groups

**TABLE 2.** Parameters That Could Affect Study Results

Parameter	Kruskal–Wallis	Analysis of Variance
Age	0.878	
Time until surgery	0.900	
Immobilization time	0.222	
Pin removal time	0.092	
Follow-up time		0.074
Direction of displacement	0.678	

related to elbow alignment (see **Figure, Supplemental Digital Content 6**, <http://links.lww.com/BOT/A769>). Cubitus varus deformity is generally accepted as a >10-degree change in elbow alignment in the literature. Cubitus varus was not observed in any patients in this study.

### Clinical Results in Range of Motion

Change in elbow flexion, extension, and range of motion was evaluated between surgical groups compared with non-fractured elbow. There was no significant difference in flexion loss between groups ( $P = 0.936$ ), but there were significant differences in elbow extension and range of motion loss between groups ( $P < 0.05$  for both) (see **Figure, Supplemental Digital Content 7**, <http://links.lww.com/BOT/A770>). Changes in elbow extension and range of motion were least in the closed reduction group (mean: 0.94 degrees and 2 degrees, respectively). These parameters were the worst in the posterior approach and triceps transection groups (mean: 9.94 degrees and 14 degrees, respectively).

### Flynn Cosmetic and Functional Scores

All patient results were scored according to the change in carrying angle (cosmetic score) and the change in range of motion (functional score), as described by Flynn.<sup>10</sup> According to the cosmetic scores, there was no significant difference between surgical groups ( $P = 0.090$ ) (Table 3). However, there were significant differences in functional scores between groups ( $P = 0.001$ ) (Table 4). Best functional results were observed in the closed reduction group. Posterior open reduction group and triceps transection group resulted in the worst functional scores. Medial and lateral open reduction groups had good results similar to the closed reduction group. Despite the fact that there was no significant difference, medial open reduction group gave slightly better results than lateral open reduction group according to Flynn functional scores (Table 4).

### Change in Triceps Strength

There was a significant difference in triceps strength between the groups ( $P = 0.001$ ). Triceps strength was similar in the closed reduction, medial, lateral, and posterior approach groups. However, there was a significant change in triceps strength in the triceps transection group. There was a mean 13% decrease in triceps strength in the triceps transection group compared with the closed reduction group (see **Table, Supplemental Digital Content 8**, <http://links.lww.com/BOT/A771>).

## DISCUSSION

Supracondylar humerus fractures are the most prevalent elbow fractures in children.<sup>11,12</sup> In the treatment of these fractures, anatomic reduction is one of the most essential factors influencing outcomes. Because of the excellent functional outcomes, closed reduction and percutaneous pinning have been the “gold standard” methods and treatments of choice for these fractures in the literature.<sup>2–4</sup> However, unfortunately, anatomic reduction cannot always be achieved by closed means. In cases of unsuccessful closed reduction, open reduction methods are required.

Different approaches for open reduction (medial, lateral, posterior, or anterior) are described in the literature.<sup>13,14</sup> In case of vascular injury (pulseless and cold hand), an anterior open reduction is usually the method of choice, and there is consensus in the literature on this subject.<sup>6,15–18</sup> Patients with vascular injury were excluded in our study; therefore, an anterior approach was not evaluated. In our study, we aimed to determine which open reduction technique (medial, lateral, posterior, posterior, and triceps transection) provides the best results after failed closed reduction in patients without neurovascular compromise.

In our study, mean age was  $6.87 \pm 2.81$ , male–female ratio was 2.5, and 80% of the fractures were seen on the nondominant extremity (see **Table, Supplemental Digital Content 9**, <http://links.lww.com/BOT/A772>). These parameters were consistent with previous epidemiologic studies concerning these fractures.<sup>19–22</sup> However, our open to closed reduction ratio was 72%. This ratio is considerably higher compared with previous studies.<sup>23–25</sup> Because of the fact that most of the patients excluded from the study were treated with closed reduction and pinning, the corrected open reduction ratio was 49%. This ratio is still high when compared with the literature. In addition, all the fractures were Gartland type 3 and average time until surgery was 13.85 hours, which might affect open reduction rates. Nevertheless, it is not evident in the literature whether open reduction rates are increased by delays in surgery.<sup>26–29</sup> We believe that learning curve is an important factor when performing closed reduction. In our study, we saw that open reduction rates decrease by years. Another reason for the high open reduction rates might be our strict policy about alignment. As shown in **Supplemental Digital Content 5** (see **Figure**, <http://links.lww.com/BOT/A768>), we used intraoperative qualification of fracture alignment. We did not accept minimal alignment changes. Because of this reason, we did not observe any cubitus varus or flexion/extension deformities so that open reduction rate was higher to overcome minimal alignment changes.

**TABLE 3.** Surgical Groups Compared as Flynn Cosmetic Scores

Flynn Cosmetic Scores	Closed Red.	Medial App.	Lateral App.	Posterior App.	Posterior App. + Triceps Transection
Excellent, %	89.47	100	100	72.72	72.22
Good, %	10.53	—	—	27.27	22.22
Fair, %	—	—	—	—	5.55
Poor	—	—	—	—	—



**TABLE 4.** Surgical Groups Compared as Flynn Functional Scores

Flynn Functional Scores	Closed Red.	Medial App.	Lateral App.	Posterior App.	Posterior App. + Triceps Transection
Excellent, %	84.21	81.81	63.63	27.27	16.66
Good, %	15.79	9.09	27.27	72.72	44.44
Fair, %	—	9.09	—	—	16.66
Poor, %	—	—	9.09	—	22.22

Variables that may have an influence on clinical outcomes (age, time until surgery, immobilization time, pin removal time, follow-up time, and displacement direction of the fracture) were similar in all groups (Table 2). This demonstrates that the groups were homogenous, and furthermore, most patients were treated with a similar algorithm.

The approximate change in carrying angle and Baumann angle was 1.87 degrees and 1.11 degrees, respectively. There was no significant difference between surgical groups in terms of these parameters ( $P = 0.250$  and  $0.787$ , respectively). Also, there was no significant difference in Flynn cosmetic scores between groups ( $P = 0.090$ ). Despite the fact that there was no significant difference, change in carrying angle and change in Baumann angle parameters were approximately 2 times higher in the posterior and triceps transection groups (see **Figure, Supplemental Digital Content 6**, <http://links.lww.com/BOT/A769>). It was reported earlier that posterior and lateral approaches had higher rates of cubitus varus.<sup>13</sup> Aktekin et al observed on average a 5.9-degree change in carrying angle with a posterior approach.<sup>30</sup> In addition, several authors have reported high rates of cubitus varus with posterior approaches.<sup>7,31,32</sup> Weiland et al<sup>33</sup> reported a 15% rate in cubitus varus with a lateral approach and concluded that medial elbow pathologies such as impaction leading to cubitus varus cannot be sufficiently evaluated with this approach. In contrast, Shifrin et al and Kumar et al did not observe cubitus varus with a medial approach.<sup>34,35</sup> Although there was no significant difference between groups, change in elbow alignment ranked as “Closed = Medial = Lateral < Posterior = Triceps transection.” These results have indicated that when performing the posterior approach, transecting triceps tendon does not seem to benefit from fracture alignment.

In our study, there was no significant difference between changes in flexion parameter. However, there was a significant difference between groups for change in extension and change in ROM parameters. Most extension and ROM loss was experienced in the posterior and triceps transection groups (see **Figure, Supplemental Digital Content 7**, <http://links.lww.com/BOT/A770>). Results suggest that medial and lateral approaches restrict joint motion less than posterior approaches. In addition, it was observed that medial and lateral approaches produced similar results in terms of joint motion compared with closed reduction. Gruber and Hudson reported that posterior approaches resulted in a restriction in the range of motion.<sup>7</sup> Similarly, many authors observed worse functional results with a posterior approach than other approaches.<sup>13,30,36</sup>

There was no significant difference in Flynn cosmetic scores between groups that reflects the similar angular alignment

between groups. However, there was a significant difference between groups for Flynn functional scores. Medial and lateral approaches demonstrated similar functional results with the closed reduction group but better results than the posterior approach and triceps transection groups. The functional scores ranked as “closed reduction > medial = lateral > posterior > triceps transection.”

Triceps strength was lowest in the triceps transection group, and the difference was significant. There is little in the literature with respect to the effects of posterior approaches on triceps function. Kasser et al<sup>37</sup> compared contralateral elbow triceps strength in a triceps splitting approach and observed a 6% loss in muscle strength. In contrast, Gürkan et al<sup>36</sup> did not observe any loss in triceps strength in their triceps transecting study. In our study, a decrease of approximately 13% was observed in terms of triceps strength in the triceps transection group. We did not report any ulnar nerve injury. This study is a retrospective cohort study, and all the patients were evaluated in the final control. There can be some misdiagnosed partial ulnar nerve injuries or ineffective patient records. Also most of the ulnar nerve injuries approximately resolve in 2–3 weeks without any sequel. In the final control, we did not observe any permanent ulnar nerve lesions.

Limitations of this study included fewer patients, different surgeons, and not using sophisticated methods to evaluate triceps strength. The strengths of our study were that 5 different surgical approaches were evaluated in the same study and the similarity of the surgical groups for parameters that can influence the outcomes.

## CONCLUSIONS

It is well known that closed reduction and percutaneous pinning has the best functional results and is recommended as the first treatment of choice in the literature. Posterior approaches lead to restriction in extension and poor functional results. In the posterior approach, transecting the triceps tendon from olecranon does not benefit from fracture reduction but results in a loss in triceps strength and should be avoided. In case of failed closed reduction, medial and lateral open reduction approaches result in similar cosmetic and functional outcomes that are only slightly worse compared with closed reduction.

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## Invited Commentary

Open reduction of otherwise closed supracondylar humeral fractures should be a rare thing.<sup>1</sup> Large published series from multiple pediatric trauma centers indicate open reduction rates of less than 5%–10% to be the norm for type-3

supracondylars. In twenty years at the same level I pediatric trauma center, open reduction for an otherwise closed supracondylar fracture has occurred in well less than 1% of cases.<sup>2</sup> Thus, this study by Kizilay et al<sup>3</sup> does demonstrate a surprisingly high rate of open reduction: 73% (51/70). Potential explanations for this should be of interest to anyone who treats these fractures.