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Comparative Evaluation of Two Fluoroscopic Techniques in Pediatric Supracondylar Humerus Fractures: A Retrospective Study on Surgical Efficiency and Early Outcomes

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Statistical Analysis C
Data Interpretation D
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Background: Supracondylar humerus fractures are the most common elbow fractures in children and are frequently treated with closed reduction and percutaneous pinning when displaced. Because this procedure relies heavily on intraoperative fluoroscopy, surgical setup can influence operative time, radiation exposure, and workflow efficiency. However, comparative evidence on different fluoroscopic positioning strategies and antisepsis protocols remains limited. This retrospective, non-randomized study was designed to compare a conventional technique with a modified fluoroscopic approach in pediatric Gartland type II supracondylar humerus fractures.

Material/Methods: This retrospective, non-randomized comparative study included 91 children aged 1 to 13 years with Gartland type II supracondylar humerus fractures treated between 2019 and 2023. Patients were divided into 2 groups according to the surgical method: conventional method (CM, n=49) and modified method (MM, n=42). Demographic data, operative duration, fluoroscopy exposure, preparation time, radiological alignment, pin removal timing, complications, and Mayo Elbow Performance Scores were compared.

Results: There were no significant differences in age, sex distribution, or radiographic alignment between the groups. The MM group had significantly shorter operative time, preparation time, and fluoroscopy duration. No infections or neurovascular complications were observed. Functional outcomes and fracture union were similar in both groups.

Conclusions: The modified technique appears to be a safe and efficient alternative to the conventional method, providing shorter operative and fluoroscopy times while maintaining comparable early clinical and radiological outcomes.

Keywords: supracondylar fracture • pediatric elbow • K-wire fixation • surgical efficiency • intraoperative fluoroscopy

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Introduction

Supracondylar humerus fractures are the most frequently observed elbow fractures in children, particularly between the ages of 3 and 7 years, and are commonly managed by orthopedic surgeons [1-3]. If the fracture is not treated appropriately, it can cause severe limitation of motion and deformity in the elbow, significantly affecting the patient's quality of life [4].

Most supracondylar humerus fractures are non-displaced and are treated with nonsurgical approaches. However, they constitute the majority of all pediatric fractures requiring surgical treatment (displaced fractures, vascular and nerve injuries, open fractures) [5]. Aside from select cases that require open reduction, supracondylar humerus fractures are typically treated using the 3-step closed reduction and percutaneous pinning (CRPP) technique, known for its low infection rate and minimal risk of joint stiffness [1-3]. In the first stage, reduction is achieved by closed manipulation. In the second stage, the reduction is checked with fluoroscopy. In the last stage, fixation is performed with percutaneous Kirschner (K) wires [6,7].

Although various fluoroscopic positioning strategies have been previously described, there is limited evidence comparing their operative efficiency and clinical outcomes under differing antisepsis protocols in pediatric supracondylar fractures [6,8]. These methods have advantages and disadvantages when compared with each other.

Pediatric supracondylar humerus fractures represent not only the most common elbow fractures in childhood but also one of the leading causes of pediatric fracture-related hospitalizations requiring surgical intervention. Prolonged operative time is associated with increased anesthesia exposure, higher operating room utilization, and greater healthcare costs. In addition, repeated fluoroscopic imaging results in cumulative radiation exposure for both the patient and the surgical team, which is of particular concern in the pediatric population due to their increased tissue sensitivity and longer life expectancy. Therefore, optimization of intraoperative workflow and reduction of fluoroscopy duration are not merely technical considerations but have direct implications for patient safety, functional recovery, and healthcare efficiency. In this context, evaluating alternative operative setups that can improve surgical efficiency without compromising clinical and radiological outcomes is of substantial clinical relevance.

This study aimed to compare operative efficiency, fluoroscopy duration, and early clinical outcomes between a conventional and a modified fluoroscopic technique in the surgical treatment of pediatric Gartland type II supracondylar humerus fractures.

Material and Methods

Study Population

The records of 108 patients aged 1 to 13 years who underwent closed reduction and subsequent K-wire fixation after supracondylar humerus fracture between January 2019 and December 2023, classified as Gartland type II, were accessed from the hospital archives. Only patients classified as having Gartland type II fractures by 2 independent orthopedic surgeons based on preoperative radiographs were included. Cases with radiographic signs of complete displacement, rotation, or neurovascular compromise suggesting type III were excluded. This study was designed as a retrospective, non-randomized analysis based on clinical, radiological, and functional assessments of pediatric patients treated for supracondylar humerus fractures.

Individuals presenting with open fractures, additional injuries in other body regions, age younger than 1 or older than 13 years, or any pre-existing systemic condition or neurovascular impairment prior to surgery were excluded from the study. Accordingly, 91 out of a total of 108 patients constituted the study group. Group assignment was based on the attending surgeon's routine operative preference. One senior surgeon routinely performed the conventional method, while another applied the modified technique. As this was a retrospective review, no randomization or matching was performed. A total of 49 patients underwent the conventional fluoroscopy technique, while 42 patients were treated using a modified fluoroscopy approach. Demographic data, fluoroscopy duration during the procedure, time from intubation to surgical onset, intervals between surgery, pinning, and subsequent K-wire extraction, as well as any complications, were systematically assessed across all cases. Operative time was defined as the interval from skin incision to final dressing application, and was recorded in surgical nursing notes. Preparation time included anesthesia induction and surgical draping or antisepsis procedures, recorded by the anesthesia nurse. Functional outcomes were assessed using the Mayo Elbow Performance Score. It encompassed postoperative monitoring through imaging studies and clinical assessments. All patients were evaluated through the examination of clinical forms.

Fluoroscopy and Surgical Procedure

Within the first 12 hours after the trauma, patients were taken to surgery under general anesthesia in the supine position. In CM, the surgical area is disinfected with 10% povidone-iodine and covered with sterile drapes. After the affected arm is placed on the operating table, the reduction phase is started. Light but continuous traction is applied to the arm at 10 degrees of flexion for 3 minutes. If the deformity persists despite

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Figure 1. In the modified method, the patient is positioned supine, and fluoroscopy is used in a non-sterile manner during fracture reduction with assistant support.

Figure 3. Intraoperative fluoroscopic assessment of Kirschner wire position, fracture stability, and elbow motion before wire bending, cutting, and splint application.

Figure 2. After localized antisepsis with 10% povidone-iodine, cross-pinning is performed under fluoroscopic guidance. The ulnar nerve is protected during medial pin insertion.

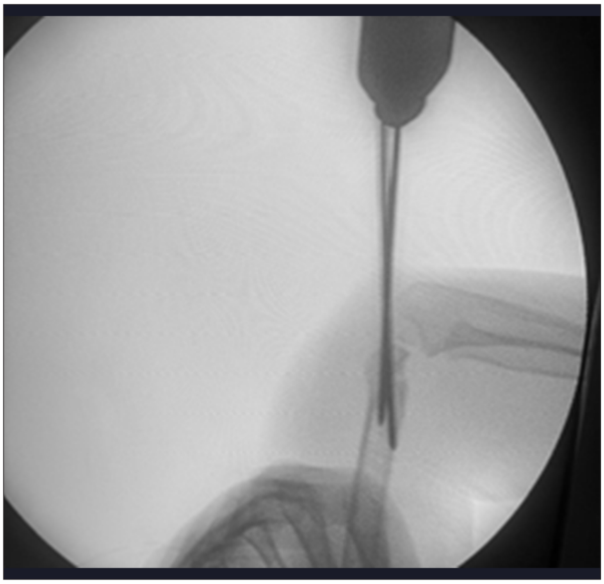

Figure 4. Post-reduction fluoroscopic control showing K-wire localization, fracture alignment, stability assessment, and radiological measurements.

traction, a slow milking process is performed from proximal to distal with several repetitions. Fluoroscopy is used in the anterior-posterior position to correct medial and lateral translation and varus and valgus deformity. While the elbow is initially in extension, the thumb is placed on the olecranon and the elbow is flexed properly while being pushed distally and forward. When the reduction is felt to be complete, the forearm is placed in the supine position for posterolateral fractures and in the prone position for posteromedial fractures and held fixed by the assistant. Without moving the arm, the C arm of the fluoroscopy is moved to obtain a lateral image, and angulation and translation are evaluated. After reduction is achieved, the first fixation procedure is performed according to AO principles with a K-wire (2.0 mm in those over 6 years of age, 1.6 mm in those under 6 years of age) sent from the lateral condyle in full flexion. Then, the flexion is reduced by approximately 30

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to 45 degrees, the ulnar nerve is retracted with the help of a finger, and the second K-wire is sent from the medial condyle. The cross-fixation method is used. After the fracture fixation is achieved, stabilization and joint movements are evaluated with the motion procedure with the help of fluoroscopy. After the surgery, the elbow is flexed at 80 to 90 degrees and the forearm is supinated, and a long arm splint is applied.

In MM, the patient is repositioned laterally on the operating table while remaining in the supine position (**Figure 1**). Without the use of sterile draping, fracture reduction is achieved while an assistant controls arm positioning depending on posterolateral or posteromedial fracture direction (**Figure 2**). Then, sterile gloves are worn and only the parts of the elbow to be fixed with the K-wire are disinfected with 10% povidone-iodine (**Figure 3**). It is not covered with any sterile drape. The arm table is not used. The fracture is fixed with the cross-fixation technique from the lateral and medial without touching the areas that are not disinfected with the K-wires. To obtain a lateral fluoroscopic image in the MM group, the assistant maintained gentle traction and rotation of the patient's shoulder while the elbow was kept stable. The C-arm remained in a fixed position. After stabilization and movement controls are performed with fluoroscopy, a splint is applied with the elbow in 80 to 90 degrees of flexion, and a long arm splint is applied with the forearm in supination. The MM technique required an assistant to maintain arm positioning throughout the procedure, which may limit its applicability in single-surgeon settings (**Figure 4**).

Radiological Evaluation

Radiological assessments were conducted by obtaining anteroposterior and lateral radiographs of the elbow on postoperative days 1, 21, 28, and 42. Fracture union was confirmed through radiographic follow-up evaluations. The Baumann angle was measured on anteroposterior radiographs of both the affected and unaffected elbows (for comparison) during postoperative day 90 follow-up. Fracture union was defined as the presence of bridging callus across at least 3 cortices on anteroposterior and lateral radiographs, accompanied by the absence of pain at the fracture site. Radiographs were independently evaluated by 2 orthopedic surgeons blinded to group allocation. Disagreements were resolved by consensus.

Postoperative Follow-Up

Postoperatively, the long arm splint was removed on day 21, and passive-active exercises were started for all patients. K-wires were removed on direct radiographs at 4 to 6 weeks postoperatively due to periosteal callus formation and blurring of the fracture line. In cases in which callus formation around the fracture line was inadequate, the K-wires were kept in place for another 1 to 2 weeks. Functional evaluation was performed on postoperative days 60 and 90. Functional outcomes were assessed using the Mayo Elbow Performance Score, which evaluates pain, motion, stability, and daily function, with a maximum score of 100 points.

Ethical Principles

The authors declare that all experiments on human participants were conducted in accordance with the Declaration of Helsinki, and that all procedures were conducted with the adequate understanding and written consent of the participants or their legal guardians. The study was approved by the Ağrı İbrahim Çeçen University Clinical Research Ethics Committee (Number: E-95531838-050.99-95935, date: 01.03.2024).

Statistical Evaluation

All data were analyzed statistically using IBM SPSS Statistics Version 25 (IBM Corp, Armonk, NY, USA). The normality of the data distribution was assessed using the Shapiro-Wilk test (as the sample size was less than 50 for each group) and visual methods (histograms, Q-Q plots), which confirmed that the data followed a normal distribution. Therefore, parametric tests were used for all comparisons. Numerical data are shown as mean ± standard deviation. The independent samples *t* test was used to compare numerical data between the 2 groups. The chi-square test was used to evaluate categorical data. A P value <0.05 was accepted as the threshold for statistical significance.

Results

The study included 91 patients with Gartland type II supracondylar humerus fractures, who underwent CRPP after surgical indication and met the inclusion criteria. The classification was confirmed independently by 2 orthopedic surgeons using preoperative anteroposterior and lateral elbow radiographs. The mean ages of the patients in the MM and CM groups were 5.81 ± 2.56 and 6.12 ± 2.54 years, respectively ($P=0.504$) (**Table 1**). The male sex ratios in the groups were 25 (59.5%) and 29 (59.2%), respectively ($P=0.974$), with no difference in terms of sex distribution. The mean clinical and radiological follow-up period was 90 days (range: 84-102 days), during which all outcome measures were recorded. Operative time was significantly shorter in the MM group (12.64 ± 2.44 min) compared with the CM group (37.27 ± 3.82 min; $P<0.001$). The preparation time from anesthesia to closed reduction was 1.76 ± 0.69 minutes in the MM group, shorter than in the CM group ($P<0.001$). The total mean fluoroscopy time during reduction and surgery was significantly shorter in the MM group ($P=0.001$). The Mayo Elbow Score, applied to all 91 patients at the final follow-up, did not show a statistically significant difference between the CM and MM groups ($P=0.168$). When the

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Table 1. The age and sex distribution of the patients. Data are expressed as mean±standard deviation or n (%).

	Modified fluoroscopy method (n=42)	Classical fluoroscopy method (n=49)	*P* value
Age (y)	5.81±2.56	6.12±2.54	0.504
Male	25 (59.5%)	29 (59.2%)	0.974
Female	17 (40.5%)	20 (40.8%)	0.974

Table 2. The comparison of surgical features and outcomes. Data are expressed as mean±standard deviation.

	Modified fluoroscopy method (n=42)	Classical fluoroscopy method (n=49)	*P* value
Operation time (minutes)	12.64±2.44	37.27±3.82	**<0.001**
Fluoroscopy time (seconds)	15.40±2.93	38.02±4.55	**<0.001**
Preparation time (minutes)	1.76±0.69	14.27±2.17	**<0.001**
Mayo Elbow Score	82.71±7.60	76.53±7.15	0.168
Bauman angle (day 90)	72.67±1.88	73.06±3.61	0.248
Bauman angle (contralateral elbow)	75.98±1.65	76.55±1.78	0.121
Difference of Bauman angle	5.31±2.44	4.27±3.21	0.057
Fracture union time (days)	30.88±2.44	31.78±3.20	0.245
Removal of K-wire (days)	37.40±3.27	42.14±3.78	**<0.001**

Baumann angle was measured in the direct radiographs taken at the day 90 postoperative control visit, there was no significant difference between the MM and CM groups ($P=0.248$). Comparison of the operated and unaffected elbows showed no statistically significant difference in Baumann angle measurements across the 2 groups ($P=0.121$). The time until pin removal in the MM group was 37.40±3.27 days and was significantly shorter than in the CM group ($P<0.001$) (**Table 2**). Although the mean K-wire retention time exceeded 5 weeks in both groups, no infection or joint stiffness was observed. The extended duration was based on surgeon preference rather than radiographic necessity, which should be acknowledged in interpretation. The comparison of union times between the 2 groups revealed no statistically significant difference ($P=0.245$). No cases of pin tract infection, delayed union, nerve injury, or wound dehiscence were recorded. Superficial skin irritation near pin sites was noted in 4 patients, which resolved spontaneously after pin removal.

Discussion

This study demonstrated that the surgical approach used for the treatment of supracondylar humerus fractures in our clinic resulted in a significant reduction in operation time, preparation time, and intraoperative fluoroscopy duration when compared with the conventional CRPP method. Although the positioning and antisepsis strategies used in the MM are not entirely novel, their combined application in routine clinical practice and systematic evaluation within a comparative framework provides useful operational insights. In addition, the K-wire removal time was brought forward earlier in the MM. Another practical benefit of the MM is a reduction in procedural cost, owing to the elimination of sterile draping materials and shortened operation room utilization time, although this was not formally quantified in our study. Although fluoroscopy duration and pin removal timing showed differences between groups, these findings should be interpreted with caution, as surgeon experience, intraoperative team coordination, and institutional protocols were not standardized and may have acted as confounders. Because each technique was performed by a different senior surgeon, the observed differences in operative and fluoroscopy times may reflect surgeon-specific workflow and experience rather than the technique itself.

Although most supracondylar humerus fractures in children are managed conservatively, approximately 16% are reported to necessitate surgical intervention [9]. The primary goal of supracondylar humerus fracture treatment is to restore normal elbow structure and function, prevent potential

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neurovascular complications, and ensure an aesthetically pleasing outcome [10]. Therefore, successful completion of the operation makes the operation time an effective factor in surgical treatment [11]. In a study comparing different CRPP techniques, the average operation times were 28.3±1.6 and 30±3.6 minutes [12], and in a study comparing patients who underwent CRPP due to different fracture types, the average operation times were reported to be between 20.4 minutes and 46.6 minutes [13]. In the study comparing a new fluoroscopic method with the classical method by Dagtas and Unal, the operation times ranged between 21.54±3.48 and 38.14±5.92 [8]. In the present study, when MM was used as the surgical technique, operative time was significantly shortened compared with CM, regardless of fracture type and fluoroscopy technique.

In a study in which different methods were used in supracondylar humerus fracture surgery, intraoperative fluoroscopy exposure was compared. The authors emphasized that surgeons should avoid persisting with unsuitable surgical methods that unnecessarily extend intraoperative fluoroscopy duration, and instead opt for techniques that minimize radiation exposure [14]. In the present study, significantly shorter fluoroscopy time was found in the MM group than in the CM group. This will provide significantly lower radiation exposure in MM compared with CM. In our study, MM significantly reduced fluoroscopy duration, which may have potential long-term implications in reducing cumulative radiation exposure to both patients and surgical staff. Although no deep infections were observed in this cohort, the modified method's reliance on localized antisepsis without full sterile draping raises a theoretical concern for increased infection risk. The absence of infection in our series is reassuring, but this finding must be interpreted with caution given the relatively small sample size, which may be underpowered to detect rare but clinically significant complications such as deep surgical site infections. Larger studies are required to confirm the safety profile of this approach.

In a study conducted by Moraleda et al with a mean follow-up period of 6.6±2.8 years, it was observed that the results of patients evaluated with the Mayo Elbow Score after CRPP in surgical treatment of supracondylar humerus fractures were significantly improved [15]. In the present study, when the MM group and CM group were compared on Mayo Elbow Scores, we observed better scores in the MM group, but there was no statistical significance. We attributed this beneficial change to the accelerated recovery resulting from the use of MM, shorter surgery time, earlier removal of the K-wire, and early initiation of rehabilitation.

In a study by Mehlman et al, which utilized the CRPP method along with 2 different fluoroscopy techniques, it was found that 83% of patients had a Baumann angle within normal limits in postoperative radiological assessments, and the functional outcomes were also deemed satisfactory [16]. In another study comparing the classical fluoroscopy and mini fluoroscopy systems, it was reported that the Baumann angle was similar [17]. In the study of Dagtas and Unal, the Baumann angles were between 71.27±2.69 and 71.57±5.65 in the radiological evaluations after surgical treatment of supracondylar humerus fractures and were within normal limits [8]. In the present study, no significant superiority was achieved between the 2 methods in terms of Baumann angle. It was observed that both groups provided similar improvements as the results in the literature.

Although there are studies in the literature indicating that K-wire removal should be done in postoperative week 3 to 4 following CRPP [18], it is also known that some surgeons do not remove K-wires until week 4, 5, or 6 [19]. This has been linked to the tendency of surgeons to rely more on their clinical judgment regarding safety for K-wire removal, rather than strictly basing the decision on radiographic signs of fracture healing [8]. Considering the potential bias associated with this approach, the time for K-wire removal in the present study was somewhat longer in the MM group than that in the existing literature, but still shorter than that observed in the CM group. The prolonged K-wire retention in both groups—despite exceeding the commonly accepted 3- to 4-week threshold—was based on surgeon preference for an additional safety margin rather than a lack of radiographic healing, and was not associated with clinical infections or joint stiffness in our cohort. However, this finding is limited by the retrospective nature of the study and the possibility of underreported minor complications.

This study has several limitations. Its retrospective, non-randomized design is the most important, introducing inherent selection bias, as patients were allocated based on surgeon preference. This, combined with the fact that 2 different surgeons performed the 2 techniques, limits our ability to make causal inferences about the technique itself versus surgeon-related factors. Second, no formal power analysis was conducted, which increases the risk of type II errors, particularly for rare but important outcomes such as deep infection or nerve injury. The relatively small sample size may also limit the generalizability of our findings. Third, the modified technique's reliance on an assistant for arm positioning may not be feasible in all clinical settings. Fourth, while we aimed to include only Gartland type II fractures, some radiographic overlap with type III fractures may exist. Finally, being a single-center study carries inherent risks of information bias, especially regarding the underreporting of minor complications such as superficial pin site infections. Future prospective, randomized controlled trials with power analysis and cost-effectiveness evaluation are necessary to validate these preliminary findings.

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Conclusions

In this retrospective comparative study, the modified fluoroscopy and antisepsis technique demonstrated comparable clinical and radiographic outcomes to the classical method for treating pediatric Gartland type II supracondylar humerus fractures. The primary advantages of the MM were improved operative efficiency, evidenced by significantly shorter operative times, preparation times, and reduced fluoroscopy duration. While these findings suggest that the MM is a safe and efficient alternative, its applicability depends on institutional resources and the availability of a skilled assistant. Prospective randomized studies with cost-analysis and long-term functional outcomes are needed to validate these findings and define the role of MM in routine practice.

Ethical Principles

The authors declare that all experiments on human participants were conducted in accordance with the Declaration of Helsinki, and that all procedures were carried out with the adequate understanding and written consent of the participants. The study was approved by the Ağrı İbrahim Çeçen University Clinical Research Ethics Committee (Number: E-95531838-050.99-95935, Date: 01.03.2024).

Data Availability

Data are available on request from the authors.

Consent to Participate

All participants signed the Free and Informed Consent Form before the start of the study.

Declaration of Figures' Authenticity

All figures submitted have been created by the authors who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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