Conventional versus lateral cross-pinning (Dorgan's technique) for fixation of displaced pediatric supracondylar humeral fractures: a randomized comparative study

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Background

Although closed reduction and percutaneous pinning is the standard treatment for the displaced pediatric supracondylar humeral fractures, controversy still exists regarding the optimal pin configuration. The aim of this study was to compare the outcomes of the conventional versus lateral cross-pinning (Dorgan's technique) in treatment of displaced pediatric supracondylar humeral fractures.

Patients and methods

A total of 50 children were randomly divided into two equal groups: group I (treated via conventional technique) comprised 15 males and 10 female patients, with a mean age of 5.2±2.7 years, and group II (treated via Dorgan's technique) comprised 17 males and eight female patients, with a mean age of 7.8±3.1 years. Preoperative and postoperative neurologic and radiological evaluations were performed. Functional and cosmetic outcomes were evaluated according to Flynn's criteria. The mean follow-up periods were 25.24±7.2 and 27.56±6.3 months in groups I and II, respectively.

Results

There was no statistical significant difference between both groups regarding patients' and fracture characteristics, postoperative protocol, union time, and complication rate (pin-tract infections and extensive granulation tissue formation around Kirschner wires). The radiological, functional, and cosmetic outcomes were satisfactory in all patients, with no statistically significant difference between both groups. Dorgan's technique was more time consuming than conventional cross-pinning, with no cases developing any iatrogenic neurological insult in such group; however, iatrogenic transient ulnar nerve injury occurred in one case in group I.

Conclusion

Both cross-pinning techniques provide a biomechanically stable fixation, allowing early and safe active elbow movements with satisfactory functional, cosmetic, and radiological outcomes, but Dorgan's method was more time consuming compared with the conventional method. A properly performed Dorgan's technique completely avoids the risk of iatrogenic ulnar nerve injury without endangering the radial nerve. Level of evidence: level II, randomized comparative study.

Keywords:

biomechanically stable fixation, cosmetic and radiological outcomes, pediatric supracondylar humeral fractures, postoperative iatrogenic ulnar nerve injury, satisfactory functional

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Introduction

Pediatric supracondylar humeral (SCH) fracture is one of the most common fractures, accounting for 50–70% of all elbow fractures [1–3]. Closed reduction and percutaneous pin fixation is the gold standard treatment for the displaced fractures; however, controversy exists regarding the optimal pin configuration [4–7]. The cross-pinning configuration offers better biomechanical stability than the two lateral pinning, because it engages both the medial and lateral columns at fracture site, whereas latter pinning stabilizes only the lateral and central columns [8,9].

The conventional cross-pinning technique via the insertion of one or two pins medially and laterally through the medial and lateral epicondyles – which are biomechanically superior – increases the possibility of ulnar nerve injury by two to four folds [10–12].

John Dorgan, Consultant Orthopedic Surgeon in Liverpool, originated the lateral cross-pinning technique that was named after him [4,13]. Dorgan's method provides a biomechanically stable fixation with the avoidance of the risk of ulnar nerve injury [5,13]. It has been reported that the rate of

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iatrogenic ulnar nerve injury was 6% with the conventional cross-pinning technique and 0% with the lateral cross-pinning technique [14].

The aim of the present study was to evaluate and compare the cosmetic, functional, and radiological outcomes of the conventional versus Dorgan's cross-pinning technique in displaced pediatric SCH fractures.

Patients and methods

The procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 and 2008. This study was authorized by the Institutional Review Board, and all patients' parents gave informed consent after explaining the therapeutic procedure and its possible complications before inclusion in the study.

This is a prospective randomized control study that comprised 50 children with displaced SCH fracture who were admitted and managed in our university hospital from to February 2014 to October 2017.

Patients with isolated, closed, recent (not more than 7 days duration even if on top of a previous healed fracture in the same elbow), displaced, and rotated (Garland III) SCH fractures were included in this study. Patients with Gartland types I and II fractures, patients with open fractures, patients with associated ipsilateral arm or forearm fractures, patients who required open reduction, and those with associated neurological and/or vascular injury were excluded from the study. A detailed history was obtained regarding age, mechanism of injury, and previous trauma to the injured elbow. Clinical evaluation of the neurovascular status, skin condition, and swelling was done. Plain radiography of the affected elbow in postero-anterior, lateral, and oblique views was done after initial reduction and protection of the injured limb in above elbow back slab. Patients were randomly divided into two groups, each comprised 25 cases. Patients in group I were managed by conventional medial and lateral cross-pinning whereas lateral cross-pinning (Dorgan's technique) was used in group II cases.

Surgical technique

Under general anesthesia, all patients were placed in a supine position with their shoulders close to the edge of the operating table. A single dose of parenteral antibiotic – calculated according to the body weight of the child – was administered at the time of induction of anesthesia. The procedure was done under complete aseptic condition and without application of a tourniquet.

Under c-arm guidance, closed reduction of the fractures was done in all patients through sequential steps starting by a sustained traction applied to the forearm with an extended elbow whereas counter-traction was applied by the assistant to disengage the fractured fragments, which in most cases overcomes rotation, and then correcting medial or lateral displacements by applying a laterally or medially directed force, respectively. With the elbow flexed more than 90°, the posterior displacement and angulation were corrected by applying anteriorly directed force from posterior aspect of the distal fragment.

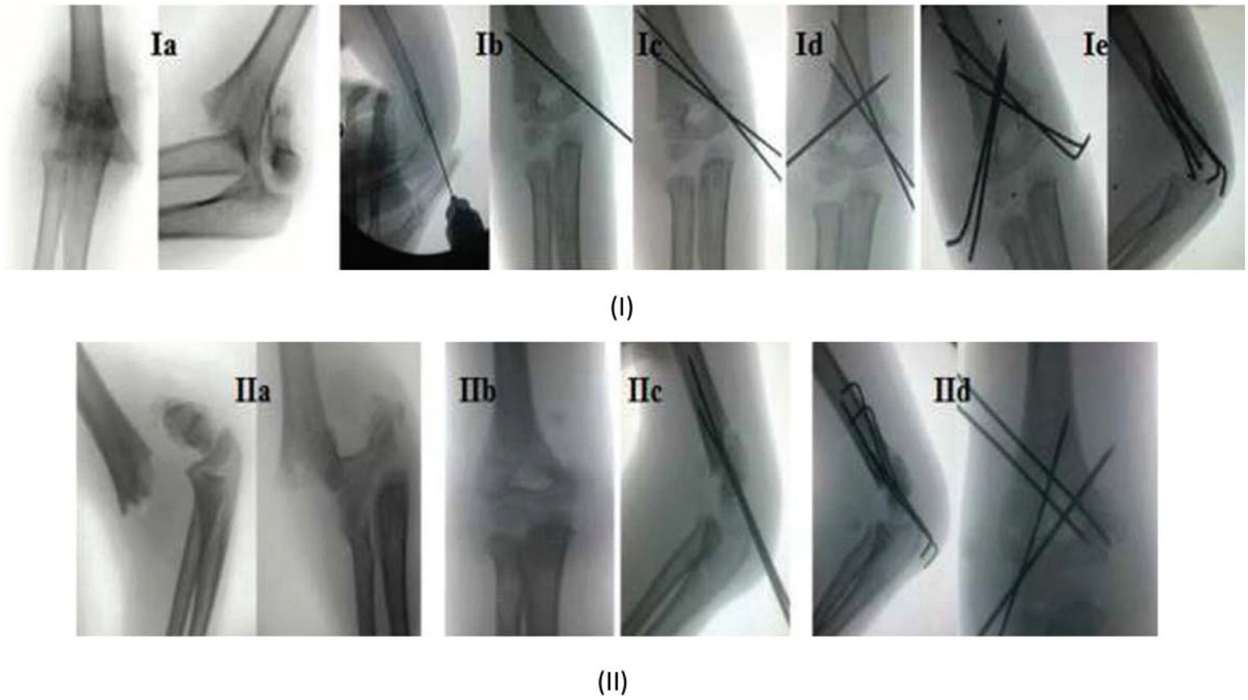
Two to four smooth Kirschner wires of equal diameter were selected to stabilize the fractures in all patients. The pin size was chosen according to the child's body weight (1.5 mm if the body weight is <20 kg, and 2 mm if over 20 kg).

In group I (conventional cross-pinning technique), the medial Kirschner wire was first inserted. With 70–90° elbow flexion, manual identification of the medial epicondyle was done and the first wire was put manually, and then the drill was used to introduce it into the medial condyle aiming to engage the opposite lateral cortex above the fracture line. The lateral wire was then inserted through the lateral condyle and was engaged to the medial cortex. Additional extramedial and/or lateral wires – depending on the fracture configuration or comminution – may be inserted (Fig. 1).

In group II (Dorgan's cross-pinning technique), the first wire was introduced through the lateral condyle across the fracture engaging the medial cortex, whereas the second wire was introduced through the lateral cortex via entering the skin posterior to the mid-coronal plane, proximal to the fracture line, and directed in an antegrade manner across the fracture line into the medial condyle. Cortical engagement of the medial condyle should be achieved with care not to penetrate it to avoid injury of the ulnar nerve. If additional stability was mandated by the fracture characteristics, an extra distal and/or proximal wires could be introduced (Fig. 1).

In both techniques, a minimum of two crossing wires were used with the point of the crossing of the wires should be above the fracture line. The Kirschner wires were then bent at a 90° before intersection to prevent migration. The affected limb was placed in a well-

Figure 1



(I) Conventional cross-pinning using two medial and two lateral wires (the medial wires were inserted first, followed by the lateral wires). (a) Prereduction images showing the characteristic displacement in AP and lateral views. (b) After achieving reduction, the first medial wire was inserted whereas the flexed elbow was in the inverted lateral position then checked in the AP view. (c) An extramedial wire was inserted adding more stability. (d) The lateral wire was inserted adding lateral column fixation with the crossing point above the fracture line. (e) Another lateral wire was inserted and checked in both AP and lateral views completing the conventional cross-pinning using two medial and two lateral wires. (II) Lateral cross-pinning (Dorgan's technique) using two distal and two proximal lateral crossing wires. (a) Prereduction images showing the characteristic displacement in AP and lateral views. (b) Sustained traction could correct all elements of the displacement in the AP view. (c) After correcting posterior displacement and angulation, insertion of two distal lateral wires like the classical lateral pinning and checking the reduction and position of wires while the flexed elbow was in the inverted lateral position. (d) Achieving a bicolumn fixation via lateral cross-pinning by insertion of another two proximal wires engaging the distal fragment. AP, anteroposterior.

padded above-elbow back slab with the forearm in a neutral position and the elbow flexed in 70–90°.

Immediately postoperatively, vascular and neurological assessments for median, ulnar, and radial nerves were performed. Anteroposterior and lateral radiographs of the operated elbow were obtained immediately postoperatively and after 1 week for assessment of reduction and wires position. The above elbow slab was removed after 7–15 days depending on fracture configuration, adequacy of reduction, stability of fixation, and patient and parents' compliance, allowing early progressive active and active-assisted elbow range of motion (ROM) with wires in place (Fig. 2a, b). Once healing was radiologically detected – usually between 4 and 6 weeks, Kirschner wires were removed. At the last follow-up, anteroposterior and lateral radiographs of both elbows were taken to assess Baumann angle and humerocapitellar angle. The ROM and carrying angle of both elbows were assessed by goniometer. Functional and cosmetic outcomes were evaluated according to the criteria proposed by Flynn *et al.* [3].

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics for Windows, version 22.0 (IBM Corp., Armonk, New York, USA). It was done using a two-tailed Student's t test, and P value less than 0.05 was considered statistically significant.

Results

The age of the patients ranged from 3 to 10 years in group I and from 4 to12 years in group II patients, with a mean age of 5.2±2.7 and 6.1±3.1 years, respectively. There were 15 males and 10 females in group I and 17 males and eight females in group II. The left elbow was affected in 13 children in group I and in 14 children in group II, whereas the right elbow was affected in 12 children in group I and in 11 children in group II. All cases were Gartland type III fractures. Regarding the fracture displacement, there were 13 children in group I and 11 children in group II with posteromedial displacement, seven children in group I and eight children in group II with posterolateral displacement, and five children in group I and six

Figure 2

The stable, bicolumn fixation with cross-wiring allowed early and safe splint removal with progressive ROM over wires. (a) Early removal of the splint 10 days postoperatively after stable fixation via four conventional cross-wiring allowed progressive improvement of the ROM by the third postoperative week. (b) Early removal of the splint 15 days postoperatively after stable fixation via four lateral cross-wiring allowed progressive improvement of the ROM by the third postoperative week. ROM, range of motion.

children in group II with direct posterior displacement. The radial pulse was not detected in five cases at the time of presentation, which was then felt after closed reduction. None of the cases had preoperative neurological deficits. The mean time from injury to the definitive surgical procedure was 15.6±6.5 h in group I (range, 10–28 h) and 17.2±6.4 h in group II (range, 11–27 h).

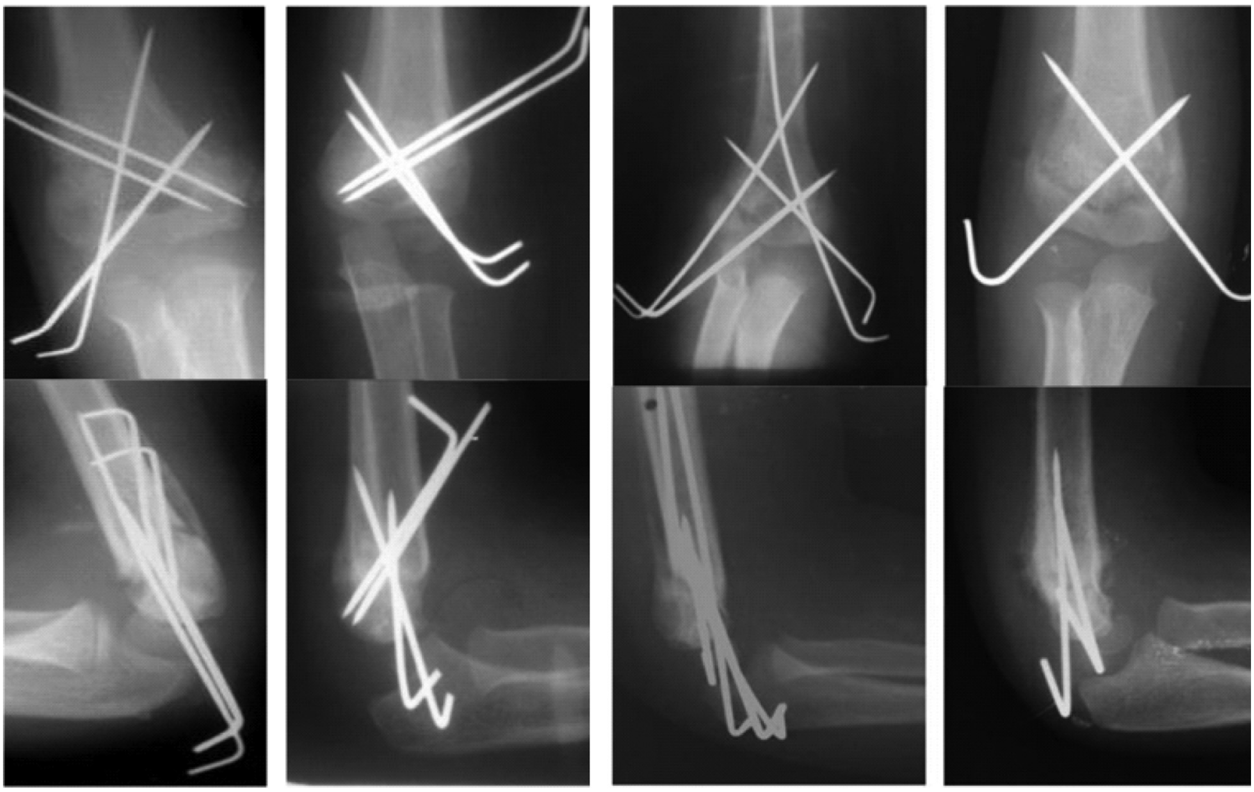
The follow-up period ranged from 12 to 40 months in group I, with a mean of 25.24±7.2 months, and from 11 to 36 months in group II, with a mean of 27.56±6.3 months. The patients' demographic data are demonstrated in Table 1. There was no statistically significant difference between both groups regarding age (P=0.527), sex (P=0.473), injured side (P=0.378), mechanism of injury (P=0.567), injury/surgery interval (P=0.265), follow-up periods (P=0.123), or fracture types. All the fractures united radiologically after a mean duration of 5.9±1.3 and 5.6±1.7 weeks for groups I and II, respectively (Fig. 3). All the wires were removed in the outpatient clinic without anesthesia after a mean period of 6.4±1.6 and 6.9±1.2 weeks for groups I and II, respectively.

There was no statistically significant difference between the two groups regarding the elbow ROM (Fig. 4). At the time of wires removal, the mean elbow flexion loss was 6.2° in group I and 6.8° in group II (P=0.586), whereas the mean elbow extension loss was 6.9° in group I and 7.6° in group II (P=0.368). The functional ROM was regained after a mean period of 8.2±1.5 weeks for group I and 9±1.7 weeks for group II, whereas the full elbow ROM was regained after a mean period of 18.2 ±3.5 weeks for group I and 19±2.7 weeks for group II.

Table 1 Patients' demographic data

Criteria	Group I	Group II	*P* value	Significance
Age(years)				
Range	3–10	4–12	0.527	NS
Mean±SD	5.2±2.7	6.1±3.1		
Sex [*n* (%)]				
Male	15 (60)	17 (68)	0.473	NS
Female	10 (40)	8 (32)		
Side [*n* (%)]				
Left	13 (52)	14 (56)	0.378	NS
Right	12 (48)	11 (44)		
Injury/surgery interval (h)				
Range	10–28	11–27	0.265	NS
Mean±SD	15.6±6.5	17.2±6.4		
Displacement [*n* (%)]				
Posteromedial	13 (52)	11 (44)	0.243	NS
Posterolateral	7 (28)	8 (32)		
Direct posterior	5 (20)	6 (24)		
Mechanism of injury [*n* (%)]				
Fall from height	13 (52)	12 (48)	0.567	NS
Motor vehicle accidents	2 (8)	4 (16)		
Bicycle and game accidents	10 (40)	9 (36)		
Follow up (months)				
Range	12–40	11–36	0.123	NS
Mean±SD	25.24±7.2	27.56±6.3		

Figure 3



(a) (b) (c) (d)

Satisfactory radiological results (restoration of the radiological parameters and healing with no secondary displacement). (a) Stable bicolumn fixation after Dorgan's technique using two proximal and two distal lateral cross-pinning. (b) Stable bicolumn fixation after Dorgan's technique using two proximal and two distal lateral cross-pinning for a new supracondylar fracture on top of a previously united and remodeled fracture. (c) Stable bicolumn fixation after conventional cross-pinning using two medial and two lateral wires. (d) Stable bicolumn fixation after conventional cross-pinning using only one medial and one lateral wire.

Figure 4

Clinical results (functional and cosmetic). (a) Satisfactory clinical results after conventional cross-pinning. (b) Satisfactory clinical results after Dorgan's technique.

Table 2 Modified Flynn's criteria to evaluate outcome of treatment

Outcomes	Loss of elbow ROM (deg.)	Loss of carrying angle (deg.)
Excellent	0–5	0–5
Good	6–10	6–10
Fair	11–15	11–15
Poor	>15	>15

ROM, range of motion.

The mean carrying angle loss was 3.2±4.3° in group I and 3.5±4.7° in group II (P=0.745). The mean Baumann angle loss was 4.9±5.3° in group I and 5.2±5.1° in group II (P=0.567). The mean Humerocapitellar angle loss was 6.2±5.6° in group I and 5.9±5.5° in group II (P=0.683), indicating a statistically nonsignificant difference between the two groups.

According to the modified Flynn's criteria (Table 2), the functional outcome was excellent in 25 patients in group I, whereas the outcome was excellent in 24 patients and good in one patient in group II. The cosmetic outcome was excellent in 23 patients and good in two patients in group I, whereas the outcome was excellent in 24 patients and good in one patient in group II. No fair or poor functional or cosmetic outcome was obtained in both groups. There was no significant statistical

Table 3 Patients radiological, functional, and cosmetic outcomes

	Group I	Group II	*P* value	Significance
Procedure time (min)	16.34±4.5	25.45±5.2	0.001	S
Healing time (weeks)				
Range	4–6	4–6	0.987	NS
Mean±SD	4.9±1.3	5.1±1.2		
Time needed for wires removal (weeks)				
Range	4–6	4–6	0.987	NS
Mean±SD	4.9±1.3	5.1±1.2		
Elbow flexion loss (deg.)	6.2	6.8	0.586	NS
Elbow extension loss (deg.)	6.9	7.6	0.368	NS
Time for restoration of full ROM (weeks)				
Range	10–23	12–25	0.934	NS
Mean±SD	18.2±3.5	19±2.7		
Bauman angle loss (deg.)	4.9±5.3	5.2±5.1	0.567	NS
Humerocapitellar angle loss (deg.)	6.2±5.6	5.9±5.5	0.683	NS
Carrying angle loss (deg.)	3.2±4.3	3.5±4.7	0.745	NS
ROM (functional) [*n* (%)]				
Excellent	25 (100)	24 (96)	0.976	NS
Good	0 (0)	1 (4)		
Fair	0 (0)	0 (0)		
Poor	0 (0)	0 (0)		
Carrying angle (cosmetic) [*n* (%)]				
Excellent	23 (92)	24 (96)	0.987	NS
Good	2 (8)	1 (4)		
Fair	0 (0)	0 (0)		
Poor	0 (0)	0 (0)		
Complication [*n* (%)]				
Ulnar nerve injury	1 (4)	0 (0)	0.476	NS
Pin-tract infection	2 (8)	3 (12)		
Granulation tissue formation	2 (8)	1 (4)		

ROM, range of motion; S, significant.

difference between both groups regarding both the functional and cosmetic outcomes (*P*=0.276, 0.287, respectively).

Regarding the time of the procedure, there was a statistically significant difference (*P*=0.001) between both groups in favor of group II. Dorgan's method was more time consuming (mean, 25.45±5.2 min) in comparison with conventional cross-pinning method (mean, 16.34±4.5 min). The radiological, functional, and cosmetic outcomes of both groups are demonstrated in Table 3.

Five patients developed minor pin-tract infection (two cases from group I and three cases from group II) that were managed with alcohol and oral antibiotics, and early removal of Kirschner wires was not required in any case. Extensive granulation tissue formation around Kirschner wires was observed in three patients (two cases from group I and one case from group II), who were treated with topical silver nitrate. No deep infection or compartment syndrome was observed in any cases of both groups till the final follow-up.

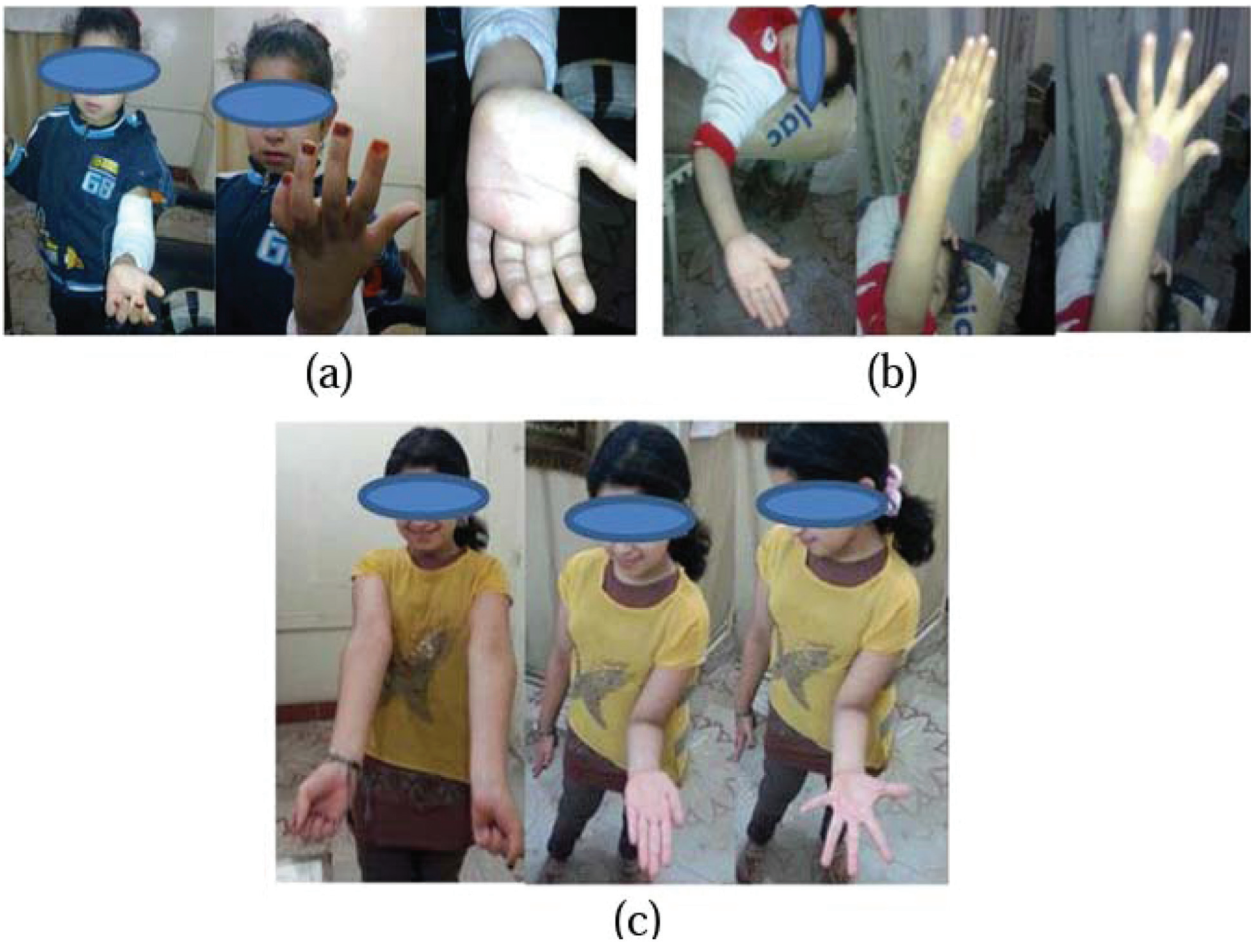
Postoperative iatrogenic ulnar nerve injury was detected in one case in group I (Fig. 5). This child was Gartland type III with posteromedial displacement. This injury resolved after 5 months without any interventions. There were no recorded neurological complications in group II cases.

Discussion

Pediatric SCH fractures are associated with considerable morbidity. The goal in treating such injuries is to restore the anatomy of distal humerus by achieving a perfect reduction with enough stability allowing early rehabilitation and obtaining satisfactory outcomes with least complications [15,16]. Closed reduction and percutaneous pin fixation is the gold standard treatment for the displaced fractures, but controversy exists about the optimal Kirschner wire configuration [4–7].

Comparing the different pinning techniques for such injury depends mainly on evaluating the radiological, cosmetic, and functional outcomes, in addition to recording the operative time, time needed for union

Figure 5



A case with iatrogenic ulnar nerve injury after conventional cross-pinning with only one medial wire. (a) Clinical signs of ulnar nerve affection on the third postoperative week. (b) Progressive improvement over the next 5 months till recovery. (c) Three-year follow-up with complete recovery of the ulnar nerve and excellent clinical results.

and wires removal, and complications mainly related to the technique of application and/or wires' configuration. This clinical study lacks any biomechanical workup comparing the mechanical characteristics of both techniques, but there are many different biomechanical studies addressing the mechanical characteristics of both constructs. They reported that the addition of a medial pin providing crossed-pin fixation improves the stability of SCH fractures, and that the use of two lateral pins alone is associated with a higher likelihood of loss of fixation [17–20]. The cross-wire technique was popularized in recent years by several authors [13,21,22] as the biomechanical studies have demonstrated that crossed pin constructs are significantly more stable than lateral pin fixation alone [23,24].

Memisoglua *et al.* [25] concluded that all two lateral crossed pins (Dorgan's technique) showed biomechanically equal properties to the two crossed medio-lateral, lower to three crossed pins configuration (two lateral and one medial pin), and superior to the two laterally divergent pins and two laterally parallel pins. Using cadaveric elbows, authors studied resistance to internal rotation, and found that the torque required to produce10° of rotation averaged 37% less with two parallel pins, and 80% less with two crossed lateral pins [26]. Using a saw-bone model, Lee *et al.* [23] found that two divergent lateral pins were comparable to crossed pins in extension, varus, valgus, and rotational loading, but were inferior in axial rotation testing.

There were other biomechanical studies that had focused on the number and diameter of pins necessary when treating displaced pediatric SCH fractures [19,23]. Pradhan *et al.* [20] demonstrated that at both 15 and 25°of rotation, the configurations including a medial pin were more stable than those without. In their samples, two lateral pins and one medial pin were the most stable construct overall, followed by one lateral and one medial pin, three lateral pins, and lastly two lateral pins. This finding was true whether comparing large pin models or small pin models. The torque required to produce 15 and 25° of rotation was greater using larger diameter pins. Furthermore, when comparing the amount of torque required to produce 15 and 25° of rotation, the crossed-pin configurations using small pins were stronger than both lateral pin configurations using large pins. They concluded that larger diameter pins provide greater resistance to torsional stress. The diameter of the pin does make a difference in fracture stability [20]. In our study, the pin size was chosen according to the child's body weight (1.5 mm if the body weight is <20 kg, and 2 mm if over 20 kg). There was no difference regarding the outcome with using two, three, or four wires with both techniques except that the more the wires used in fixation, the earlier ROM could be started.

In our study, according to modified Flynn's criteria [3], there were satisfactory functional and cosmetic outcome in all patients with no statistically significant difference between both groups, except that Dorgan's method was more time consuming. In a case series study on 139 patients with displaced SCH fractures, Memisoglu *et al.* [14] reported 92% satisfactory cosmetic and functional outcome in patients who were treated by Dorgan's method, whereas in patients who were treated by conventional cross-pinning, they reported 91% satisfactory cosmetic outcome and 94% satisfactory functional outcome. Altay *et al.* [4] reported 96% satisfactory functional outcome and 100% satisfactory cosmetic outcome in patients who were treated by conventional cross-pinning. In patients who were treated by Dorgan's method, both functional and cosmetic outcomes were satisfactory in all patients. Ducic *et al.* [5] reported 90 and 89.5% excellent outcome in patients treated with standard pin configuration and with Dorgan's method, respectively. The procedure time was longer and radiation exposure significantly higher in the patients who were treated by Dorgan's method. In a retrospective study done by El-Adl *et al.* [21] on 70 patients; there was satisfactory functional outcome in all patients, whereas 91.4% of patients had satisfactory cosmetic outcome. All these studies concluded that there were no significant differences in the outcomes of treatment between the two fixation methods.

Injury of the ulnar nerve has been documented when inserting the medial wire ranging from 2 to 10% [4,21,27,28]. It was mostly neuropraxia or axonotmesis owing to either ulnar nerve irritation or compression by the medial wire. According to a systematic review by Slobogean *et al.* [29], there is an iatrogenic ulnar nerve injury for every 28 patients treated with conventional cross-pinning compared with lateral pinning. There were several described techniques for medial pin placement to decrease the incidence of iatrogenic ulnar nerve injury, such as maintaining flexion of the elbow [30], using a two-finger or three-finger grip for precise identification of the medial epicondyle [31], using accurately drawn lines on the skin around the medial epicondyle [30], using a small incision over the medial epicondyle for direct visualization [32,33], and using a nerve stimulator to identify the location of the ulnar nerve [34]. Theoretically, in Dorgan's technique, the radial nerve could be injured at the point of entry of the proximal Kirschner wire. This could be avoided by entering the skin posterior to the mid-coronal plane of the distal humerus as the radial nerve is situated anterior to the lateral intermuscular septum at this level [21].

In our study, postoperative iatrogenic ulnar nerve injury was detected in one case in group I. This child was Gartland type III with posteromedial displacement. This injury resolved after 5 months without any interventions. Iatrogenic ulnar nerve injury was avoided with medial pin placement by manual identification of the medial epicondyle while maintaining 70–90° elbow flexion. We did not use a mini-incision over the medial epicondyle or a nerve stimulator to identify the location of the ulnar nerve. There were no recorded radial or ulnar neurological complications in group II as the point of entry of the proximal Kirschner wire was posterior to the mid-coronal plane of the distal humerus. Moreover, this wire did not penetrate the medial condyle.

Memisoglu *et al.* [14] reported a significant difference between the two groups regarding iatrogenic ulnar nerve damage [none in cases treated by Dorgan technique vs. six (9%) cases in patients treated by medio-lateral crossing wires). Ducic *et al.* [5] observed 9.9% iatrogenic ulnar nerve injury in 71 patients treated with standard procedures, whereas neurological complications were not observed in the patients treated by Dorgan's method. Sensory loss was observed in four patients, which recovered spontaneously after 3 months, whereas motor function loss occurred in two patients, which returned after 2–5 months. Nerve function was completely restored in all cases. Skaggs *et al.* [35] observed 4% iatrogenic ulnar nerve injury in 145 patients treated by cross-pinning, and Boyd and Aronson [36] reported ulnar nerve injury in two of 71 patients treated with crossed pins. Altay *et al.* [4] reported 8% iatrogenic ulnar nerve injuries postoperatively in patients treated with standard procedures and none in patients treated with Dorgan's technique. However, there was no iatrogenic neurological injury – either for the ulnar or the radial nerves – reported by El-Adl *et al.* [21] in their 70 patient series.

We had less incidence of iatrogenic ulnar nerve injury in crossing wires with spontaneous recovery. Ulnar nerve injury may be sensory and/or motor deficit. Sometimes, the sensory deficit is difficult to be detected especially in very young and uncooperative patients. Moreover, the number of cases in this study is lower than the previous studies. So, we need a larger sample for bringing certainty in this issue. Rasool [37] reported that the safety of percutaneous cross wires may be related to the surgeon's experience.

In our study, minor pin-tract infections and extensive granulation tissue formation around Kirschner wires occurred in 10 and 6% of the patients, respectively. These complications were owing to problems related to pin exposure, and not specific to any method of treatment. Burying the Kirschner wires deep into the skin eliminated these problems but required anesthesia for their removal [5]. In the study by Memisoglu *et al.* [14], pin-tract infection was detected in 9.3% and 8% of cases in patients treated by Dorgan technique and medio-lateral crossing wires, respectively, with no statistically significant difference between the two groups. Shannon *et al.* [13] – in his series of 20 patients – reported 5% pin-tract infection and excessive granulation tissue formation in 25% of patients.

Ducic *et al.* [5] observed 4.4% pin-tract infection, and 22% formation of excessive granulation tissue. El-Adl *et al.* [21] reported 8.6% minor pin-tract infections, 2.85% deep infection, and 45.7% excessive granulation tissue formation. Queally *et al.* [22] reported 7% pin-site infection and 14% excessive formation of granulation tissue. Altay *et al.* [4] observed minor pin-tract infection in 7.8% of patients. Saha [38] reported 5.8% pin-tract infection.

There was no optimal time for removal of pins and mobilization in patients with displaced pediatric SCH fractures. Delayed pins removal and immobilization cause pin-tract infection or elbow stiffness, whereas early removal of pins may increase the risk of redisplacement or refracture. There were no studies where the duration of pinning or immobilization was explicitly linked to any outcome of interest. In contrast to other studies that recommended immobilization with a long above-the-elbow splint for 4 weeks [22,39], our postoperative protocol in all patients was that the above elbow slab was removed after 7–15 days and gentle active and active-assisted ROM elbow exercises were initiated, and after 4–6 weeks, the Kirschner wires were removed.

Conclusion

Both cross-pinning techniques provide a biomechanically stable fixation allowing early and safe active elbow movements with satisfactory functional, cosmetic, and radiological outcomes but Dorgan's technique was more time consuming compared with the conventional method. A properly performed Dorgan's technique completely avoids the risk of iatrogenic ulnar nerve injury without endangering the radial nerve.

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Conflicts of interest

There are no conflicts of interest.

References

1 Gattu A, Babu K. Percutaneous pinning in displaced supracondylar fracture of humerus in children. IJOS 2017; 3:156–160.

2 Herring JA. Fracture about the elbow. In: Herring JA editor. Tachdjian's pediatric orthopedics. 3rd ed. Philadelphia, PA: W.B. Saunders; 2002. 3. 2139–2221.

3 Flynn JC, Matthews JG, Benoit RL. Blind pinning of displaced supracondylar fractures of the humerus in children. Sixteen years' experience with long-term follow-up. J Bone Joint Surg Am 1974; 56:263–272.

4 Altay MA, Erturk C, Isikan UE. Comparison of traditional and Dorgan's lateral cross-wiring of supracondylar humerus fractures in children. Saudi Med J 2010; 31:793–796.

5 Ducic S, Radlovic V, Bukva B, Radojicic Z, Vrgoc G, Brkic I, *et al.* A prospective randomized non-blinded comparison of conventional and Dorgan's crossed pins for pediatric supracondylar humeral fractures. Injury 2016; 47:2479–2483.

6 Naik LG, Sharma GM, Badgire KS, Qureshi F, Waghchoure C, Jain V. Cross pinning versus lateral pinning in the management of type III supracondylar humerus fractures in children. J Clin Diagn Res 2017; 11: RC01–RC03.

7 Khairy A. Fixation of supracondylar humeral fracture in children by medial and lateral pinning versus lateral pinning. MOJ Orthop Rheumatol 2016; 6:1–8.

8 Kruschemandl I, Aldrian S, Kottstorfer J, Seis A, Thalhammer G, Egkher A. Crossed pinning in pediatric supracondylar humerus fractures: a retrospective cohort analysis. Int Orthop 2012; 36:1893–1898.

9 Pellegrin DM, Brivio A, Pescatori E, Tessari L. Supracondylar humerus fractures in children: closed reduction and cross pin fixation in prone position. GIOT 2008; 34:199–204.

10 Swenson AL. The treatment of supracondylar fractures of the humerus by Kirschner-wire transfixion. J Bone Joint Surg Am 1948; 30:993–997.

11 Wind WM, Schwend RM, Armstrong DG. Predicting ulnar nerve location in pinning of supracondylar humerus fractures. J Pediatr Orthop 2002; 22:444–447.

12 Vaidya S, Rajbhandari A, Pradhan N, Shrestha S. Percutenous fixation of displaced supracondylar fracture in children comparing lateral with medial and lateral pin. J Pediatr Ortohp 2009; 13:521–555.

13 Shannon FJ, Mohan P, Chacko J, D'Souza LG. Dorgan's percutaneous lateral cross-wiring of supracondylar fractures of the humerus in children. J Pediatr Orthop 2004; 24:376–379.

14 Memisoglu K, Kesemenli CC, Atmaca H. Does the technique of lateral cross-wiring (Dorgan's technique) reduce iatrogenic ulnar nerve injury? Int Orthop (SICOT) 2011; 35:375–378.

15 Surapaneni SB, Koneru S, Tummala VSB, Boyapati G, Vithala S. Management of displaced supracondylar fracture of humerus in children by closed reduction and K wire fixation. Int J Orthop Sci 2017; 3:495–498.

16 Tomaszewski R, Wozowicz A, Wojakiewicz PW. Analysis of early neurovascular complications of pediatric supracondylar humerus fractures: a long-term observation. BioMed Res Int 2017; 2017:1–5.

17 Lee YH, Lee SK, Kim BS, Chung MS, Baek GH, Gong HS, *et al.* Three lateral divergent or parallel pin fixations for the treatment of displaced supracondylar humerus fractures in children. J Pediatr Orthop 2008; 28:417–422.

18 Sankar WN, Hebela NM, Skaggs DL, Flynn JM. Loss of pin fixation in displaced supracondylar humeral fractures in children: causes and prevention. J Bone Joint Surg Am 2007; 89:713–717.

19 Zionts LE, McKellop HA, Hathaway R. Torsional strength of pin configurations used to fix supracondylar fractures of the humerus in children. J Bone Joint Surg Am 1994; 76:253–256.

20 Pradhan A, Hennrikus W, Pace G, Armstrong A, Lewis G. Increased pin diameter improves torsional stability in supracondylar humerus fractures: an experimental study. J Child Orthop 2016; 10:163–167.

21 El-Adl WA, El-Said MA, Boghdady GW, Ali AS. Results of treatment of displaced supracondylar humeral fractures in children by percutaneous lateral cross-wiring technique. Strategies Trauma Limb Reconstr 2008; 3:1–7.

22 Queally JM, Paramanathan N, Walsh JC, Moran CJ, Shannon FJ, D'Souza LG. Dorgan's lateral cross-wiring of supracondylar fractures of the humerus in children: a retrospective review. Injury 2010; 41:568–571.

23 Lee SS, Mahar AT, Miesen D, Newton PO. Displaced pediatric supracondylar humerus fractures: biomechanical analysis of percutaneous pinning techniques. J Pediatr Orthop 2002; 22:440–443.

24 Weinberg AM, Castellani C, Arzdorf M, Schneider E, Gasser B, Linke B. Osteosynthesis of supracondylar humerus fractures in children: a biomechanical comparison of four techniques. Clin Biomech (Bristol, Avon) 2007; 22:502–509.

25 Memisoglua K, Musaoglua R, Cengizb A, Kesemenlia CC. Biomechanical analysis of percutaneous all lateral pinning (Dorgan's technique) technique for supracondylar humerus fractures in children. J Biomech 2011; 44:10–10.

26 Beaty JH, Kasser JR. Supracondylar fractures of the distal humerus. In: Beaty JH, Kasser JR, editors. Rockwood and Wilkins' fractures in children. 5th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2001. 577–624.

27 Skaggs DL, Hale JM, Bassett J, Kaminsky C, Kay RM, Tolo VT. Operative treatment of supracondylar fractures of the humerus in children. The consequences of pin placement. J Bone Joint Surg Am 2001; 83A:735–740.

28 Khan AQ, Goel S, Abbas M, Sherwani MK. Percutaneous K wiring for Gartland type III supracondylar humerus fractures in children. Saudi Med J 2007; 28:603–606.

29 Slobogean BL, Jackman H, Tennant S, Slobogean GP, Mulpuri K. Iatrogenic ulnar nerve injury after the surgical treatment of displaced supracondylar fractures of the humerus: number needed to harm, a systematic review. J Pediatr Orthop 2010; 30:430–436.

30 Reynolds RA, Mirzayan R. A technique to determine proper pin placement of crossed pins in supracondylar fractures of the elbow. J Pediatr Orthop 2000; 20:485–489.

31 Woo CY, Ho HL, Ashik MBZ, Lim KBL. Paediatric supracondylar humeral fractures: a technique for safe medial pin passage with zero incidence of iatrogenic ulnar nerve injury. Singapore Med J 2017; 59:1–10.

32 Gordon JE, Patton CM, Luhmann SJ, Bassett GS, Schoenecker PL. Fracture stability after pinning of displaced supracondylar distal humerus fractures in children. J Pediatr Orthop 2001; 21:313–318.

33 Green DW, Widmann RF, Frank JS, Gardner MJ. Low incidence of ulnar nerve injury with crossed pin placement for pediatric supracondylar humerus fractures using a mini-open technique. J Orthop Trauma 2005; 19:158–163.

34 Michael SP, Stanislas MJ. Localization of the ulnar nerve during percutaneous wiring of supracondylar fractures in children. Injury 1996; 27:301–302.

35 Skaggs DL, Sankar WN, Albrektson J, Vaishnav S, Choi PD, Kay RM. How safe is the operative treatment of Gartland type 2 supracondylar humerus fractures in children. J Pediatr Orthop 2008; 28:139–141.

36 Boyd DW, Aronson DD. Supracondylar fractures of the humerus: a prospective study of percutaneous pinning. J Pediatr Orthop 1992; 12:789–794.

37 Rasool MN. Ulnar nerve injury after K-wire fixation of supracondylar humerus fractures in children. J Pediatr Orthop 1998; 18:686–690.

38 Saha PK. Comparative evaluation of results of cross pin fixation by conventional method with Dorgan's method in displaced supracondylar fracture in children. Int J Sci Study 2015; 3:135–139.

39 Eberhardt O, Fernandez F, Ilchmann T, Parsch K. Cross pinning of supracondylar fractures from a lateral approach. Stabilization achieved with safety. J Child Orthop 2007; 1:127–133.