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Technical Notes

Tips and pitfalls of reduction and fixation in displaced supracondylar fractures in children

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ABSTRACT

Supracondylar humeral fractures are the most common injury of the elbow in children. Compared to flexion type fractures, extension type fractures are more common, up to 98%. Gartland classification has been used to guide the management of this injury, which is based on the extent of the displacement. If not adequately managed, completely displaced (type III) fractures may have a higher incidence of concomitant injury or complications, including neurovascular injury, compartment syndrome, or cubitus varus. Closed reduction followed by percutaneous pinning has been suggested as the standard operative method for the displaced supracondylar humeral fractures. However, these fractures can be challenging to reduce, with the traditional technique of closed reduction. Lateral-entry pinning is known as a sufficient method of fixation for this injury. However, the lateral pin only fixation technique may also result in loss of reduction in some particular patterns of fractures, such as fractures with medial column comminution. We discuss and describe the reduction techniques of completely displaced supracondylar humeral fractures, including technical tips and pitfalls for closed reduction and open reduction. We also discuss indications of medial pinning, and its safe method, when the lateral-entry pins may not achieve adequate stability.

Keywords: Children fractures, Displaced, Fixation, Humeral fractures, Reduction, Supracondylar fractures, Tips

In the management of supracondylar humeral fractures in children, an anatomical reduction is mandatory to achieve a good functional outcome and patient satisfaction. Surgical stabilization has been the mainstay to maintain the gained reduction. Closed reduction and percutaneous pinning are currently accepted as the standard of care for Gartland type III (completely displaced) fractures.[1] However, it requires the surgeon's accumulated experience and is not free of complications, such as malunion or deformity of the elbow. It may come from the inadequate quality of reduction, insufficient fixation stability, or malpositioning of Kirschner (K) wires. Therefore, it may be necessary to know technical tips and tricks to successfully reduce and maintain its stability. We describe the technical notes to reduce difficult supracondylar fractures successfully, including pin leverage technique and open reduction. Furthermore, indication and method of medial pinning were described, which may need to augment fixation stability.

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TECHNICAL TIPS TO ACHIEVE THE SATISFACTORY REDUCTION

The typical technique of fracture reduction is in a closed manner, under fluoroscopy control. Longitudinal, progressive traction is applied in the extended position of the elbow. Then, the surgeon's thumb is placed onto the olecranon and pushes it anteriorly, which may achieve the reduction of the angular deformity in the sagittal plane. According to the direction of displacement, the arm is then pronated (in posteromedial displacement) or supinated (in posterolateral displacement) while the elbow is hyperflexed. However, a satisfactory reduction and alignment may not be gained because of severe displacement, instability, and soft-tissue interposition. Late presented fractures may also make the closed reduction difficult, resulting in an unsatisfactory outcome. Several techniques have been suggested to improve the reduction quality, using pin leverage,[2] posterior intrafocal pin,[3] or lateral external fixator.[4] Open reduction may be an acceptable treatment method when fractures are not amenable to reduction by closed methods. Nevertheless, there are controversies about its approach and functional outcome after open reduction.[5]

Modified pin leverage technique in closed reduction

Gartland type III and IV fractures are difficult to obtain and maintain reduction before and during the fixation with pinning. Especially in patients with severe swelling or at risk of developing compartment syndrome, a closed reduction can be challenging. Fractures with a flexion-type pattern are also more likely to need open reduction, especially when the ulnar nerve injury is associated. Ulnar nerve injury may give a clue for a higher energy injury with associated soft-tissue damage, which might make closed reduction more difficult.[6] Pin leverage technique was reported to show an excellent result,[2] when satisfactory closed reduction after general anesthesia could not be achieved after three attempts. Similarly, the Kapandji technique could be an alternative to achieve a successful sagittal alignment.[3] In these techniques, a K-wire or a Steinmann pin is inserted cephalad to the posterior aspect of the distal humerus at the level of the fracture site. The inserted wire or pin is then levered to correct the posterior displacement of the distal fragment. To maintain the reduction, the inserted wire or pin may be driven across the anterior cortex of the humerus. As the pin penetrates the anterior cortex, there is a chance to lose the reduction. Therefore, authors do not advance the pin to purchase the anterior cortex and usually maintain the leverage effect with the flexion of the elbow. In most cases, closed anatomical reduction is commonly obtained with this maneuver.

Nevertheless, the posterior pin leverage may achieve a satisfactory alignment, malreduction still may occur at the coronal plane. It may show a considerable amount of medial/lateral translation or varus/valgus angulation. Direct manipulation may correct it, using a thumb and index finger on the medial/lateral condyles. However, in a swollen elbow or after repeated reduction trials, it is difficult to obtain the acceptable reduction. We also apply the pin leverage technique at the coronal plane, at the lateral aspect or medial aspect of the elbow. K-wire is introduced and advanced at the fracture site. Then, it is levered to correct the translation or angular deformity of the distal fragment. The coronal leverage procedure is usually performed after the sagittal leverage, but sometimes its sequence may be reversed [Figure 1].

Maintenance of achieved reduction is also important before the internal fixation by K-wires. The surgeon's thumb usually presses the distal fragment on the olecranon to maintain the reduction if the pin leverage technique is not used. However, the surgeon's hand may block the image of the elbow or interfere with the procedure of K-wire fixation. Since the leverage wire is distant from the fracture site, it may facilitate the following fixation procedure.

Indications and techniques of open reduction

The soft-tissue interposition is one of the most common reasons for failed closed reductions in supracondylar humeral fractures in children. Several irreducible fractures are suggested to need open reduction for this injury. In cases with pucker sign on the anterior arm, the brachialis muscle may prevent the anatomical reduction. A milking maneuver can be attempted, which gently milks the brachialis muscle distally and anteriorly from the penetrated proximal fragment. However, the interposition of disrupted periosteum and brachialis may make the accurate closed reduction fail.

Failed closed reduction several times may necessitate an open reduction to reduce further soft-tissue injury. In posterolaterally displaced fractures, the median nerve and brachial artery are at risk over the sharp edge of the proximal fragment. Furthermore, these important structures can be entrapped at the fracture site during the closed reduction. Open reduction may be a reasonable option if vascular exploration is needed, in some instances with pink, pulseless fractures.[7] Type-IV fractures also may need longer operative times and a higher frequency of open reduction, compared with type III fractures. Multidirectional instability is the leading cause of reduction difficulty, since both anterior and posterior periosteal hinges are lost in these fractures.[8] Therefore, it is essential to identify these injuries preoperatively, which may allow better pre-operative planning of possible switches from closed reduction to open reduction.

Authors prefer to select the anterior approach, when the open reduction is performed in these situations. A small transverse incision is made over the cubital crease, which is sufficient to insert the thumb for reduction (thumb reduction technique).[9] While traction is applied to the forearm, the pressure over the proximal fragment with the thumb can correct the coronal tilting, translation, and rotation [Figure 2]. Once a satisfactory reduction is achieved and maintained, K-wire fixation follows. The anterior approach has several advantages to free up intervening soft tissues, confirm the intactness of important structures, and even repair them when injured. Furthermore, it can minimize the scar, comparing to the longitudinal incision with medial or lateral approaches.[10]

In fractures with an intercondylar component, although it is not common, open reduction may be necessary to obtain the anatomical reduction of the articular fracture. While the anterior approach is a safe and commonly used method, it is difficult to visualize the articular fracture through this window. The posterior approach may be selected, as it can

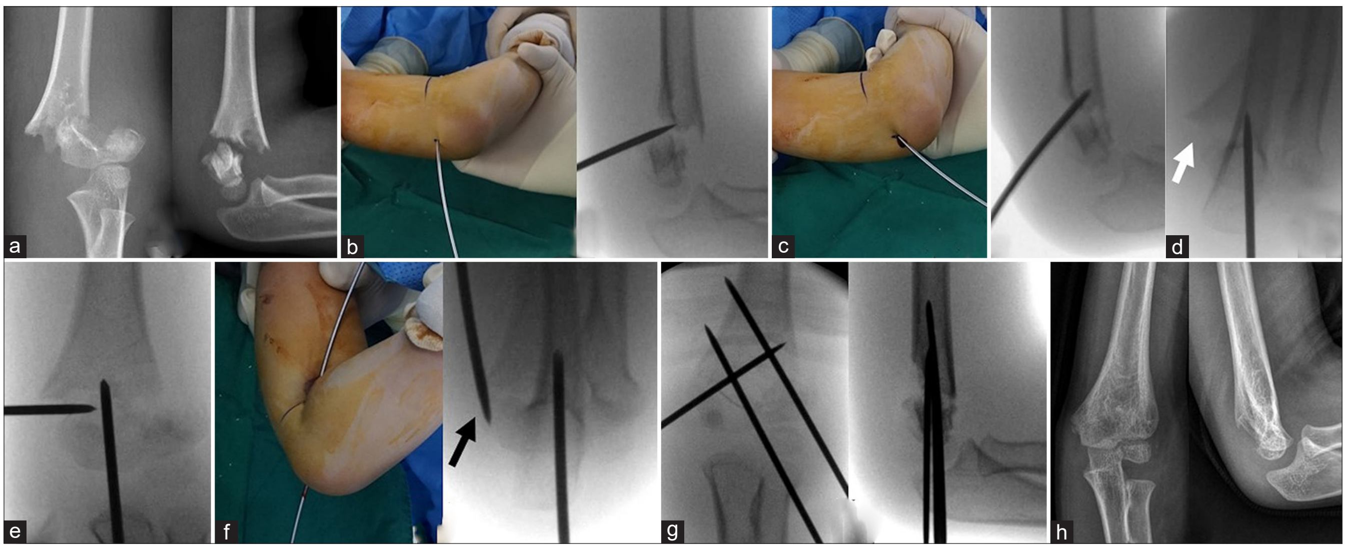

Figure 1: Type III displaced fracture (a), a 2 mm K-wire was introduced at the posterior aspect of the fracture site (b). After inserting the first K-wire between the fragments, the alignment was achieved at the sagittal plane with the K-wire leverage (c). However, there is a moderate translation at the coronal view (d). Another K-wire was introduced at the medial side (e). Using leverage technique, an anatomical reduction was gained (f). Two lateral K-wires and one medial K-wire were inserted (g). A satisfactory healing was achieved without deformity (h).

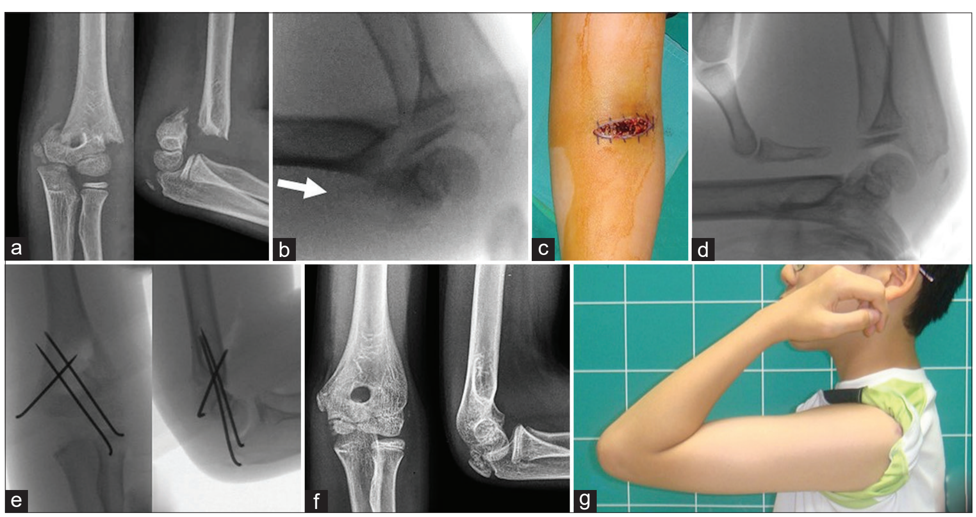

Figure 2: An 8-year-old boy suffered a completely displaced supracondylar fracture (a). A closed reduction could not achieve an acceptable reduction (b). A transverse incision was made over the anterior elbow crease (c). Thumb pressure was applied over the spike of the proximal fragment and the reduction was gained (d). Cross-pinning was performed (e). A successful healing was achieved (f) with a satisfactory function (g).

provide better visualization of the intra-articular fracture [Figure 3]. Through the triceps sparing approach, the fracture site is easily reached to perform the reduction. However, there are concerns regarding the potential disruption to the blood supply, resulting in osteonecrosis, with this approach.

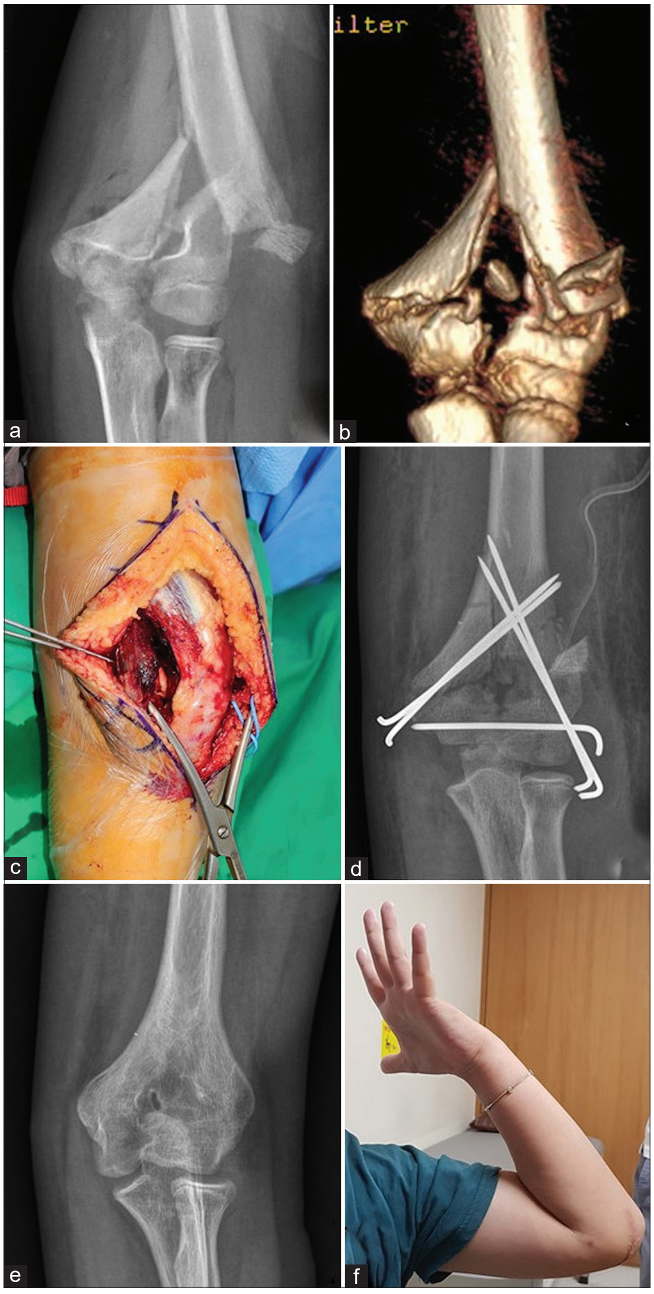

Figure 3: A 9-year-old boy suffered a displaced supracondylar humeral fracture (a). An intra-articular fracture was clearly noted on the CT scan (b). Using the triceps sparing approach, the articular reduction was performed (c). Post-operative radiograph shows a satisfactory reduction by cross-pinning (d). A successful healing (e) was achieved with the functional recovery at 1 year after operation (f).

Furthermore, post-operative stiffness of the elbow may be increased by adding a posterior dissection to an injury with an existing traumatic anterior soft-tissue injury.[5] Comparably, a recent report of open reduction using a posterior approach showed an excellent functional outcome with a high safety level.[11]

PIN CONFIGURATIONS FOR SUPRACONDYLAR HUMERAL FRACTURES

Once reduction has been accomplished, percutaneous K-wire fixation of the fracture can be carried out with the elbow hyperflexed. The authors prefer to fix two K-wires from the lateral entry. We generally use a K-wire of 2.0 mm or greater in diameter, while it varies according to the patient's age and body weight. These K-wires should achieve strong purchase in the lateral column and the medial cortex of the proximal fragment. The pins are usually inserted in a divergent fashion to have sufficient stability. Fixation stability is usually confirmed by the real-time lateral view of fluoroscopy, with flexion and extension of the elbow. When it is insufficiently stable either from inadequate pin configuration or fracture personality, medial K-wire pinning is additionally needed. There has been a continuous controversy regarding optimal or safest pin configuration, with several options including traditional crossed pins (one lateral and one medial pin), three crossed pins (two lateral and one medial pin), and lateral-entry pins.

The use of lateral-entry fixation alone was found to be as clinically effective as the cross-pinning method, even in the most unstable fractures.[12] As it avoids injury to the ulnar nerve, it is a very safe procedure. There are important technical variables to maintain the stability after K-wire pinning, including pin spread, pin divergence, pin numbers, or pin size. It is important to maximize pin separation at the level of the fracture site, to achieve sufficient stability. Inadequate pin spread in the coronal plane should be avoided, as it is the primary factor responsible for loss of reduction.[13] Furthermore, pins should engage sufficient bone in both the proximal and the distal segments. Bicortical purchase by the pin is another factor in achieving a stable construct. However, lateral-entry pins in particular fractures may not achieve adequate stability, such as fractures with medial comminution [Figure 4].

Cross pin construct may have better stability than the lateral-entry pins biomechanically [Figure 5]. Traditional cross-pinning with one lateral pin followed by one medial pin may not be optimal in terms of reduction maintenance. During the procedure to fix the medial pin, the elbow needs to be extended up to 45°. It may cause the redisplacement of

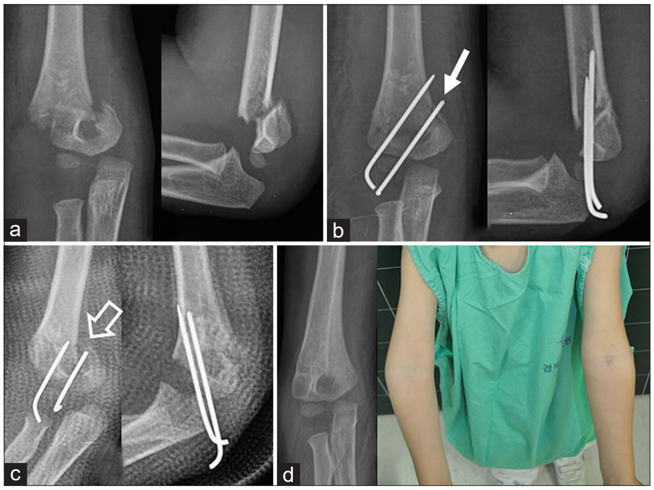

Figure 4: Preoperative radiographs of a 4-year-old boy with a type III supracondylar humeral fracture (a). Postoperative radiograph shows a satisfactory reduction and a sufficient pin spread after lateral-entry pinning (b). Note that the distal pin enters the fracture site (arrow). 2-week postoperative radiographs demonstrate loss of reduction (arrow, c). Eventually, the deformity of cubitus varus occurred 6 months after operation (d).

fracture as the fixation stability is insufficient with lateral one pin.

When do we need medial pinning?

Fracture personality is known to contribute to reduction loss, with inherently less stable injuries such as Gartland type IV fractures, flexion-type fractures, or fractures with medial comminution.

When the medial column is comminuted, the fixation with lateral-entry pins only may lead to instability. In a biomechanical model simulated with medial column comminution, the torsional and varus bending stiffness were lower with lateral only entry pins, while a significant increase in stiffness was achieved by the addition of one medial pin.[14] Close attention is needed when the fracture line is located at the medial column. To gain a firm purchase, the lateral pins are not enough and you need in these cases to add a medial pin in addition to one or two lateral pins depending on the degree of the comminution.

How to fix the medial pin safely?

The risk of iatrogenic ulnar nerve injury is inherent by the medial pin, when performing the crossed pinning. There have been several reports of ulnar nerve palsy after crossed pinning, reaching up to 11%.[15] It may occur through direct wire penetration or laceration of nerve, or through narrowing of the cubital tunnel (the path of the ulnar nerve) [Figure 6]. Therefore, medial wire fixation must be carefully performed

Figure 5: An 8-year-old girl had a displaced supracondylar humeral fracture (a). A 3-dimensional CT scan shows medial comminution (b). As an unstable fixation was anticipated with lateral-entry pinning, cross-pinning was performed (c). Post-operative radiographs show a satisfactory reduction, having sufficient purchase of cortices in the proximal fragment (d). A successful healing was achieved with a satisfactory function 1 year after operation (f).

after identifying the medial epicondyle and securing the ulnar nerve.

The position of the elbow is important during the medial pinning. In some children with anterior ulnar nerve instability, the ulnar nerve can subluxate anterior to the medial epicondyle during the elbow flexion. To minimize the ulnar nerve injury risk, semi-extension of the elbow joint (about 45° flexion) is recommended. To locate the medial epicondyle as an insertion point, the surgeon may palpate it by firmly pressing with the thumb. However, it is difficult to accurately locate it by superficial palpation, usually secondary to significant swelling in most displaced fractures. Fluoroscopic imaging may help to find it as the ossification of medial epicondyle may appear at 5–7 years. However, in younger patients, it is still difficult to locate the starting point of the medial pin.

When crossed pinning is performed, we prefer to make a small incision to insert the medial pin directly into the medial epicondyle safely.[16] While comparing with the non-injured elbow, the location of the medial epicondyle is assumed under the fluoroscopic image. Then, a 1 cm incision is made directly over the medial epicondyle. The medial pin is placed and directed proximally and slightly anteriorly to firmly engage the lateral cortex [Figure 7]. This technique will reduce the risk of direct damage to the ulnar nerve, while a little possibility of neuropraxia still remains.

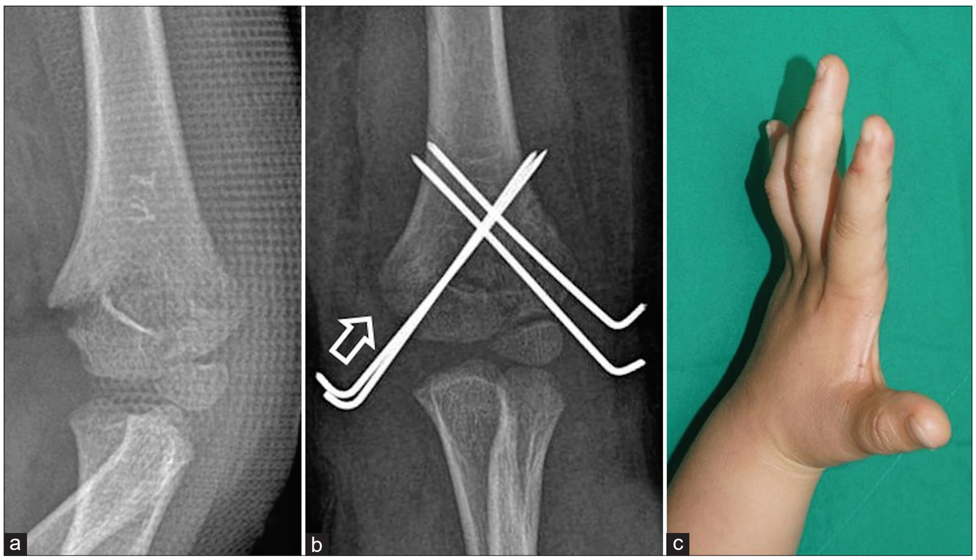

Figure 6: Pre-operative anteroposterior radiograph of a 4-year-old boy with displaced supracondylar humeral fracture (a). Cross-pinning achieved an acceptable reduction. However, the medial pin was started at the inaccurate area, which seems distal to the unossified medial epicondyle (arrow) (b). Ulnar claw hand occurred in this patient (c).

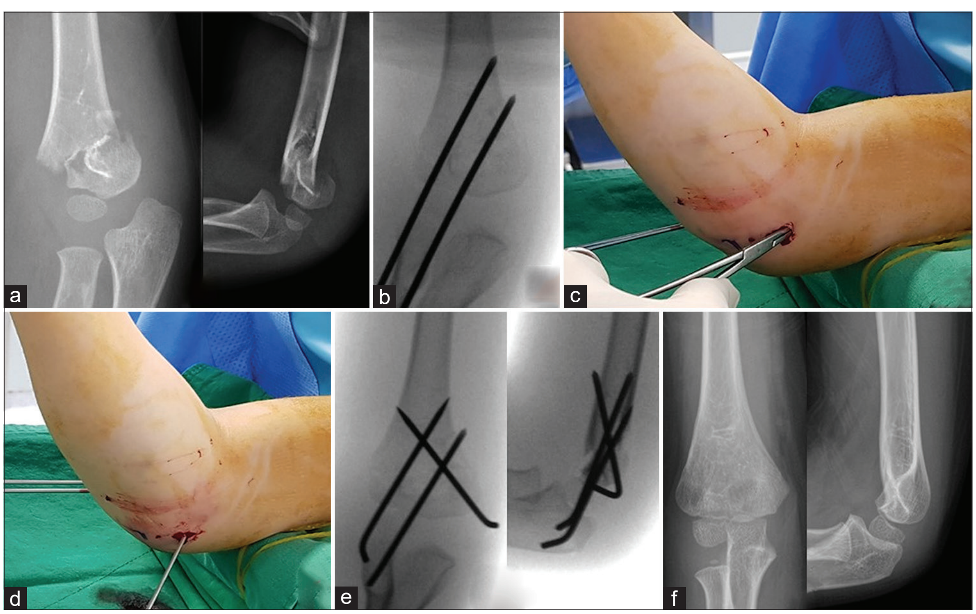

Figure 7: A 4-year-old boy sustained a type III supracondylar humeral fracture (a). After closed reduction, two lateral pins were inserted first (b). Then, a small incision was made over the medial epicondyle (c). An additional medial pin was inserted with the elbow at about 45° of flexion (d). Post-operative radiographs show a satisfactory reduction (e). A successful healing was achieved without loss of the reduction (f).

CONCLUSION

Completely displaced, Gartland type III supracondylar humerus fractures usually require operative treatment. At present, closed reduction with percutaneous pinning is the standard of care for this injury. As some fractures are challenging to reduce, technical tips are needed to achieve an acceptable reduction, such as pin leverage or open reduction techniques. To maintain the achieved reduction and its stability, the methods of pin fixation are critical. In the construct of cross entry pins, a medial pin is needed, especially when the fracture has medial comminution. However, the pitfalls and tips of medial pinning are important to know to avoid an inherent risk to danger the ulnar nerve.

AUTHORS' CONTRIBUTIONS

OCW conceived and designed the study, conducted research, provided research materials, and collected and organized data. KJW and PKH analyzed and interpreted data. OCW wrote the initial and final draft of the article and provided logistic support. All authors have critically reviewed and approved the final draft and are responsible for the manuscript's content and similarity index.

ETHICAL APPROVAL

The authors confirm that this review had been prepared in accordance with COPE roles and regulations. Given the nature of the review, the IRB review was not required.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his clinical information and images to be reported in the journal. The patient understands that his name and initials will not be published and due efforts will be made to conceal his identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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