THE EUROPEAN SOCIETY OF MEDICINE
Medical Research Archives, Volume 14 Issue 3

REVIEW ARTICLE

Beyond Traditional Pinning: Toward Three-Dimensional Stability in Pediatric Supracondylar Fractures

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OPEN ACCESS

PUBLISHED
31 March 2026

CITATION
Burnei, G., Zamfirescu, V., Burnei, A., Beyond Traditional Pinning: Toward Three-Dimensional Stability in Pediatric Supracondylar Fractures. Medical Research Archives, [online] 14(3).

ISSN
2375-1924

ABSTRACT

Supracondylar fractures of the humerus represent the most common elbow fractures in children and continue to pose important therapeutic challenges in pediatric orthopaedic trauma. Achieving stable fixation while minimizing neurovascular complications and preventing long-term deformities remains a central objective of treatment. Although percutaneous Kirschner wire fixation following closed reduction is widely accepted as the standard technique, the optimal pin configuration remains a subject of ongoing debate. Traditional lateral pinning offers neurologic safety but may provide limited rotational stability in unstable fractures, whereas crossed medial–lateral constructs improve stability at the cost of increased risk to the ulnar nerve. This review examines the evolution of fixation strategies and emphasizes the concept of three-dimensional stability in supracondylar fracture management. Particular attention is given to X and double-X fixation techniques, which aim to provide multiplanar mechanical control while avoiding medial pin placement, thereby combining enhanced biomechanical stability with improved neurologic safety. Fixation strategies that provide multiplanar, three-dimensional stability may represent an important advancement in the surgical management of unstable pediatric supracondylar humerus fractures. Techniques such as X and double-X pin configurations have the potential to improve rotational control and resistance to varus collapse while avoiding medial pin placement and reducing the risk of iatrogenic ulnar nerve injury.

Introduction

Supracondylar fractures of the humerus remain the most common elbow fractures in childhood and continue to represent a major challenge in pediatric trauma surgery. The primary objectives of treatment are anatomical reduction, mechanical stability, protection of neurovascular structures, and prevention of long-term deformities such as cubitus varus or valgus. Although closed reduction followed by percutaneous Kirschner wire fixation remains the accepted standard, the optimal configuration of fixation continues to be debated.[1]

Traditionally, lateral pin fixation has been widely adopted because it reduces the risk of iatrogenic ulnar nerve injury. However, in unstable fractures—particularly Gartland type III and IV lesions—lateral pin constructs may provide insufficient rotational control. Biomechanical investigations have shown that pin configuration significantly influences the resistance of the fixation construct to rotational and varus forces.[2,3]

Crossed medial–lateral pinning improves mechanical stability but introduces a recognized risk of ulnar nerve injury.[4] Consequently, modern pediatric orthopaedics increasingly seeks fixation strategies that combine mechanical stability with neurologic safety.

Within this evolving perspective, the concept of three-dimensional stability has gained increasing importance. Fracture fixation should not only prevent displacement in a single plane but should simultaneously control translation, angulation, and rotation of the distal fragment.

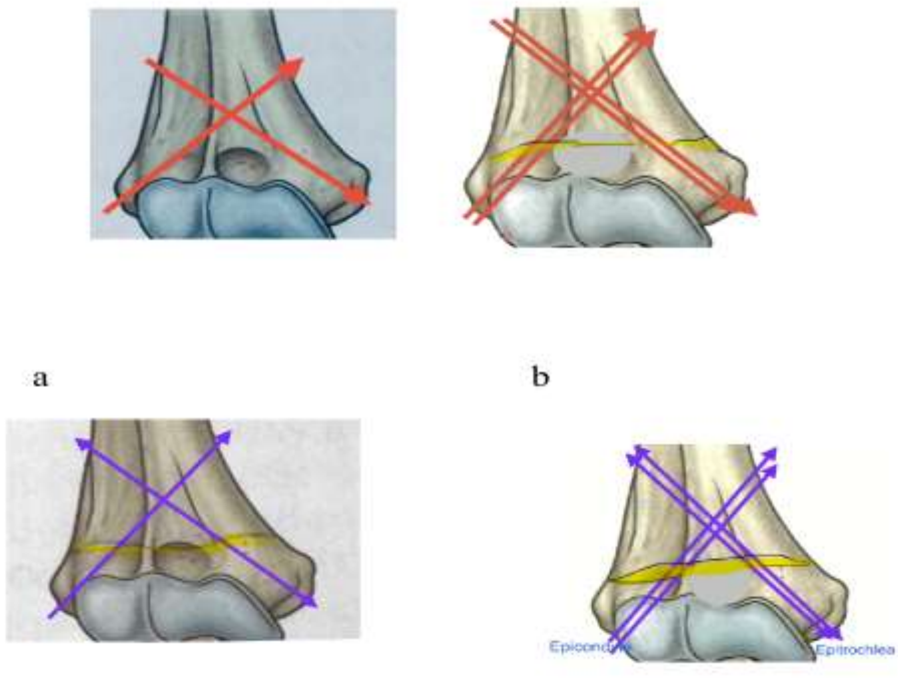

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Figure 1. X and double-X pin configuration.

(a,b) During closed reduction and percutaneous pinning (CRPP), the medial column pin is inserted over a guide under fluoroscopic control from a lateral and proximal trajectory toward the medial epicondyle. The lateral column pin is introduced from the lateral epicondyle, directed proximally and medially across the fracture, and advanced approximately 5 mm beyond the medial cortex.

(c,d) With open reduction through a lateral approach, the medial column pin is inserted directly into the cancellous bone of the medial column, perforating the medial cortex. After anatomic reduction, a toggle maneuver stabilizes the distal fragment medially. The lateral column pin is then placed under fluoroscopic guidance.

The X and double-X osteosynthesis techniques were developed in response to this biomechanical objective.[5] These methods rely on obliquely oriented Kirschner wires that intersect across the fracture site and generate fixation points distributed in multiple spatial planes. Such constructs increase resistance to torsional and varus stresses while minimizing the need for direct medial pin placement.

In the standard X configuration, two wires intersect proximal to the fracture site and create four fixation points, providing improved torsional resistance compared with parallel lateral pin constructs.[5] In more unstable fracture patterns, the double-X construct utilizes two intersecting wire pairs, creating up to eight fixation points and further enhancing rotational stability and control of varus forces.[6]

Long-term clinical experience with the double-X technique has demonstrated promising results in the stabilization of complex pediatric fractures.[6] Additional reports describing the use of double-X fixation in rare or difficult fracture patterns have also documented stable fixation and satisfactory functional recovery.[7]

The importance of achieving reliable fixation is underscored by studies analyzing postoperative complications following surgical treatment of pediatric supracondylar fractures. Although most patients achieve excellent outcomes, loss of reduction, malalignment, and nerve injury remain clinically relevant complications that surgeons must consider when selecting a fixation technique.[8]

More recent analyses of supracondylar fracture management emphasize that successful treatment depends on both accurate reduction and mechanically stable fixation constructs, particularly in environments with limited surgical resources.[9]

Advances in biomechanical research have further clarified the influence of Kirschner wire configuration on fracture stability. Finite element analysis studies have demonstrated that intersecting pin constructs can provide superior resistance to displacement compared with certain traditional lateral pin configurations.[10]

Similarly, clinical outcome studies evaluating surgically treated supracondylar fractures have reported excellent functional results when stable pin constructs are achieved.[11]

Retrospective comparative studies assessing closed versus mini-open reduction with percutaneous pinning also indicate that the stability of fixation plays a central role in determining postoperative outcomes.[12]

Additional minimally invasive techniques have been proposed to facilitate reduction in difficult fracture situations. Closed Kirschner wire prying reduction has been described as an effective technique for managing highly unstable Gartland type IV fractures.[13] Likewise, drill-and-pry reduction techniques have been reported to facilitate reduction in delayed presentations with early callus formation.[14]

The challenge of maintaining reduction in highly unstable injuries should not be underestimated. In a commentary on fixation loss in a type IV supracondylar fracture treated with divergent lateral pins, Bauer and colleagues noted that "a very unstable supracondylar humerus fracture can rapidly humble even the most experienced surgeons."[15] In such situations, multiplanar fixation constructs such as X or double-X configurations may provide more reliable control of the distal fragment.

From a biomechanical perspective, the principle underlying these techniques is the achievement of true spatial stabilization of the distal humeral fragment. By distributing fixation points across multiple planes, the construct improves resistance to rotational displacement and reduces the likelihood of secondary loss of reduction.

The evolution of fixation strategies for pediatric supracondylar fractures reflects a broader shift in orthopaedic thinking. Earlier treatment approaches focused primarily on preventing gross displacement. Contemporary strategies increasingly emphasize multiplanar mechanical control, neurologic safety, and early restoration of elbow function.

From this perspective, Kirschner wire configurations can be conceptualized along a progressive spectrum of mechanical stability:

1. Inverted V configuration
2. Parallel lateral pins
3. Divergent lateral pins
4. Crossed medial–lateral pins
5. X fixation
6. Double-X fixation

While preliminary clinical experience with X and double-X constructs is encouraging, further prospective comparative studies will be valuable in defining their precise role in modern treatment algorithms. Nevertheless, fixation techniques that enhance three-dimensional stability without increasing complication rates represent an important step forward in the management of pediatric supracondylar humerus fractures.

Ultimately, the goal of contemporary treatment is not merely fracture fixation but stable, safe, and biologically respectful stabilization that allows rapid functional recovery for the child.

Conflict of Interest:

The authors have no conflicts of interest to declare.

Funding Statement:

None

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