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Comparison of Healing Outcomes Between K-Wire Pin and Screw Fixation in Lateral Humerus Condyle Fractures in Pediatric Population: A Systematic Review and Meta-Analysis

Tommy Mandagi[1*], Iman Dwi Winanto[2], Reza Mahruzza[2]
[1]Resident of Department of Orthopaedics & Traumatology, Fakultas Kedokteran, Universitas Sumatera Utara/Adam Malik General Hospital, Medan
[2] Staff of Department of Orthopaedics & Traumatology, Fakultas Kedokteran, Universitas Sumatera Utara/Adam Malik General Hospital, Medan

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ABSTRACT

Lateral condylar humerus fractures are common pediatric elbow injuries, often resulting from trauma or falls. These fractures are typically seen in children aged 6 to 10 years and require appropriate fixation to prevent complications like malunion and nonunion. This systematic review and meta-analysis compare the outcomes of K-wire pin and screw fixation methods for pediatric lateral condylar humerus fractures. Data from studies published in the last decade were analyzed, focusing on clinical outcomes such as healing time, complications (delayed union, non-union, infection, stiffness), and functional recovery. Results show no significant difference in delayed union or non-union between the two methods. However, screw fixation was associated with a higher risk of non-union and avascular necrosis, although these differences were not statistically significant. In contrast, K-wire pin fixation was linked to a significantly higher risk of infection (RR 6.53) and stiffness (RR 1.77) compared to screw fixation. No significant difference was found in lateral overgrowth, fishtail deformity, or cubitus varus. These findings suggest that while screw fixation offers greater stability, K-wire pin fixation may be more prone to complications. Clinicians should carefully consider fracture type and patient-specific factors when choosing the fixation method.

Corresponding Author:
Tommy Mandagi
Resident of Department of Orthopaedics & Traumatology, Fakultas Kedokteran, Universitas Sumatera Utara/Adam Malik General Hospital, Medan
Email: tommy.mandagi@gmail.com

INTRODUCTION

Lateral condylar humerus fractures in children are among the most common elbow injuries, typically caused by direct trauma or blunt force. These injuries predominantly occur in children aged 6–10 years and require optimal management to prevent long-term complications such as malunion, nonunion, or joint stiffness (Saeed & Waseem, 2024). As intra-articular fractures, they demand precise stabilization to ensure proper healing and preservation of elbow function. Consequently, selecting the most effective and safe fixation method remains a critical challenge in the management of these fractures.

The two most commonly used fixation techniques are K-wire pins and screws. Each method has its own advantages and limitations (Jung et al., 2021). K-wire fixation is often preferred due to its minimally invasive nature and relatively simple application. However, this method carries risks such as loss of fracture alignment, pin migration, or infection. On the other hand, screw fixation provides superior mechanical stability, reducing the risk of fracture displacement. Nevertheless, this technique is more invasive and may lead to soft tissue damage or other complications (Cho, Kang, & Kang, 2023). As a result, the choice of the optimal fixation method remains a subject of debate in clinical practice.

To date, the evidence comparing the effectiveness of K-wire pins and screws in treating lateral condylar humerus fractures remains limited and inconsistent. Some studies suggest that screw fixation yields

better outcomes in terms of fracture stability and healing time, while others report no significant differences in long-term functional outcomes between the two methods (Cho, Kang, & Kang, 2023). These discrepancies may stem from variations in study design, analytical methods, or patient demographics. Therefore, a comprehensive synthesis of the available evidence is needed to clarify the relative advantages and disadvantages of these fixation techniques.

A systematic review and meta-analysis are well-suited to address this gap by integrating data from multiple studies, enhancing statistical power, and providing more reliable conclusions. By consolidating evidence from prior research, this approach can serve as a foundation for developing improved clinical guidelines for managing lateral condylar humerus fractures in children.

This study aims to conduct a systematic review and meta-analysis of studies comparing the outcomes of K-wire pin and screw fixation in pediatric lateral condylar humerus fractures. The findings are expected to provide evidence-based guidance for clinicians in selecting the most appropriate fixation method for pediatric patients, as well as identify areas for further research.

LITERATURE REVIEW

Lateral condylar humerus fractures are a common type of elbow injury in children, typically caused by direct trauma or blunt force, with a peak incidence between the ages of 9 and 14 years (Thorén et al., 1997). These fractures are more prevalent in boys than girls, often resulting from falls or sports-related activities such as baseball or arm wrestling. Approximately 50% of lateral condylar fractures are associated with posterior elbow dislocations, particularly in active children or those with immature skeletal systems (Thorén et al., 1997). In contrast, medial condylar fractures are rare and usually occur due to falls on an outstretched hand or direct blows to the elbow (Awad, Sabry, & Elhadidy, 2023). Transphyseal distal humerus fractures are more common in children under six years old and have been linked to difficult vaginal deliveries or non-accidental trauma in infants (Awad, Sabry, & Elhadidy, 2023). Risk factors for these fractures include high physical activity levels, participation in sports, and the immature ossification process of pediatric bones, which makes them more susceptible to injury (Okubo et al., 2019).

The unique anatomy of the pediatric distal humerus, characterized by multiple ossification centers, plays a significant role in the susceptibility to condylar fractures. The ossification process follows a predictable sequence known as CRITOE (capitellum, radial head, internal epicondyle, trochlea, olecranon, and external epicondyle), with each center appearing and fusing at specific ages (Miller & Thompson, 2023). Understanding this sequence is crucial for diagnosing fractures and differentiating them from normal developmental variations. The lateral condyle, which begins ossifying around age 11, is particularly vulnerable to injury due to its role as an attachment site for extensor muscles and the radial collateral ligament (Wu et al., 2016). Trauma or excessive stress on the elbow can disrupt this ossification process, leading to deformities or growth disturbances. Careful clinical and radiological monitoring is essential to ensure proper bone development and prevent long-term complications (Wu et al., 2016).

The management of lateral condylar humerus fractures depends on the degree of displacement and associated complications. Non-displaced fractures (less than 2 mm displacement) are typically managed conservatively with immobilization, while displaced fractures often require surgical intervention, such as open reduction and internal fixation (ORIF) using K-wire pins or screws (Marcheix et al., 2011). K-wire fixation is minimally invasive but carries risks such as pin migration and infection, whereas screw fixation provides greater stability but is more invasive and may cause soft tissue damage (Cho, Kang, & Kang, 2023). Recent advancements, such as bioabsorbable pins, offer promising alternatives by eliminating the need for secondary removal surgeries and reducing infection risks (Su & Nan, 2020). Despite these options, the choice of fixation method remains controversial, with varying outcomes reported in the literature. Systematic reviews and meta-analyses are needed to provide evidence-based guidance on the optimal treatment approach for these fractures, particularly in pediatric populations (Cho, Kang, & Kang, 2023)..

METHODOLOGY

This study is a systematic review and meta-analysis designed to compare the outcomes of fixation using K-wire pins versus screws in pediatric lateral condylar humerus fractures. The research analyzes data from various relevant and published studies to provide comprehensive conclusions. The population for this study consists of scientific publications, including national and international journals, retrieved from electronic databases such as PubMed, Scopus, and Europe PMC, published within the last 10 years. The articles selected for analysis focus on pediatric patients under 18 years of age who have undergone fixation for lateral condylar humerus fractures using either K-wire pins or screws. The inclusion criteria for the studies include comparisons of K-wire and screw fixation, prospective or retrospective designs, reporting of clinical outcomes such as healing time or complications, and availability in English or Indonesian.

The search for relevant studies was conducted using specific keywords across databases, including "lateral condyle fracture," "pediatric," "children," "pin," "screw," "K-wire," and "Kirschner wire." Duplicate studies were removed using the Rayyan.ai web application. The PICO framework was used to define the

study parameters, with the population being pediatric patients diagnosed with lateral condylar fractures, the intervention being K-wire fixation, the control being screw fixation, and the outcomes including clinical results such as delayed union, non-union, avascular necrosis, infection, stiffness, lateral overgrowth, and implant failure. The independent variable in this study is the fixation method, categorized into K-wire or screw fixation, while the dependent variables include clinical and radiological outcomes such as healing time, postoperative complications, and extremity function.

The research procedure began with a comprehensive literature search across electronic databases, followed by the removal of duplicates using Rayyan.ai. Studies meeting the inclusion criteria were selected for further analysis, focusing on comparisons of pin and screw fixation in pediatric lateral condylar fractures. Data from the selected studies were systematically extracted and analyzed. A meta-analysis was conducted using Review Manager 5.4 to compare the effectiveness of the two fixation methods. Pooled effect estimates and 95% confidence intervals were calculated for clinical outcomes, with statistical significance assessed using the Z-test and heterogeneity evaluated using Cochran's Q test and the I^2 statistic. A random-effects model was applied for heterogeneous outcomes.

The methodological quality of the included studies was assessed using the ROBINS-I tool, which evaluates bias in non-randomized studies based on factors such as confounding, selection bias, and outcome measurement. Studies were categorized as having low, moderate, serious, or critical risk of bias. Publication bias was assessed using Egger's and Begg's tests, visualized through funnel plots. The GRADE approach was used to assess the certainty of evidence, evaluating risk of bias, inconsistency, indirectness, imprecision, and publication bias, with evidence rated as very low, low, moderate, or high certainty. Operational definitions were established for key variables, including fixation method, delayed union, non-union, avascular necrosis, infection, stiffness, and lateral overgrowth. The research flow, illustrated in a diagram, outlines the steps from database search to final study inclusion, ensuring a systematic and transparent approach to comparing the outcomes of K-wire and screw fixation in pediatric lateral condylar humerus fractures.

RESULT

This study followed PRISMA guidelines and was registered in PROSPERO (CRD42024623611). Searches in PubMed (n = 192), Scopus (n = 101), and EMBASE (n = 111) yielded 404 studies. After removing 31 duplicates, 373 studies were screened. Based on title/abstract review, 352 were excluded, leaving 21 for full-text assessment. Ten studies were excluded: 1 on medial epicondyle fractures, 2 without screw fixation comparison, 1 with adult population, 4 lacking primary outcomes, and 2 as meeting abstracts. Eleven studies met inclusion criteria (Cummings et al., 2023; Gilbert et al., 2016; Wendling-Keim et al., 2021; Ganeshalingam et al., 2018; Li and Xu, 2012; Stein et al., 2017; Afaque and Singh, 2020; Pabin Thapa et al., 2019; Ranjan et al., 2018; Su, Chen, and Qin, 2019; Vergara and Fretes, 2023).

Ganeshalingam (2018) showed percutaneous K-wire/screw fixation was effective for non-displaced fractures, with a lateral approach for open reduction (235 vs. 101 patients). Gilbert (2016) used a lateral approach (43 vs. 41 patients). Li (2012) reported a lateral approach (30 vs. 32 patients). Stein (2017) used closed reduction (22 vs. 26 patients). Wendling-Keim (2021) employed open reduction (21 vs. 22 patients). Afaque (2020) used a lateral approach (19 vs. 21 patients). Thapa (2019) did not specify the approach (23 vs. 23 patients). Ranjan (2010) used open reduction (22 vs. 20 patients). Su (2019) reported open reduction (43 vs. 43 patients). Cummings (2023) used a lateral approach in a large cohort (553 vs. 209 patients). Navarro (2023) also used a lateral approach (19 vs. 11 patients). Fracture types included Milch I (97 vs. 35), Milch II (231 vs. 167), Jakob type 1 (94 vs. 22), Jakob type 2 (272 vs. 161), and Jakob type 3 (293 vs. 130).

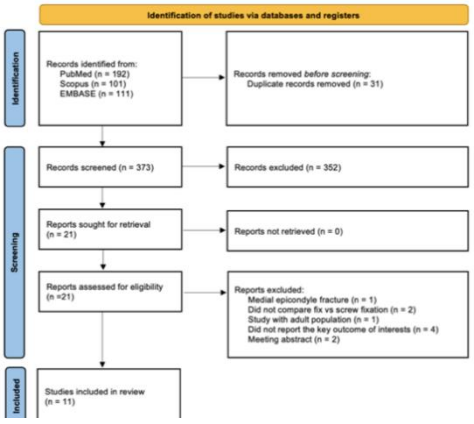

Figure 1. Identification of Studies

The rates of non-union for pin and screw fixation are relatively low and comparable, with non-union rates reported at approximately 2.4% for pin fixation and 1.3% for screw fixation (Cummings et al., 2023). Although screw fixation is often considered biomechanically more stable, the difference in non-union rates between the two techniques is not statistically significant. However, this study found that the risk of non-union was 2.78 times higher in patients undergoing screw fixation compared to pin fixation, although this result was not statistically significant (p = 0.19) due to the confidence interval including 1. Low heterogeneity (I^2 = 36%) indicates good consistency among the analyzed studies.

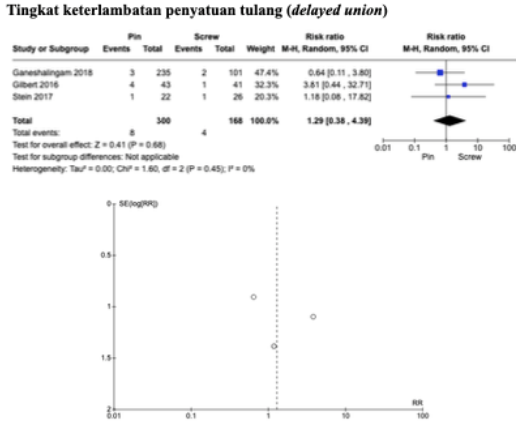

Figure 2. Delayed Union

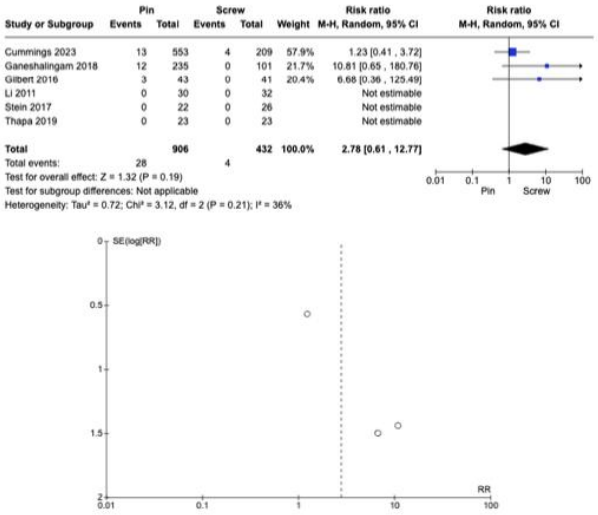

Figure 3. Meta-analysis for the rate of bone non-union

DISCUSSION

This meta-analysis aimed to compare the outcomes of managing pediatric lateral condylar humerus fractures using pin fixation versus screw fixation. The study provides a comprehensive evaluation of associated risks, including delayed union, non-union, avascular necrosis, infection, stiffness, and lateral overgrowth. While some results suggest potential advantages of one method over the other, others show no significant differences, reflecting the complexity of selecting the optimal fixation method for this condition.

Lateral condylar fractures in the pediatric population are common elbow injuries, accounting for 12–20% of all elbow fractures in children (Tejwani, Phillips, & Goldstein, 2011). These injuries are typically caused by indirect forces applied to the elbow during a fall on an outstretched hand, involving angular and rotational forces. The primary challenge in managing these fractures is ensuring proper alignment and stability to support the healing process, as inadequate fixation can lead to complications such as delayed union. The two commonly used fixation techniques—pins and screws—each have their advantages and disadvantages. Previous studies have shown that fractures treated with pins have a delayed union rate of 16%, while screw fixation significantly reduces this risk, with success rates reaching 85–95% (Birkett, Al-Tawil, & Montgomery, 2020b). However, this study found no statistically significant difference in the risk of delayed union between pin and screw fixation. This is supported by an I^2 value of 0%, indicating no heterogeneity

among the analyzed studies. Thus, while other findings support the superiority of screws in reducing delayed union, this study suggests that the difference between the two methods may not be statistically significant in certain cases.

The risk of avascular necrosis with pin fixation tends to increase in more complex fractures, such as Milch Type III fractures, and when open reduction techniques are used (Shabtai et al., 2020). Although specific rates of avascular necrosis for pin fixation are not well-documented in the literature, this method is known to carry risks of complications, including avascular necrosis. On the other hand, screw fixation is generally associated with lower rates of avascular necrosis. However, this meta-analysis found that the risk of avascular necrosis was 2.95 times higher in patients undergoing screw fixation compared to pin fixation, although this result was not statistically significant ($p = 0.33$) due to the wide confidence interval, which included 1. Zero heterogeneity ($I^2 = 0\%$) indicates high consistency among the studies.

Infection rates were reported to be higher with pin fixation compared to screw fixation. A previous study reported an infection rate of 1.8% in cases treated with closed reduction and pinning, while another study found that 2.5% of patients required oral antibiotics for infection (Weiss et al., 2009). Factors influencing infection rates include surgical technique, fracture type, and postoperative care. This meta-analysis found that the overall risk of infection was significantly higher in the pin fixation group compared to the screw fixation group, with a risk ratio (RR) of 6.53 (95% CI: 2.44–17.45), which was statistically significant ($p = 0.0002$) and supported by low heterogeneity ($I^2 = 0\%$).

Stiffness is a common complication following surgical intervention for lateral condylar fractures in children. Previous studies have reported stiffness in approximately 25% of cases after surgical intervention (Justus et al., 2017). However, this study found that pin fixation significantly increased the risk of stiffness compared to screw fixation, with an RR of 1.77 (95% CI: 1.26–2.48), which was statistically significant ($p = 0.001$) and supported by low heterogeneity ($I^2 = 0\%$).

Lateral overgrowth was reported in approximately 73% of children with lateral condylar fractures (Pribaz et al., 2012). However, this meta-analysis found no significant difference in the risk of lateral overgrowth between pin and screw fixation groups, with an RR of 1.19 (95% CI: 0.66–2.14), which was not statistically significant ($p = 0.56$) and supported by moderate heterogeneity ($I^2 = 20\%$).

Regarding fishtail deformity and cubitus varus, no significant differences were found between pin and screw fixation. The risk of fishtail deformity was similar for both methods, with an RR of 0.91 (95% CI: 0.22–3.68), which was not statistically significant ($p = 0.89$). Similarly, the risk of cubitus varus deformity did not differ significantly between the two methods, with an RR of 1.66 (95% CI: 0.26–10.51), which was not statistically significant ($p = 0.59$).

Overall, the results of this meta-analysis indicate that while there are differences in some clinical aspects between pin and screw fixation, many outcomes are not statistically significant. This reflects the complexity of selecting the optimal fixation method for lateral condylar fractures in children. Factors such as fracture type, surgical technique, and postoperative care must be carefully considered to minimize the risk of complications and ensure optimal outcomes.

CONCLUSIONS

This meta-analysis compared the outcomes of screw and pin fixation for pediatric lateral condylar humerus fractures. No significant difference was found in the risk of delayed union between the two methods. However, screw fixation showed a tendency for higher non-union and avascular necrosis risks, though these differences were not statistically significant. In contrast, pin fixation was associated with significantly higher risks of infection (RR 6.53, $p = 0.0002$) and stiffness (RR 1.77, $p = 0.001$). No significant differences were observed in lateral overgrowth, fishtail deformity, or cubitus valgus between the two methods. Overall, pin fixation had a higher risk of complications, but this difference was not statistically significant. Most studies had low risk of bias, indicating reliable results, though caution is needed when interpreting studies with moderate bias. These findings highlight the need for careful consideration of fixation methods based on patient-specific factors.

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