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(REVIEW ARTICLE)

Surgical strategies for treating distal diaphyseal metaphyseal fractures of the forearm in pediatric patients: A review of the current literature

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Abstract

Introduction: Distal diaphyseal metaphyseal fractures of the forearm have always represented a challenge in pediatric orthopedic management due to their location in an anatomical transition zone with little remodeling potential and without a defined therapeutic consensus, therefore this article aims to critically analyze the recent scientific literature regarding the surgical alternatives available for the treatment of these fractures in children, Methodology for this, a systematic review of the literature was carried out in databases such as PubMed, Scopus and ScienceDirect, including articles published between 2010 and 2024, using MeSH terms such as "Forearm Fractures", "Pediatric", "Metaphyseal-diaphyseal junction" and "Elastic intramedullary nailing" which allowed the selection of original studies, systematic reviews and relevant clinical guidelines, among the most relevant results it was found that multiple therapeutic options are highlighted, including fixation with Kirschner nails, osteosynthesis plates and antegrade elastic intramedullary nailing (a-ESIN) the latter has gained relevance due to its lower rate of refractures and faster functional recovery despite the potential risks to the posterior interosseous nerve. This allowed us to conclude that antegrade elastic intramedullary fixation is emerging as a safe and effective technique for the management of pediatric distal diaphysometaphyseal fractures, but more controlled and multicenter studies are required to consolidate the evidence.

Keywords: Intramedullary fixation; Pediatric orthopedics; Diaphysometaphyseal area; Surgical treatment; ESIN

1. Introduction

Currently, forearm fractures represent one of the most common trauma diagnoses in the pediatric population with an incidence between 20% and 25% of all childhood fractures treated in emergency services and pediatric orthopedics (Bae, 2008), of these approximately between 75% and 84% affect the distal third of the forearm, which underlines the clinical importance of this anatomical location (García-Rueda et al., 2023). It should be noted that within this group, distal diaphysometaphyseal fractures of the radius constitute a significant diagnostic and therapeutic challenge since this transition zone between the diaphysis and the distal metaphysis presents a combination of anatomical and biomechanical characteristics that limit both the capacity for bone remodeling and the stability of traditional fixation methods (Stark et al., 2024).

Likewise, the bone geometry in this region is characterized by a reduced medullary diameter, a thicker cortex, and a greater distance from the distal physis, which decreases the bone's self-correction capacity in the event of poor alignment. According to Lam et al., 2023, clinically, these fractures usually occur in active children, generally of school

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age, as a result of falls on an outstretched hand or direct high-energy trauma, which is why the therapeutic approach to these injuries has evolved in recent decades, but controversies still persist regarding the most appropriate surgical technique to achieve correct alignment, stability, and rapid functional recovery (Golder et al., 2023).

Despite the increasing incidence reported in recent literature, scientific evidence on the optimal management of these fractures remains limited. National epidemiological studies, such as those by Cortés et al. (2022) and García-Rueda et al. (2023), highlight that, in Colombia, fractures of the distal radius are the most prevalent among the pediatric population, with figures ranging from 15.7% to 31.9% depending on the hospital setting. The therapeutic challenge lies in the absence of consensual clinical guidelines and the variability of surgical criteria used by different pediatric orthopedic specialists. This lack of standardization has led to the choice of technique depending largely on the surgeon's experience, the availability of resources, and the individual characteristics of each patient.

In this context, this literature review aims to critically analyze the different surgical strategies described for the treatment of distal radial diaphyseal fractures in the pediatric population, identifying their advantages, limitations, and the level of available evidence, with the aim of contributing to informed clinical decision-making and improving outcomes in this vulnerable population.

2. Methodology

To prepare this narrative review of the literature, an exhaustive search was carried out in electronic databases. PubMed, Scopus, and ScienceDirect, which are recognized for their broad reach in biomedical and scientific publications, thus emerged a search strategy that included articles published between January 2010 and May 2024, thus ensuring the inclusion of updated and relevant evidence on the topic.

To carry out the search, the following combinations of MeSH (Medical Subject Headings) terms and key descriptors were used: “Forearm Fractures”, “Pediatric”, “Metaphyseal-diaphyseal junction”, “Elastic intramedullary nailing”, and “Pediatric radius fractures” terms. In addition, Boolean operators such as AND and OR were used to broaden or refine the results, according to the needs of each specific search.

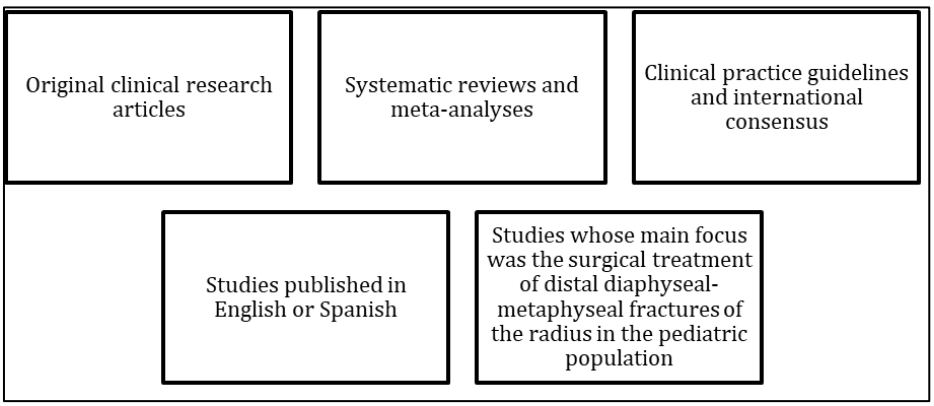

Figure 1 Inclusion criteria

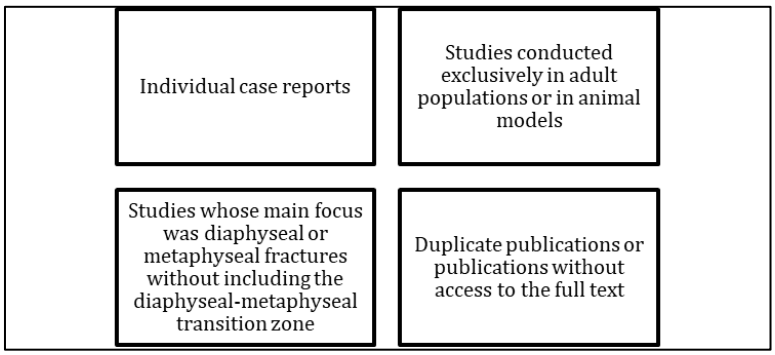

Figure 2 Exclusion criteria

The selection process was carried out in three phases:

- Review of titles and abstracts: 98 potentially relevant articles were initially identified.
- Full-text evaluation: After the review, 55 articles that did not meet the inclusion criteria were discarded.
- Final selection: 25 studies were ultimately included, considered to be of sufficient methodological quality and relevant to the objectives of this review. The quality of the selected studies was assessed according to the criteria of the Oxford Centre for Evidence-Based Medicine (OCEBM, 2011) evidence scale.

The types of studies included large case series, comparative cohort studies, systematic reviews, and high-impact narrative review articles that specifically addressed the surgical techniques used, clinical outcomes, complication rates, and current recommendations for the management of distal diaphyseal metaphyseal fractures of the forearm in children. This methodological process ensured the inclusion of relevant, current, and scientifically rigorous information, providing a solid basis for the analysis and discussion of the findings.

3. Review results

The review of the literature shows the absence of an international consensus regarding a single and standardized therapeutic protocol for the management of distal diaphysometaphyseal fractures of the radius in the pediatric population. Most of the available studies agree in highlighting the anatomical and biomechanical complexity of this region, which makes it difficult to apply conventional strategies and requires individualizing the treatment in each case (Lieber and Sommerfeldt, 2011; Stark et al., 2024; Dietzel et al., 2024).

Regarding Kirschner nail fixation, it has been for decades the technique of choice for distal metaphyseal fractures of the radius in children due to its low cost, easy availability, and short learning curve (Bae, 2008; Slongo et al., 2007). In the context of diaphysometaphyseal fractures, the literature points out multiple limitations, among which the technical difficulty in obtaining sufficient anchorage in the proximal fragment stands out, as well as the risk of implant migration and fixation instability, especially in oblique or multifragmentary fractures (Lieber et al., 2010; Dietzel et al., 2024), which contrasts with a study by Kubiak et al. (2019) reported a 22% reduction loss rate in patients treated with K-wires in fractures located in this transition zone.

For its part, plate osteosynthesis has been proposed as an alternative to achieve rigid fixation and maintain adequate anatomical reduction, especially in comminuted fractures or those with an unstable pattern (Lam et al., 2023; Stark et al., 2024). Its use in children poses several drawbacks: high risk of refracture after plate removal (up to 30% according to Stark et al., 2024), need for a second surgery to remove the implant, longer surgical time, and greater damage to soft tissues (Stark et al., 2024; Dietzel et al., 2024). In addition, in very distal fractures, the length of the distal fragment may be insufficient to accommodate more than two screws, compromising the stability of the construct (Lam et al., 2023).

On the other hand, antegrade elastic intramedullary nailing (a-ESIN) has gained prominence in the last decade as a safe and minimally invasive technique for the treatment of these fractures (Du and Han, 2023; Dietzel et al., 2024). Its main advantages include shorter surgical time, lower refracture rate (reported between 5% and 7%), better control of the fracture site, and rapid functional recovery (Lam et al., 2023; Stark et al., 2024).

Historically, the main fear regarding this technique was the risk of injury to the posterior interosseous nerve (PIN) given the proximity of the approach to the radial neck (Thomson, 1982; Du and Han, 2023). Recent studies have shown that, following a careful posterolateral approach and under fluoroscopic control, the risk of neurological injury is considerably reduced (Dietzel et al., 2024; Lam et al., 2023). Evidenced in a series published by Dietzel et al. (2024), the a-ESIN technique showed consolidation rates greater than 95%, with a low rate of neurological and functional complications.

In complex cases or in multifragmentary fractures, external fixation can be used as a salvage option, although it is less frequent due to its discomfort and the risk of infection of the pins (Stark et al., 2024). On the other hand, the use of the short intramedullary nail (S-ESIN), which allows the management of distal segments with shorter implants, has recently been described as a useful alternative, especially in fractures where the length of the distal fragment limits the application of other techniques (Dietzel et al., 2024).

4. Discussion

The surgical management of distal diaphyseal and metaphyseal fractures of the forearm in the pediatric population remains a widely debated and lacking consensus topic in the international orthopedic literature. The complexity of these injuries lies in their anatomical location in the transition zone between the diaphysis and metaphysis, characterized by a reduced capacity for bone remodeling and significant biomechanical challenges in achieving stable and lasting fixation.

The choice of the ideal treatment depends on multiple variables, including the patient's age, the degree of displacement, angulation, the fracture pattern, and the presence of associated injuries (Bae, 2008). Current AO Pediatric Trauma guidelines recommend that the surgical decision be individualized, also considering the surgeon's experience and the availability of resources (Jozsa et al., 2020).

Regarding surgical techniques, fixation with Kirschner wires (K-wires) has been traditionally used in distal metaphyseal fractures due to its low cost and relative ease of application. However, its use in diaphysometaphyseal fractures presents clear limitations, such as the difficulty in achieving adequate stability in the proximal fragment, greater risk of loss of reduction and a higher rate of postoperative complications (Lieber et al., 2010).

Plate osteosynthesis offers rigid fixation, allowing precise anatomical reduction, but its use in the pediatric population is controversial due to the need for a second surgery to remove the implant and the increased risk of refracture after extraction, which reaches up to 30% according to recent studies. In addition, the limited number of screws that can be placed in the distal fragment represents a significant technical challenge to ensure adequate stability of the assembly (Lam et al., 2023).

On the other hand, elastic stable intramedullary nailing (ESIN), specifically through an antegrade approach (a-ESIN), has gained recognition as an effective and less invasive alternative in the treatment of these fractures. This technique allows reducing surgical time, minimizing soft tissue damage and facilitating earlier functional recovery. However, one of the main historical fears regarding its use has been the risk of injury to the posterior interosseous nerve (PIN), especially when the nail is entered improperly (Du and Han, 2023).

Regarding recent biomechanical studies have shown that the application of the a-ESIN technique using a safe posterolateral approach and under fluoroscopic control can significantly minimize this risk, without compromising the stability of the fixation. Likewise, the evidence published by Du and Han (2023) and Jozsa et al. (2020) shows favorable functional results, with adequate consolidation rates and a low incidence of neurological complications.

A critical aspect highlighted in the current discussion is the lack of randomized controlled trials directly comparing the different surgical techniques available for this type of fracture. Most of the available evidence comes from retrospective case series or narrative reviews, which limits the quality of clinical recommendations (Kubiak et al., 2019). Therefore, technique selection should be based on an individual assessment of the case, considering anatomical, biomechanical, and clinical aspects, as well as the preferences and experience of the treating surgical team.

It is also important to highlight the need for medium and long-term follow-ups that allow for the evaluation of not only bone consolidation and radiographic alignment, but also functional recovery and patient and family satisfaction. Finally, the development of multicenter studies, with robust methodology and multivariate analysis of clinical outcomes, will be essential to establish evidence-based management guidelines for this type of fractures in the pediatric population (Stark et al., 2024).

5. Conclusion

The literature review carried out shows that antegrade elastic intramedullary fixation (a-ESIN) represents a promising surgical option for the treatment of distal diaphysometaphyseal fractures of the radius in the pediatric population. Its careful application allows reducing surgical times, avoiding complications and achieving early functional recovery. However, given the heterogeneity of the available studies and the absence of randomized controlled clinical trials, further multicenter research is required to establish standardized and robust management algorithms.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that there are no financial, personal or professional conflicts of interest related to the preparation of this manuscript.

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