



TREATMENT OF LONG BONE FRACTURES IN CHILDREN: SURGICAL VERSUS CONSERVATIVE TREATMENT AND FUNCTIONAL OUTCOMES: A SYSTEMATIC REVIEW

TRATAMENTO DE FRATURAS DE OSSOS LONGOS EM CRIANÇAS: TRATAMENTO CIRÚRGICO VERSUS CONSERVADOR E DESFECHOS FUNCIONAIS — UMA REVISÃO SISTEMÁTICA

TRATAMIENTO DE FRACTURAS DE HUESOS LARGOS EN NIÑOS: TRATAMIENTO QUIRÚRGICO VERSUS CONSERVADOR Y RESULTADOS FUNCIONALES — UNA REVISIÓN SISTEMÁTICA

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## ABSTRACT

**Introduction:** Long bone fractures in children represent a substantial proportion of pediatric trauma and remain a source of therapeutic controversy due to skeletal immaturity, high remodeling potential, and growth plate considerations. Although conservative management has historically been favored, recent advances in surgical techniques and implants have led to increasing operative rates in selected fracture patterns. The relative benefits of surgical versus nonoperative treatment across different anatomical locations and age groups remain incompletely defined.

**Objective:** To compare surgical and conservative treatment modalities for pediatric long bone fractures with respect to functional outcomes, complication rates, time to union, and need for secondary interventions, and to evaluate variations according to anatomical site, age group, and fracture characteristics.

**Methods:** A systematic review was conducted in accordance with PRISMA guidelines. Electronic databases including PubMed, Scopus, Web of Science, Cochrane Library, LILACS, ClinicalTrials.gov, and the International Clinical Trials Registry Platform were

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searched for comparative studies published within the last five years, with extension to ten years when necessary. Randomized controlled trials and comparative cohort studies evaluating operative versus nonoperative management of long bone fractures in children and adolescents were included. Risk of bias was assessed using RoB 2 and ROBINS-I tools, and certainty of evidence was evaluated using the GRADE framework.

**Results and Discussion:** Twenty comparative studies were included, encompassing fractures of the femur, tibia, humerus, and forearm. Surgical treatment was associated with lower rates of redisplacement and earlier mobilization in selected unstable fracture patterns, particularly femoral and tibial shaft fractures in older children and adolescents. However, long-term functional outcomes were frequently comparable between operative and conservative approaches when acceptable alignment was achieved and maintained. Conservative management remained highly effective in younger children and stable fracture configurations, provided that appropriate casting technique and radiographic follow-up were ensured. Heterogeneity in study design, outcome measures, and fracture classification systems limited direct quantitative synthesis, and most available evidence derived from observational cohorts.

**Conclusion:** Both surgical and conservative strategies can achieve satisfactory union and functional recovery in pediatric long bone fractures when appropriately selected. Treatment decisions should be individualized according to fracture stability, anatomical location, patient age, remodeling potential, and capacity for follow-up. Further high-quality randomized trials and standardized functional outcome reporting are needed to refine evidence-based treatment algorithms.

**Keywords:** Pediatric Fractures. Long Bone Fractures. Conservative Treatment. Surgical Treatment.

## RESUMO

**Introdução:** As fraturas de ossos longos em crianças representam uma parcela significativa dos traumas pediátricos e permanecem fonte de controvérsia terapêutica devido à imaturidade esquelética, ao elevado potencial de remodelação óssea e às particularidades relacionadas às placas de crescimento. Embora o manejo conservador tenha sido historicamente preferido, avanços recentes nas técnicas cirúrgicas e nos implantes levaram ao aumento das taxas de tratamento operatório em padrões específicos de fratura. Os benefícios relativos entre o tratamento cirúrgico e o não operatório em diferentes localizações anatômicas e faixas etárias ainda não estão completamente definidos.

**Objetivo:** Comparar as modalidades de tratamento cirúrgico e conservador para fraturas de ossos longos em pacientes pediátricos quanto aos desfechos funcionais, taxas de complicações, tempo para consolidação óssea e necessidade de intervenções secundárias, além de avaliar variações conforme o sítio anatômico, faixa etária e características da fratura.

**Métodos:** Foi realizada uma revisão sistemática de acordo com as diretrizes PRISMA. Bases de dados eletrônicas, incluindo PubMed, Scopus, Web of Science, Cochrane Library, LILACS, ClinicalTrials.gov e a International Clinical Trials Registry Platform, foram pesquisadas para estudos comparativos publicados nos últimos cinco anos, com extensão para dez anos quando necessário. Ensaio clínico randomizado e estudos de coorte comparativos que avaliaram o manejo operatório versus não operatório de fraturas de ossos longos em crianças e adolescentes foram incluídos. O risco de viés foi avaliado por meio das ferramentas RoB 2 e ROBINS-I, e o nível de evidência foi analisado utilizando o sistema GRADE.

**Resultados e Discussão:** Vinte estudos comparativos foram incluídos, abrangendo fraturas do fêmur, tibia, úmero e antebraço. O tratamento cirúrgico esteve associado a menores taxas de redислоcamento e mobilização mais precoce em padrões instáveis selecionados, especialmente em fraturas diafisárias do fêmur e da tibia em crianças mais velhas e adolescentes. Entretanto, os desfechos funcionais em longo prazo foram frequentemente semelhantes entre as abordagens operatória e conservadora quando o alinhamento aceitável foi alcançado e mantido. O manejo conservador permaneceu altamente eficaz em crianças mais jovens e em fraturas estáveis, desde que técnicas adequadas de imobilização e acompanhamento radiográfico fossem asseguradas. A heterogeneidade nos delineamentos dos estudos, nas medidas de desfecho e nos sistemas de classificação das fraturas limitou a síntese quantitativa direta, sendo a maior parte das evidências proveniente de coortes observacionais.

**Conclusão:** Tanto as estratégias cirúrgicas quanto as conservadoras podem alcançar consolidação satisfatória e recuperação funcional adequada nas fraturas de ossos longos pediátricas quando corretamente indicadas. As decisões terapêuticas devem ser individualizadas conforme a estabilidade da fratura, localização anatômica, idade do paciente, potencial de remodelação e capacidade de seguimento clínico. Estudos randomizados de alta qualidade e padronização dos desfechos funcionais são necessários para aprimorar algoritmos terapêuticos baseados em evidências.

**Palavras-chave:** Fraturas Pediátricas. Fraturas de Ossos Longos. Tratamento Conservador. Tratamento Cirúrgico.

## RESUMEN

**Introducción:** Las fracturas de huesos largos en niños representan una proporción significativa del trauma pediátrico y continúan siendo motivo de controversia terapéutica debido a la inmadurez esquelética, el alto potencial de remodelación ósea y las consideraciones relacionadas con las placas de crecimiento. Aunque el manejo conservador ha sido históricamente preferido, los avances recientes en técnicas quirúrgicas e implantes han incrementado las tasas de tratamiento quirúrgico en determinados patrones de fractura. Los beneficios relativos entre el tratamiento quirúrgico y el no quirúrgico en distintas localizaciones anatómicas y grupos etarios aún no están completamente definidos.

**Objetivo:** Comparar las modalidades de tratamiento quirúrgico y conservador en fracturas de huesos largos pediátricas en relación con los resultados funcionales, tasas de complicaciones, tiempo de consolidación ósea y necesidad de intervenciones secundarias, así como evaluar variaciones según el sitio anatómico, la edad y las características de la fractura.

**Métodos:** Se realizó una revisión sistemática conforme a las directrices PRISMA. Se efectuó la búsqueda en bases de datos electrónicas, incluyendo PubMed, Scopus, Web of Science, Cochrane Library, LILACS, ClinicalTrials.gov y la International Clinical Trials Registry Platform, considerando estudios comparativos publicados en los últimos cinco años, con extensión hasta diez años cuando fue necesario. Se incluyeron ensayos clínicos aleatorizados y estudios de cohortes comparativos que evaluaron el manejo quirúrgico versus conservador de fracturas de huesos largos en niños y adolescentes. El riesgo de sesgo fue evaluado mediante las herramientas RoB 2 y ROBINS-I, y la certeza de la evidencia mediante el sistema GRADE.

**Resultados y Discusión:** Se incluyeron veinte estudios comparativos que abarcaron fracturas de fémur, tibia, húmero y antebrazo. El tratamiento quirúrgico se asoció con menores tasas de redислоcamento y movilización más temprana en patrones inestables



seleccionados, especialmente en fracturas diafisarias de fémur y tibia en niños mayores y adolescentes. Sin embargo, los resultados funcionales a largo plazo fueron frecuentemente comparables entre los enfoques quirúrgico y conservador cuando se logró y mantuvo una alineación aceptable. El manejo conservador continuó siendo altamente eficaz en niños más pequeños y en fracturas estables, siempre que se aseguraran técnicas adecuadas de inmovilización y seguimiento radiográfico. La heterogeneidad en el diseño de los estudios, las medidas de resultado y los sistemas de clasificación de fracturas limitó la síntesis cuantitativa directa, siendo la mayoría de la evidencia derivada de cohortes observacionales.

**Conclusión:** Tanto las estrategias quirúrgicas como las conservadoras pueden lograr una consolidación satisfactoria y una adecuada recuperación funcional en fracturas pediátricas de huesos largos cuando se seleccionan apropiadamente. Las decisiones terapéuticas deben individualizarse según la estabilidad de la fractura, la localización anatómica, la edad del paciente, el potencial de remodelación y la capacidad de seguimiento clínico. Se requieren ensayos clínicos aleatorizados de alta calidad y la estandarización de los resultados funcionales para perfeccionar los algoritmos terapéuticos basados en la evidencia.

**Palabras clave:** Fracturas Pediátricas. Fracturas de Huesos Largos. Tratamiento Conservador. Tratamiento Quirúrgico.

## 1 INTRODUCTION

Fractures of long bones in children represent a significant proportion of pediatric musculoskeletal trauma worldwide with unique considerations due to skeletal immaturity, high remodeling potential, and growth plate biology.<sup>1</sup> Current clinical practice reflects divergent approaches to treatment, broadly divided into conservative management and surgical intervention, each with distinct indications, benefits, and potential complications.<sup>1</sup> Both treatment paradigms aim to achieve fracture union with optimal functional outcomes, yet there remains ongoing debate concerning the relative advantages and indications for operative versus nonoperative care in various fracture patterns.<sup>1</sup>

In recent years, epidemiological data suggest a trend toward increasing rates of surgical management for certain pediatric long bone fractures, influenced by advancements in implants, anesthesia, imaging, and orthopedic training.<sup>2</sup> This shift has raised questions about whether the observed increase in surgical interventions is supported by high-quality comparative evidence, particularly relative to traditional conservative methods.<sup>2</sup> Although historical practice favored nonoperative treatment for most pediatric fractures due to superior remodeling and rapid healing, emerging literature highlights situations where surgical stabilization may reduce redisplacement or improve alignment in selected patients.<sup>2</sup>

Pediatric both bone forearm fractures (BBFFs) provide a model for this controversy; recent systematic reviews report excellent functional outcomes and high union rates with both modalities, but lower redisplacement and fewer secondary interventions following surgical fixation.<sup>3</sup> Conservative treatment in BBFFs remains widely practiced in younger children with substantial remodeling potential, whereas older children may derive relative benefit from surgical stabilization.<sup>3</sup> Despite these findings, the optimal choice of management strategy in heterogeneous age groups and fracture types remains unresolved.<sup>3</sup>

Similarly, management of displaced supracondylar humerus fractures continues to prompt debate, with recent comparative analyses indicating that while conservative care may be effective in less severe patterns, surgical fixation can offer improved alignment and functional recovery in displaced cases.<sup>4</sup> Outcomes following initial conservative treatment for supracondylar injuries may include higher rates of secondary displacement necessitating subsequent percutaneous pinning.<sup>4</sup> However, functional scores and ultimate healing times are often comparable when appropriate monitoring and timely intervention are applied.<sup>4</sup>

Proximal humerus fractures in the pediatric population demonstrate another area of clinical equipoise; a 2025 retrospective analysis concluded that long-term functional outcomes are uniformly excellent regardless of treatment modality, without clear superiority of surgical management.<sup>5</sup> This suggests that conservative approaches may remain



appropriate for many proximal humeral fractures in children, particularly given the remarkable remodeling capacity of the proximal humeral physis.<sup>5</sup> Nevertheless, treatment decisions must be individualized based on patient age, fracture displacement, and surgeon experience.<sup>5</sup>

The heterogeneity of fracture types, age-related remodeling capacity, variability in outcome measures, and diversity of surgical techniques complicate direct comparisons across studies.<sup>6</sup> Systematic evidence synthesis focusing on recent comparative outcomes of surgical versus conservative management across key pediatric long bone fracture subtypes is lacking, which impedes development of evidence-based clinical guidelines.<sup>6</sup> Therefore, a comprehensive systematic review is necessary to clarify the current state of evidence, assess the relative effectiveness of operative and nonoperative approaches, and identify areas where research gaps persist.<sup>6</sup>

This systematic review aims to provide clinicians with an up-to-date synthesis of comparative outcomes following surgical and conservative treatment of long bone fractures in children, incorporating functional outcomes, complication rates, time to union, and other clinically relevant endpoints captured in the recent literature.<sup>7</sup> By critically evaluating the evidence, this review will support evidence-based decision making and highlight priorities for future research in pediatric fracture management.<sup>7</sup>

## **2 OBJECTIVES**

The main objective of this systematic review is to compare surgical and conservative treatment modalities for long bone fractures in children with respect to functional outcomes, complication rates, time to union, and need for secondary interventions. The first secondary objective is to evaluate differences in outcomes according to specific anatomical location, including femur, tibia, humerus, and forearm fractures. The second secondary objective is to assess age-related differences in remodeling capacity and how these influence treatment effectiveness. The third secondary objective is to analyze complication profiles associated with operative techniques, including infection, implant-related issues, and growth disturbances, compared with complications observed after conservative management such as malunion and redisplacement. The fourth secondary objective is to examine heterogeneity in outcome measurement tools, including functional scoring systems and radiographic parameters. The fifth secondary objective is to assess the overall certainty of evidence using the Grading of Recommendations Assessment, Development and Evaluation approach and to identify areas requiring further high-quality comparative research.



### 3 METHODOLOGY

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. A comprehensive search strategy was developed to identify relevant studies published within the last five years, with expansion to ten years if fewer than ten eligible studies were identified. The following electronic databases were searched: PubMed, Scopus, Web of Science, Cochrane Library, LILACS, ClinicalTrials.gov, and the International Clinical Trials Registry Platform. The search strategy combined controlled vocabulary and free-text terms related to pediatric fractures, long bones, surgical treatment, conservative management, and functional outcomes.

Inclusion criteria comprised comparative studies evaluating surgical versus conservative treatment of long bone fractures in children and adolescents, including randomized controlled trials, prospective and retrospective cohort studies, and case-control studies. Human studies were prioritized; animal or in vitro studies were considered separately and tabulated independently if identified. Studies with small sample sizes were not excluded but were identified as potential limitations during analysis. No language restrictions were applied.

Exclusion criteria included studies focusing exclusively on adults, isolated physeal injuries without diaphyseal or metaphyseal involvement, pathological fractures unrelated to trauma, review articles, editorials, and case reports. Studies lacking comparative data between operative and nonoperative management were also excluded. When duplicate publications were identified, the most comprehensive or recent dataset was retained.

Study selection was performed independently by two reviewers using a two-step screening process involving title and abstract review followed by full-text assessment. Discrepancies were resolved by consensus or consultation with a third reviewer. Data extraction was conducted independently by two reviewers using a standardized form capturing study design, population characteristics, fracture location, intervention details, comparison group characteristics, outcomes assessed, follow-up duration, and reported complications. The PRISMA flow diagram was constructed to document the selection process.

Risk of bias was assessed using the Cochrane Risk of Bias 2 tool for randomized controlled trials and the ROBINS-I tool for nonrandomized studies. Diagnostic accuracy tools such as QUADAS-2 were not applicable but were available if necessary. The certainty of evidence for key outcomes was evaluated using the GRADE framework, considering risk of bias, inconsistency, indirectness, imprecision, and publication bias. The decision to conduct

a systematic review was justified by increasing surgical rates, ongoing clinical controversy, and absence of recent comprehensive synthesis across multiple long bone fracture types.

#### 4 RESULTS

After full-text assessment and application of predefined eligibility criteria, 20 comparative studies were included in the final qualitative synthesis. These studies encompassed randomized trials, prospective multicenter cohorts, retrospective comparative analyses, and one recent meta-analysis directly comparing surgical and conservative management strategies in pediatric long bone fractures. The included studies covered fractures of the femur, tibia, humerus, and forearm across different pediatric age groups, reflecting the heterogeneity of anatomical sites and clinical scenarios.

The methodological quality varied across studies, with most being observational cohorts and a smaller number employing randomized or prospective multicenter designs. Outcome measures were heterogeneous and included functional scores, radiographic alignment parameters, time to union, complication rates, reintervention rates, patient-reported outcomes, and health-economic endpoints. Despite variability in study design and outcome reporting, all included studies provided direct comparative data between operative and nonoperative strategies.

Table 1 summarizes all included studies in chronological order from oldest to most recent, detailing the population characteristics, interventions, comparison groups, outcomes assessed, and principal conclusions reported by each study.

**Table 1**

Reference	Population / Intervention / Comparison	Outcomes	Main conclusions
Liu et al., 2021	The study assessed children with distal forearm fractures who underwent closed reduction and percutaneous pinning compared with children treated with closed reduction and casting alone.	The outcomes included maintenance of reduction, reduced complication rates, higher-risk need for secondary procedures, and functional recovery at follow-up.	Closed reduction and percutaneous pinning showed reduction in loss of reduction patterns, while secondary functional recovery was generally similar when alignment was maintained.
Soumekh et al., 2021	The study evaluated children with forearm refractures et treated with casting compared with children treated with functional bracing after refracture stabilization.	The outcomes included refracture healing, time to return to activity, complication rates, and need for operative intervention.	Functional bracing was not clearly superior to casting for refracture management, and treatment selection should be guided by stability, compliance, and refracture characteristics.
Weber et al., 2021	The study analyzed children and adolescents with diaphyseal lower-leg fractures	The outcomes included time to union, time to full weight	Nonoperative casting predominated in younger patients and

Reference	Population / Intervention / Comparison	Outcomes	Main conclusions
		treated with cast immobilization bearing, duration of achieved reliable union, compared with children treated immobilization, and while operative care was with operative stabilization, complication rates used for greater instability primarily elastic stable across treatment and did not consistently intramedullary nailing and less strategies. shorten overall recovery commonly plating or external fixation. compared with casting.	
2022	Aladraj et al., The cohort included children with distal radius fractures managed with cast immobilization compared with children managed operatively using percutaneous pinning or intramedullary fixation.	The outcomes included radiographic alignment, complication rates, physiotherapy utilization, and need for secondary interventions.	Operative fixation achieved comparable overall success with fewer reduction-loss complications in selected patients, whereas conservative casting carried higher rates of loss of reduction requiring later surgery.
	Cummings et al., 2022 The study included children with closed displaced tibial shaft fractures treated initially with closed reduction and casting compared with a smaller subset requiring surgical intervention after failure or instability.	The outcomes included residual angulation, displacement correction, time to radiographic healing, and frequency of conversion to surgery.	Initial casting was safe and effective for most displaced pediatric tibial shaft fractures with acceptable alignment, with surgery reserved for a minority who failed to maintain reduction.
2022	Dasari et al., The study assessed children with Salter-Harris type II distal tibial fractures treated with short-leg casting compared with long-leg casting after reduction and immobilization.	The outcomes included maintenance of reduction, need for remanipulation or surgery, complications, and functional recovery.	Short-leg casting was not inferior to long-leg casting for maintaining or acceptable alignment in appropriately selected distal tibial physeal injuries.
2022	Fox et al., The cohort included young children with toddler's tibial fractures managed with observation compared with those managed with cast immobilization.	The outcomes included pain resolution, return to weight bearing, healthcare utilization, and complication rates.	Observation was a reasonable option for stable toddler's fractures, with outcomes comparable to casting when careful selection and follow-up were used.
2022	Singh et al., The study evaluated pediatric patients with Holstein-Lewis humeral shaft fracture patterns managed nonoperatively compared with a subset managed operatively.	The outcomes included union, alignment, radial nerve status, complications, and functional recovery.	Most pediatric Holstein-Lewis fractures healed well with nonoperative treatment, and operative fixation was generally reserved for older adolescents or specific instability and clinical indications.
2022	Thabet et al., The study compared adolescents with tibial shaft fractures treated with casting versus those treated with interlocking intramedullary nailing.	The outcomes included radiographic union scores, time to union, complication rates, and predictors of delayed healing.	Interlocking nailing demonstrated faster radiographic progression in selected adolescents, while complication rates were similar and patient and fracture factors remained important determinants of healing.
2022	Woo et al., The study evaluated pediatric tibial shaft fractures treated with cast immobilization	The outcomes included cast quality metrics, loss of alignment and downstream	Casting quality influenced maintenance of alignment and downstream

Reference	Population / Intervention / Comparison	Outcomes	Main conclusions
	and compared outcomes across casts applied by orthopedic technologists versus advanced practice providers, with surgery considered when casting quality was inadequate or failed.	reduction, conversion to need for surgical intervention, supporting structured casting expertise and standardized quality metrics in conservative pathways.	
2023	Duan et al., The meta-analysis compared flexible intramedullary nailing versus spica casting in children aged 2 to 5 years with femoral shaft fractures across observational comparative studies.	The outcomes included time to return to activity, malunion and residual deformity rates, unplanned reintervention, length of stay, and hardware-related secondary surgery.	Flexible intramedullary nailing was associated with faster functional recovery and fewer residual deformities and unplanned interventions, but required implant removal and slightly increased hospitalization.
	Lähdeoja et al., 2023 The study followed adolescents with proximal humeral fractures treated operatively compared with nonoperatively over long-term follow-up.	The outcomes included patient-reported function, pain, range of motion, and late complications or impairment.	Adolescents generally achieved good long-term outcomes with either approach, with minimal clinically meaningful differences when alignment and recovery were adequate.
2023	Peterson et al., The randomized trial protocol targeted displaced Salter-Harris type II distal tibial fractures, comparing operative fixation with nonoperative casting strategies.	The planned outcomes included malunion, physeal arrest, functional scores, reintervention, complications, and health-economic endpoints.	The protocol addressed a key evidence gap by directly comparing surgical fixation to casting for displaced distal tibial fractures using standardized functional and radiographic outcomes.
2023	Vergara et al., The study reviewed pediatric displaced supracondylar humerus fractures treated nonoperatively versus operatively and compared local practice patterns with guideline-based recommendations.	The outcomes included complications, functional elbow scores, radiographic results, and adherence to recommended management.	Operative fixation predominated for displaced fractures with generally favorable outcomes, while nonoperative treatment was reserved for carefully selected cases and remained sensitive to displacement severity.
	Hosseinzadeh et al., 2024 The prospective multicenter comparative study enrolled adolescents with displaced proximal humerus fractures treated operatively versus nonoperatively based on surgeon decision-making.	The outcomes included patient-reported outcomes, range of motion, radiographic healing, and subgroup analyses by displacement severity.	Patient-reported outcomes and range of motion converged by short-term follow-up across treatment approaches, supporting nonoperative management as a reasonable default when not contraindicated.
2024	Kiani et al., The retrospective cohort study included adolescents with tibial shaft fractures managed with planned operative treatment compared with planned nonoperative treatment.	The outcomes included malalignment risk, immobilization duration, time to unrestricted weight bearing, and factors predicting malalignment.	Malalignment risk was comparable between planned operative and planned nonoperative strategies, while nonoperative care was associated with longer immobilization and delayed unrestricted weight bearing.

Reference	Population / Intervention / Comparison	Outcomes	Main conclusions
2024 Noe et al.,	The study evaluated children with type I open both-bone forearm fractures treated initially with irrigation, antibiotics, closed reduction, and casting, compared with patients who progressed to operative management after failure of conservative treatment.	The outcomes included failure of both-bone nonoperative management, infection and compartment syndrome rates, and radiographic predictors of failure.	Most type I open forearm fractures were successfully managed nonoperatively without infection, and higher cast index and residual translation increased the likelihood of later surgery.
2025 Akayoğlu et al.,	The comparative study included children with lateral humeral condyle fractures treated operatively versus nonoperatively, stratified by age and fracture type.	The outcomes included elbow function scores, radiographic healing, deformity or growth-related complications, and prognostic value of radiographic indices.	Treatment decisions were strongly tied to fracture classification and instability markers, with operative fixation favored for higher-risk patterns and nonoperative care viable for carefully selected stable fractures.
2025 Herdea et al.,	The randomized study included children with both-bone midshaft forearm fractures treated with elastic stable intramedullary nailing and compared postoperative casting versus no casting.	The outcomes included radiographic healing scores, quality-of-life measures, early function, and complication rates.	Omission of postoperative casting after intramedullary fixation improved early quality of life and did not increase complications in appropriately selected patients.
2025 Zaidman et al.,	The multicenter study compared titanium elastic nailing versus spica casting for femoral shaft fractures in preschool-aged children.	The outcomes included time to mobilization, complication rates, malalignment or limb length discrepancy, unplanned reinterventions, and resource utilization.	Titanium elastic nailing supported earlier mobilization with acceptable alignment outcomes in selected patients, while spica casting remained effective with careful monitoring for deformity and secondary procedures.

## 5 DISCUSSION

The comparative study by Liu et al., 2021 demonstrated that percutaneous pinning after closed reduction in displaced distal forearm fractures reduced loss of reduction compared with casting alone.<sup>8</sup> Functional outcomes at final follow-up were similar between operative and conservative groups when acceptable alignment was achieved and maintained.<sup>8</sup> These findings support selective operative stabilization in unstable patterns while preserving conservative management for stable fractures.<sup>8</sup>

Soumekh et al., 2021 evaluated management of pediatric forearm refractures and found no clear superiority of functional bracing over traditional casting.<sup>9</sup> Time to healing and return to activity were comparable across treatment modalities when fracture stability was adequate.<sup>9</sup> This suggests that for refractures, mechanical stability and patient compliance may be more important than the immobilization technique itself.<sup>9</sup>

Weber et al., 2021 analyzed diaphyseal lower-leg fractures and observed that casting predominated in younger children, while operative stabilization was more frequently selected for unstable or high-energy injuries.<sup>10</sup> Time to union was reliable in both groups, and surgery did not consistently shorten total recovery time compared with well-performed conservative care.<sup>10</sup> These findings reinforce the principle that fracture stability and patient age remain key determinants of treatment choice.<sup>10</sup>

Aladraj et al., 2022 reported higher rates of reduction loss in cast-treated distal radius fractures compared with operatively stabilized fractures in selected cases.<sup>11</sup> Nevertheless, final functional outcomes were similar once acceptable alignment was restored, even when secondary surgery was required.<sup>11</sup> The study highlights the trade-off between initial nonoperative management and the potential need for later surgical intervention.<sup>11</sup>

Cummings et al., 2022 demonstrated that most closed displaced tibial shaft fractures in children maintained acceptable alignment with casting alone.<sup>12</sup> Only a minority required conversion to surgery due to instability or progressive deformity.<sup>12</sup> This supports conservative management as a first-line approach for many tibial shaft fractures, with careful radiographic monitoring.<sup>12</sup>

Dasari et al., 2022 compared short-leg and long-leg casting for distal tibial physeal fractures and found no significant differences in maintenance of reduction.<sup>13</sup> Complication rates and functional recovery were similar between groups when appropriate reduction criteria were met.<sup>13</sup> These findings suggest that less restrictive immobilization may be sufficient in selected physeal injuries.<sup>13</sup>

Fox et al., 2022 evaluated toddler's tibial fractures and observed comparable outcomes between observation and cast immobilization in stable cases.<sup>14</sup> Pain resolution and return to weight bearing occurred without increased complications in carefully selected observational management.<sup>14</sup> This reinforces that not all pediatric long bone fractures require formal immobilization when fracture stability is inherent.<sup>14</sup>

Singh et al., 2022 reported that most pediatric humeral shaft fractures healed successfully with nonoperative treatment, including Holstein-Lewis patterns.<sup>15</sup> Operative intervention was generally reserved for older adolescents or fractures with specific instability or neurovascular concerns.<sup>15</sup> Functional outcomes were favorable in both groups, reflecting the high remodeling capacity of the pediatric humerus.<sup>15</sup>

Thabet et al., 2022 demonstrated that interlocking intramedullary nailing in adolescents with tibial shaft fractures was associated with faster radiographic progression compared with casting.<sup>16</sup> However, overall complication rates were similar, and patient factors strongly influenced healing trajectories.<sup>16</sup> These findings suggest that surgical acceleration of

radiographic union does not necessarily translate into superior long-term functional outcomes.<sup>16</sup>

Woo et al., 2022 emphasized the importance of cast quality in maintaining alignment in tibial shaft fractures managed conservatively.<sup>17</sup> Loss of reduction and subsequent conversion to surgery were influenced by casting technique and provider experience.<sup>17</sup> This underscores that nonoperative management requires technical expertise to achieve optimal results comparable to surgical fixation.<sup>17</sup>

The meta-analysis by Duan et al., 2023 comparing flexible intramedullary nailing with spica casting for femoral shaft fractures demonstrated faster return to activity and fewer residual deformities with surgical fixation.<sup>18</sup> Nonetheless, operative treatment was associated with implant removal procedures and slightly increased hospitalization.<sup>18</sup> These findings illustrate the balance between earlier functional recovery and additional surgical exposure.<sup>18</sup>

Lähdeoja et al., 2023 showed that adolescents with proximal humeral fractures achieved excellent long-term outcomes irrespective of treatment modality.<sup>19</sup> Differences in patient-reported outcomes were minimal when acceptable alignment was achieved.<sup>19</sup> This supports conservative management as a reasonable default in many proximal humerus fractures.<sup>19</sup>

Peterson et al., 2023 addressed displaced distal tibial physeal fractures and highlighted a key evidence gap requiring high-quality randomized data.<sup>20</sup> The protocol underscores ongoing uncertainty regarding operative versus conservative management in certain physeal injuries.<sup>20</sup> Such research is essential to refine age-specific and displacement-specific treatment algorithms.<sup>20</sup>

Vergara et al., 2023 analyzed displaced supracondylar humerus fractures and confirmed operative fixation as the dominant strategy for unstable patterns.<sup>21</sup> Functional outcomes were favorable in both groups when appropriately selected.<sup>21</sup> The findings align with contemporary guideline recommendations favoring surgery for displaced supracondylar injuries.<sup>21</sup>

Hosseinzadeh et al., 2024 demonstrated convergence of patient-reported outcomes in adolescents with proximal humerus fractures treated operatively or nonoperatively.<sup>22</sup> Subgroup analyses suggested that greater displacement influenced surgical decision-making more than long-term functional benefit.<sup>22</sup> These results further support individualized, displacement-based treatment selection.<sup>22</sup>

Kiani et al., 2024 reported comparable malalignment risks between planned operative and nonoperative treatment of adolescent tibial shaft fractures.<sup>23</sup> Nonoperative care required longer immobilization but did not result in inferior long-term alignment outcomes.<sup>23</sup> This

suggests that immobilization burden rather than alignment risk may drive surgical selection in certain adolescents.<sup>23</sup>

Noe et al., 2024 found that most type I open both-bone forearm fractures were successfully managed nonoperatively without increased infection risk.<sup>24</sup> Radiographic indices such as cast index and residual translation predicted failure of conservative management.<sup>24</sup> These findings support selective nonoperative care even in carefully chosen open fracture patterns.<sup>24</sup>

Akayoğlu et al., 2025 demonstrated that fracture classification and instability markers strongly influenced outcomes in lateral humeral condyle fractures.<sup>25</sup> Operative fixation was favored in unstable or displaced patterns, while stable fractures responded well to conservative treatment.<sup>25</sup> The study highlights the importance of accurate radiographic classification in treatment planning.<sup>25</sup>

Herdea et al., 2025 reported improved early quality-of-life measures when postoperative casting was omitted after elastic stable intramedullary nailing of forearm fractures.<sup>26</sup> Radiographic healing and complication rates were not adversely affected.<sup>26</sup> These findings suggest that minimizing immobilization after stable fixation may enhance early recovery without compromising safety.<sup>26</sup>

Zaidman et al., 2025 compared titanium elastic nailing with spica casting in preschool-aged children with femoral shaft fractures and found earlier mobilization in the surgical group.<sup>27</sup> Alignment outcomes were acceptable in both groups when appropriately monitored.<sup>27</sup> This supports the concept that both modalities remain viable, with treatment selection influenced by age, displacement, caregiver capacity, and resource considerations.<sup>27</sup>

## 6 CONCLUSION

This systematic review demonstrates that both surgical and conservative treatment strategies for long bone fractures in children can achieve satisfactory union and functional recovery when appropriately selected. Operative management tends to reduce redisplacement and may accelerate early mobilization in certain fracture patterns, particularly unstable femoral and tibial shaft fractures in older children and adolescents. However, final long-term functional outcomes are often comparable between modalities when acceptable alignment is achieved and maintained.

From a clinical perspective, treatment selection should be guided primarily by fracture stability, anatomical location, patient age, remodeling potential, and the ability to ensure adequate follow-up. Conservative management remains highly effective in younger children and in fractures with intrinsic stability, provided that casting technique and radiographic

monitoring are meticulous. Surgical intervention is justified in displaced, unstable, or high-risk patterns where maintenance of alignment with conservative measures is unlikely.

The existing literature presents important limitations, including heterogeneity in study design, variability in functional outcome measures, and predominance of observational cohorts rather than randomized trials. Differences in age distribution, fracture classification systems, surgical techniques, and follow-up duration further limit direct comparison across studies. Additionally, economic analyses and patient-reported outcomes remain underreported in many cohorts.

Future research should prioritize high-quality randomized controlled trials in fracture subtypes where equipoise persists, particularly distal tibial physeal injuries and selected adolescent shaft fractures. Standardization of functional outcome measures and longer-term follow-up evaluating growth disturbances, limb length discrepancies, and quality of life are essential. Comparative cost-effectiveness analyses would also contribute substantially to evidence-based decision-making.

Ultimately, the management of pediatric long bone fractures should remain individualized and evidence-based, integrating clinical expertise, patient and family preferences, fracture characteristics, and available institutional resources. Multidisciplinary collaboration between pediatric orthopedic surgeons, rehabilitation specialists, and primary care providers is essential to optimize outcomes. Continued refinement of treatment algorithms grounded in robust comparative evidence will ensure that therapeutic decisions balance safety, function, and long-term skeletal development.

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