

Management of Pediatric Diaphyseal Forearm Fractures: A Focused Systematic Review of Conservative and Operative Strategies

Panji Sananta¹, Respati S. Dradjat¹, Daylan Oscar Hermawan¹,
Aulia Pandu Aji¹, Bima Mahardhika Aji¹, Alexander Fernando¹

¹Department of Orthopaedic and Traumatology, Faculty of Medicine, Universitas Brawijaya
– Dr. Saiful Anwar General Hospital, Malang, Indonesia

Corresponding Author: Panji Sananta

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ABSTRACT

Introduction: Evidence specific to forearm fractures in children aged 2–5 years is limited, particularly regarding operative indications and the youngest age at which open reduction and internal fixation (ORIF) has been documented. This review synthesised age-specific evidence on shaft-involving forearm fractures in this population.

Methods: A focused systematic review was conducted in accordance with PRISMA 2020. Journal reports were eligible if they included children aged 2–5 years or a separately identifiable subgroup within this age range. ORIF was defined as explicit documentation of open fracture reduction and internal fixation in the same identifiable patient. Data were synthesised narratively because of heterogeneity in study design and outcomes.

Results: Three clinical reports met the eligibility criteria: one retrospective cohort and two case reports. In the cohort, 29 of 33 children aged 2–5 years underwent closed reduction and four underwent open reduction, but individual ages and fixation devices were not reported. A 4-year-old case involved median nerve exploration and reconstruction rather than fracture ORIF.

The youngest explicitly documented fracture ORIF was in a 5-year-old, in whom failed closed reduction was followed by plate fixation of the radius, with complete union and full motion at 12 weeks. No exact-age comparative evidence established superiority of casting or any fixation technique.

Conclusion: Evidence in children aged 2–5 years remains limited. Five years was the youngest verifiable ORIF age, not a minimum operative threshold. Management should be individualised according to fracture reducibility, stability, morphology, neurovascular status, and associated injuries.

Keywords: closed fracture reduction, forearm fracture, internal fixation, open fracture reduction, preschool children.

INTRODUCTION

Forearm fractures are common childhood injuries, but evidence specific to children aged 2–5 years is rarely reported separately. Diaphyseal injuries are clinically important because malalignment can affect radial bow, interosseous space, and forearm rotation. This review therefore applies an exact-age criterion and reports a youngest operative age only when an individual journal report

explicitly documents open reduction together with internal fixation (ORIF).^[1-3] The available reports do not provide a direct comparison of successful casting with primary fixation in preschool children. Aprato and colleagues reported a separately identifiable 2-5-year subgroup, but did not provide individual ages or an age-by-fixation cross-tabulation for the four open reductions. Zabane et al. described nerve surgery in a 4-year-old, not fracture ORIF. Ang et al. explicitly documented plate ORIF in a 5-year-old. Thus, five years is the youngest verifiable age for fracture ORIF in the retained evidence, not a minimum age for surgery.

Within the exact-age evidence set, operative treatment was used only after an acceptable reduction could not be obtained or when the injury pattern required selective fixation. The reports therefore inform indications and safety signals rather than routine primary surgery. In a 2-5-year-old, reducibility, maintenance of alignment, neurovascular status, and associated injuries remain the practical determinants of treatment.^[1-3] The clinical question is especially relevant at 2-5 years because treatment decisions must balance remodelling potential against cast stability, repeated anaesthesia, implant-related procedures, and the difficulty of assessing nerve function in a young child. The exact-age reports allow these issues to be described without borrowing outcome estimates from older children.

After strict age screening, only three clinical journal reports met the prespecified criterion. Aprato et al. reported a 2-5-year surgical subgroup^[1]; Zabane et al. reported a 4-year-old with delayed median nerve entrapment^[2]; and Ang et al. reported a 5-year-old with multiple ipsilateral upper-limb fractures.^[3] Only the Ang case states both the child's exact age and fracture ORIF technique. This review aimed to synthesise the available journal evidence on shaft-involving forearm fractures in children aged 2–5 years and to determine the youngest age at which fracture ORIF was explicitly documented. Secondary objectives were to

describe reported management pathways and complications and to identify limitations in the available evidence arising from incomplete patient-level age, fracture, and fixation data.

METHODS

Design and Reporting

This focused systematic review was conducted and reported in accordance with the PRISMA 2020 framework.^[4] The review was designed to identify clinical journal reports specifically addressing forearm fractures in children aged 2–5 years. The database counts presented in Figure 1 are provisional estimates because archived search exports were not available for verification.

Eligibility and evidence roles

Journal articles reporting clinical data on paediatric forearm fractures were eligible if they included individual patients aged 2–5 years or presented a separately identifiable subgroup within this exact age range. Eligible reports could describe closed reduction and casting, operative reduction or fixation, or treatment-related complications. Studies were excluded if participants aged 2–5 years could not be identified separately, if the fracture did not involve the forearm shaft, or if the publication did not provide original clinical data. Broader paediatric cohorts, narrative reviews, and studies reporting only pooled age data were therefore excluded from the clinical synthesis. PRISMA and methodological appraisal publications were used only as methodological references.^[4-6] For this review, open reduction and internal fixation (ORIF) was defined as explicit documentation of both open fracture reduction and internal fixation in the same identifiable patient. Open reduction without internal fixation, closed fixation, and procedures directed solely at nerve pathology were not classified as fracture ORIF.

Data extraction

For each included report, data were extracted on study design, number and age of eligible children, fracture characteristics, reduction method, fixation technique or device, follow-up, clinical outcomes, complications, and reported limitations. The youngest age at ORIF was recorded only when the patient's exact age and the use of both open reduction and internal fixation were explicitly linked at the individual-patient level. No operative age or treatment outcome was inferred from aggregated age ranges.

Methodological appraisal

The retrospective cohort study was appraised using the ROBINS-I framework, including assessment of confounding, participant selection, intervention classification, missing data, outcome

measurement, and selective reporting.^[5] Case reports were evaluated using the JBI critical appraisal criteria for case reports.^[6] These assessments were used to inform interpretation of the evidence rather than to estimate comparative treatment effects.

Data synthesis

Meta-analysis was not performed because of substantial heterogeneity in study design, fracture characteristics, treatment pathways, and reported outcomes. Findings were synthesised narratively according to operative management, the youngest documented use of ORIF, complex injury management, neurological complications, and limitations of the available evidence. Evidence from broader paediatric age groups was not used to derive age-specific treatment outcomes for children aged 2–5 years.

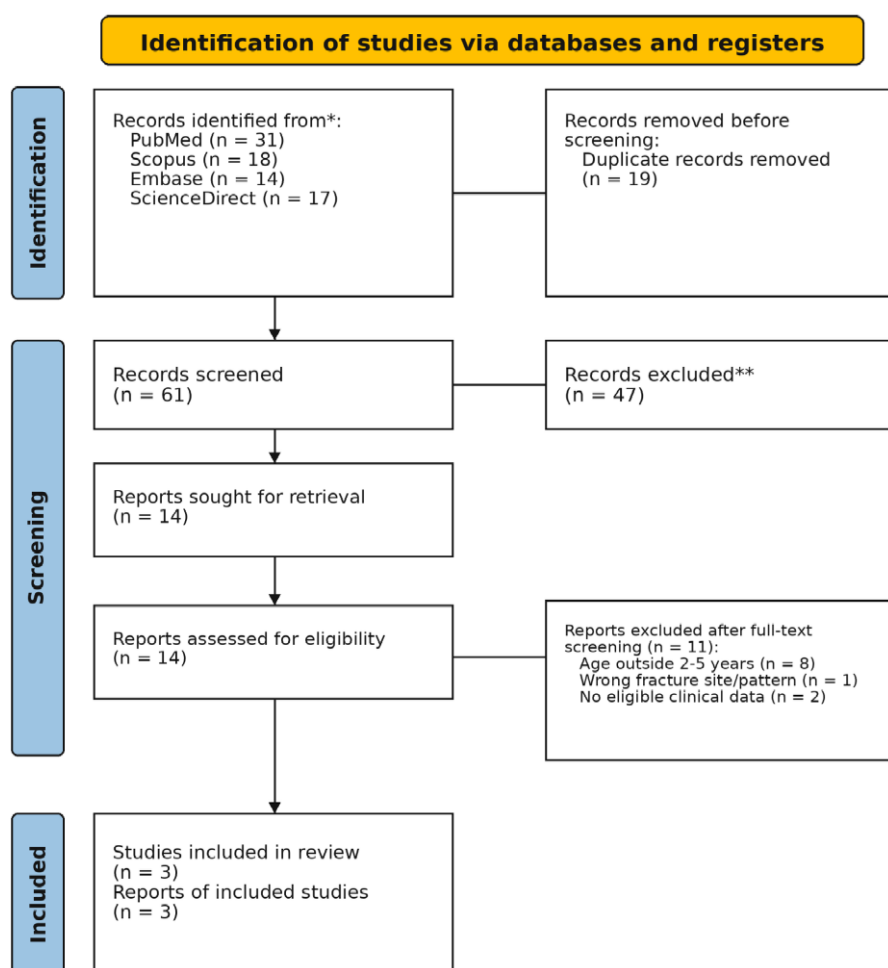


Figure 1. PRISMA flow diagram of study selection for children aged 2-5 years

RESULTS

Study selection and characteristics

Three clinical reports met the exact-age eligibility criteria: one retrospective cohort with a separately reported subgroup of children aged 2–5 years and two case reports involving children aged 4 and 5 years. The included reports differed

substantially in study design, treatment context, and reported outcomes. Only one report explicitly linked an individual patient's exact age with open fracture reduction and internal fixation. The characteristics and age-specific contributions of the included studies are summarised in Table 1.

Table 1. Characteristics and key findings of the included clinical reports.

Study	Design and population	Target-age data	Treatment and principal findings	Relevance to ORIF age
Aprato et al. 2025 ^[1]	Retrospective cohort; 326 surgically treated children aged 2-14 years	Separately reported subgroup aged 2–5 years; n=33	reported subgroup aged 2–5 years; n=33 Closed reduction in 29/33 (87.9%) and open reduction in 4/33 (12.1%). Individual ages and fixation devices for the four open reductions were not reported.	Youngest ORIF age could not be determined.
Zabane et al. 2023 ^[2]	Case report; one 4-year-old boy with a closed forearm fracture	Exact age reported	Reduction and casting were followed by surgical exploration, neurolysis, and grafting for median nerve entrapment.	Surgery involved the nerve rather than fracture ORIF.
Ang et al. 2020 ^[3]	Case report; one 5-year-old boy with multiple ipsilateral upper-limb fractures	Exact age reported	Failed closed reduction was followed by open reduction and plate fixation of the radius; complete union and full motion were reported at 12 weeks.	Youngest explicitly documented fracture ORIF in the included evidence.

Methodological appraisal

The included reports addressed different clinical questions and provided different levels of age-specific evidence. The retrospective cohort provided subgroup-level treatment data but did not link individual age, reduction method, and

fixation device. The two case reports provided patient-level information but could not support comparative treatment estimates. The design-specific methodological appraisal is summarised in Table 2.

Table 2. Methodological appraisal and implications for interpretation

Study	Appraisal approach	Main methodological limitation	Implication for this review
Aprato et al. 2025 ^[1]	ROBINS-I domains	Retrospective surgical cohort with no patient-level age–device linkage for the four open reductions	Provides exact-age subgroup reduction data but cannot establish the youngest ORIF age.
Zabane et al. 2023 ^[2]	JBIC case-report domains	Single case without comparative data	Provides a neurological complication signal but no evidence regarding fracture ORIF age or treatment effect.
Ang et al. 2020 ^[3]	JBIC case-report domains	Single complex injury involving multiple fracture sites	Establishes an exact-age example of fracture ORIF but cannot provide comparative or generalisable treatment estimates.

Management Findings in Children Aged 2–5 Years

Aprato et al. reported 33 children aged 2–5 years within a cohort of 326 surgically

treated paediatric forearm fractures.^[1] Fourteen children received deep sedation with regional block and 19 received general anaesthesia with neuromuscular blockade. Closed reduction was achieved in 11 and 18 children, respectively, whereas three and one required open reduction. Overall, 29 of 33 children (87.9%) underwent closed reduction and four (12.1%) underwent open reduction. In the complete cohort, fixation consisted predominantly of K-wires or elastic nails; however, fixation devices were not cross-tabulated according to age and reduction method.^[1] Consequently, the four open reductions in the 2–5-year subgroup could not be classified as patient-level ORIF cases, and their individual ages could not be determined. No eligible study provided a separately reported group of children aged 2–5 years treated exclusively by conservative management. Age-specific rates of union, secondary displacement, remodelling, or functional recovery following casting alone therefore could not be determined from the included evidence.

Youngest Documented Fracture ORIF

Ang et al. reported the only case in which exact age, open fracture reduction, and internal fixation were explicitly linked at the patient level.^[3] The patient was a 5-year-old boy with multiple ipsilateral upper-limb fractures, including a displaced distal-third radius-ulna injury. After unsuccessful closed reduction, the radius underwent open reduction and internal fixation with a five-hole low-profile plate.

Complete radiological union and full elbow, wrist, and forearm motion were reported at 12 weeks.^[3] Accordingly, five years was the youngest age at which fracture ORIF could be explicitly verified within the included evidence. Although Aprato et al. reported four open reductions among children aged 2–5 years, the absence of individual ages and fixation-device data prevented determination of whether ORIF had been performed at ages 2, 3, or 4 years.^[1]

Neurological complications

Zabane et al. reported a 4-year-old boy initially managed with closed reduction and casting who subsequently developed persistent pain and impaired active movement of the second and third fingers.^[2] Ultrasonography demonstrated median nerve entrapment at the radial fracture site. Surgical exploration was followed by neurolysis and grafting of a 3-cm nerve defect. Because the procedure addressed the nerve injury rather than fracture fixation, it was not classified as fracture ORIF in this review.

DISCUSSION

Principal Findings and Clinical Interpretation

This focused systematic review identified a very limited body of age-specific evidence for shaft-involving forearm fractures in children aged 2–5 years. The principal finding was that the youngest age at which fracture ORIF could be explicitly verified was 5 years.^[3] Although younger children were represented in the retrospective cohort reported by Aprato et al., individual age, open reduction, and fixation device were not linked at the patient level.^[1] The 4-year-old case reported by Zabane et al. involved surgery for median nerve entrapment rather than fracture fixation.^[2] Accordingly, the age of 5 years should be interpreted as the youngest documented ORIF age within the available evidence, rather than as a minimum age for operative treatment. The available studies also highlight an important limitation of the current literature: age-specific evidence does not permit direct comparison between conservative treatment and operative fixation in preschool-aged children. No included study provided a separately reported cohort of children aged 2–5 years successfully managed by casting alone, and therefore rates of union, secondary displacement, remodelling, functional recovery, or conversion to surgery could not be estimated specifically for this age group. Consequently, treatment decisions should not be derived from

chronological age alone but should continue to incorporate fracture morphology, reducibility, maintenance of alignment, neurovascular status, and associated injuries.

Aprato et al. provide the largest age-specific dataset in this review.^[1] Most children aged 2–5 years who had already entered an operative pathway could still be managed with closed reduction, while only a minority required open reduction. This finding suggests that open exposure was not routinely necessary even among surgically selected children. However, because the study did not cross-tabulate individual age, reduction method, and fixation device, it cannot determine whether the open reductions represented true ORIF or establish the youngest age at which internal fixation was used following open reduction. The case reported by Ang et al. provides the clearest patient-level example of fracture ORIF in the target age group.^[3] In this 5-year-old child, failed closed reduction and the mechanical characteristics of a complex ipsilateral injury led to plate fixation of the radius, whereas other fracture components were treated non-operatively. Complete union and full elbow, wrist, and forearm motion were reported at 12 weeks. Rather than demonstrating superiority of plating, this case illustrates the potential value of treating each component of a complex injury according to its individual stability and mechanical requirements. No exact-age comparative evidence was identified to determine whether elastic stable intramedullary nailing, K-wire fixation, plate fixation, or casting provides superior outcomes in children aged 2–5 years. Therefore, implant selection cannot be recommended on the basis of comparative effectiveness from the present evidence. When operative stabilisation is clinically required, the fixation strategy should instead be individualised according to fracture pattern, fracture level, stability requirements, soft-tissue considerations, and surgical expertise.

Neurological Considerations

The case described by Zabane et al. provides an important neurological safety signal.^[2] Median nerve entrapment following reduction and casting initially resembled transient neuropraxia, but persistent symptoms ultimately led to ultrasonographic evaluation and surgical exploration. The procedure consisted of nerve exploration, neurolysis, and grafting and therefore should not be interpreted as fracture ORIF. This case emphasises the importance of careful neurological assessment before and after fracture manipulation, particularly in young children in whom pain, anxiety, and limited cooperation may complicate examination. Persistent pain, progressive motor deficit, or an atypical neurological recovery should prompt reassessment, with ultrasonography potentially assisting in identifying nerve entrapment when clinically suspected. However, because this evidence derives from a single case report, the incidence of such complications and the optimal diagnostic pathway cannot be determined from this review.

Clinical Implications

The present evidence supports an age-conscious but primarily fracture-based approach to decision-making. The substantial remodelling potential of young children is an important consideration, but the included studies do not provide age-specific thresholds for acceptable angulation, translation, rotation, or shortening. Similarly, no included study identified a validated predictor of loss of reduction specifically for children aged 2–5 years. Alignment and stability should therefore be assessed individually rather than extrapolating numerical treatment thresholds from older paediatric populations as if they represented evidence specific to preschool children. Within these limitations, a practical interpretation of the available evidence is summarized in Table 3. This framework represents a clinical synthesis rather than a validated treatment algorithm.

Table 3. Evidence-informed clinical framework for forearm fractures in children aged 2–5 years

Clinical situation	Clinical consideration	Evidence-qualified interpretation
Closed fracture with acceptable and stable reduction	Closed reduction and well-molded long-arm cast with appropriate follow-up	Consistent with standard pediatric fracture management, although the included exact-age evidence does not quantify comparative success or failure of casting.
Irreducible or repeatedly unstable fracture	Consider operative stabilization, using closed techniques when technically feasible	Most surgically selected children in the Aprato cohort were reduced closed; patient-level data for the open reductions were insufficient to establish fixation type or age. ^[1]
Complex ipsilateral injury or fracture unsuitable for reliable closed stabilization	Individualize treatment for each fracture component	The Ang case demonstrates successful combined operative and non-operative management in a 5-year-old with multiple ipsilateral injuries. ^[3]
Persistent or progressive neurological findings after reduction	Repeat neurological assessment and investigate possible nerve entrapment	The Zabane case demonstrates clinically important median nerve entrapment following reduction and casting. ^[2]
Need for operative fixation	Select fixation according to morphology, stability, fracture level, and surgical considerations	No exact-age comparative evidence establishes superiority of ESIN, K-wires, plating, or another fixation method.
Interpretation of operative age	Do not use 5 years as a surgical threshold	Five years represents the youngest explicitly documented fracture ORIF in the retained evidence, not a minimum age for surgery.

The age of 5 years identified in this review should therefore not be interpreted as a contraindication to operative fixation in younger children. Rather, the absence of documented ORIF below this age reflects the limitations of patient-level reporting in the available literature. When reduction cannot be obtained or maintained, or when fracture characteristics, neurovascular compromise, open injury, or associated injuries necessitate stabilisation, management should be determined by the individual clinical situation rather than by an inferred age threshold.

Certainty and limitations

The principal limitation of this review is the extremely small and heterogeneous exact-age evidence base. Only three clinical reports met the prespecified age criterion, comprising one retrospective surgical cohort and two individual case reports. These designs address different clinical questions and cannot provide comparative estimates of treatment effectiveness. The retrospective cohort did not cross-tabulate patient age, reduction method, and fixation device, preventing determination of whether the four open reductions in children aged 2–5

years constituted ORIF or at what individual ages they occurred.^[1] The two case reports provide detailed patient-level information but cannot estimate treatment effects, complication rates, or generalisability.^[2,3] Consequently, the finding that 5 years was the youngest verifiable ORIF age should be regarded as a reporting observation rather than a biological or therapeutic threshold. A further limitation relates to the review process itself. The review was prepared from the available articles supplemented by a targeted evidence refresh rather than from a prospectively registered protocol with a complete archived database export. The study-selection counts presented in the PRISMA flow diagram should therefore be verified against the final database search records before journal submission. Meta-analysis was not undertaken because pooling a selected surgical subgroup with two single-patient reports would not provide a clinically meaningful summary estimate. Narrative synthesis was therefore considered more appropriate given the marked heterogeneity in study design, injury pattern, treatment pathway, and reported outcomes.

Implications for future research

Future studies should prospectively report children aged 2–5 years as a distinct age stratum and provide patient-level linkage between age, fracture morphology, reduction method, and fixation technique. Studies should clearly distinguish closed reduction and casting, closed reduction with fixation, open reduction without fixation, true ORIF, and surgery performed for treatment-related complications. Particularly important outcomes include maintenance of reduction, repeat manipulation, conversion to surgery, time to union, residual angulation and rotation, pronation–supination, refracture, neurological complications, implant-related complications, anaesthetic exposure, secondary procedures, and patient- or parent-reported function. Comparative studies would be most informative if restricted to fractures for which both conservative and operative strategies are considered clinically reasonable at baseline, thereby reducing confounding by indication. Prospective multicentre studies with sufficiently detailed age-specific reporting are required to determine whether particular fracture characteristics predict failure of conservative management and to clarify the relative roles of different fixation techniques in children younger than 5 years.

CONCLUSION

Evidence specifically addressing shaft-involving forearm fractures in children aged 2–5 years remains limited. Within the available literature, 5 years was the youngest age at which fracture ORIF was explicitly documented; however, this finding represents the youngest verifiable report rather than a minimum age for operative treatment. No age-specific comparative evidence establishes the superiority of casting or any particular fixation technique in this population. Management should therefore be individualised according to fracture reducibility, stability, morphology, neurovascular status, and associated

injuries, with operative fixation considered when adequate alignment cannot be achieved or maintained by conservative means. Further prospective studies with patient-level age, treatment, and outcome data are needed to define age-specific indications and comparative outcomes in preschool children.

Declaration by Authors

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