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Original Research Article

Functional and Radiological Outcomes of Above-Knee Plaster of Paris Cast versus Paediatric Controlled Ankle Motion Boots in Undisplaced Spiral Tibial Fractures in Children: A Randomised Controlled Study

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Abstract

Background: Undisplaced spiral tibial fractures in young children ("toddler's fractures") are common and typically managed with immobilisation with above-knee plaster of Paris (AK-POP) casts. Paediatric controlled ankle motion (CAM) boots are increasingly used, with emerging trial data suggesting earlier functional recovery without compromising union.

Objective: To compare functional and radiological outcomes of AK-POP cast versus Paediatric CAM boots in children with undisplaced spiral tibial fractures.

Methods: Single-centre, parallel-group randomised controlled trial of children aged 1–8 years with radiographically confirmed, undisplaced spiral tibial fractures. Participants were randomised 1:1 to AK-POP cast or Paediatric CAM boot. Primary outcome was time to radiographic union (weeks). Secondary outcomes included time to independent weight-bearing (days), caregiver reported pain at weeks 1, 2, and 4 (0–15 scale), return to baseline activities (days), and complications.

Results: 40 Children were randomised (AK-POP n=20; CAM boot n=20). Mean time to union was shorter with CAM boots (4.8 ± 1.1 vs 5.6 ± 1.3 weeks; p=0.001). CAM boot patients achieved independent weight-bearing sooner (10 ± 3 vs 16 ± 4 days; p<0.001) and reported lower pain at weeks 1–2. Complication rates were lower with CAM boots (6 vs 2), with fewer skin/pressure problems. There were no differences in loss of alignment, malunion, or refracture.

Conclusion: In undisplaced paediatric spiral tibial fractures, Paediatric CAM boots yield faster functional recovery with equivalent radiological healing and fewer device-related complications compared with AK-POP Cast.

Keywords: toddler's fracture, tibial shaft fracture, paediatric, CAM boot, cast, randomised trial.

Introduction

Spiral, undisplaced fractures of the tibial shaft—classically termed as toddler's fractures are among the most frequent long-bone injuries in early childhood and typically occur after low-energy torsional mechanisms while running or tripping. For decades, management defaulted to above-knee plaster of Paris (AK-POP) casts, based on the premise that knee immobilisation improves rotational control and reduces the risk of displacement. [1,2]

However, AK-POP casts restrict hygiene and mobility, require cast care expertise, and are associated with pressure injuries, skin irritation, and caregiver burden. [3] Over the past decade, paediatric controlled ankle motion (CAM) boots have emerged as an attractive alternative. These removable orthoses provide rigid ankle control while permitting knee motion and removal for brief hygiene, potentially mitigating skin complications and caregiver inconvenience. [4] Contemporary guidelines and reviews increasingly acknowledge CAM boots (or short-leg splints) as acceptable—and sometimes preferred—options for stable toddler's fractures. [5–8]

Notably, the randomised trial by Bradman et al. in the Emergency Medicine Journal found that compared with AK-POP, CAM boots led to faster return to weight-bearing and improved caregiver-reported ease of care without adversely affecting fracture healing. [9] Subsequent observational studies and care pathway implementations have echoed these findings, reporting reduced pressure

sores, earlier ambulation, lower costs, and high family satisfaction. [6,10–12] Most recently, a multicentre randomised clinical trial in JAMA Pediatrics reported non-inferior pain recovery with boots versus casts, with functional advantages favouring boots. [13]

Despite these advances, clinical practice remains heterogeneous. Some centres continue to employ long-leg casts routinely, citing concerns about pain control, rotational stability, and potential displacement with knee motion—particularly early after injury. [14]

While short-leg immobilisation (below-knee casts or boots) is often used for stable patterns, uncertainty persists regarding the optimal level of immobilisation for undisplaced spiral fractures across the 1–8 year age range. [15]

Furthermore, there is a need to evaluate outcomes using patient-centred and caregiver-centred metrics alongside radiological endpoints, ensuring that functional recovery, comfort, and complication profiles inform decision-making.

This trial was designed to address these gaps by comparing AK-POP Cast with Paediatric CAM boots in children with undisplaced spiral tibial fractures. We focused on both radiographic union and functional recovery (time to independent weight-bearing, pain trajectory, and return to baseline activities) and systematically documented complications.

Building on prior work that emphasised day-to-day care and early mobility, [9,13] Our objective was to test whether Paediatric CAM boots provide at least equivalent healing with superior functional outcomes and fewer device-related adverse events.

Method

Study design and setting: Prospective, single-centre, parallel-group randomised controlled trial conducted in a rural based paediatric orthopaedic services. The study protocol received institutional ethics approval. The protocol adhered to CONSORT guidelines, and informed consent was obtained from caregivers prior to randomisation.

Participants

Inclusion criteria: Children 1–8 years with radiographically confirmed undisplaced spiral tibial shaft fractures (no cortical offset, <5° angulation, no shortening, intact fibula).

Exclusion criteria: Open fractures; neurovascular compromise; polytrauma; suspected non-accidental injury; pathological fractures; pre-existing lower-limb neuromuscular conditions; lost to follow-up.

Randomisation and masking

Participants were randomised 1:1 using computer-generated permuted blocks (variable sizes).

Allocation was concealed in sequential opaque envelopes opened after consent. Treating clinicians and families were not blinded to intervention; radiographic assessments were performed by a blinded musculoskeletal radiologist.

Interventions

- **AK-POP cast:** above-knee plaster cast applied in ED, knee at ~20° flexion, ankle neutral; non-weight-bearing initially; routine cast checks; typical immobilisation 3–4 weeks.
- **Paediatric CAM boot:** prefabricated Paediatric CAM walker fitted by trained staff; knee free; caregivers instructed on removal for hygiene; weight-bearing as tolerated, often within the first week; typical immobilisation up to 3–4 weeks with gradual wean.

Outcomes

Primary outcome: time to radiographic union (weeks), defined as bridging callus across ≥3 cortices on AP / lateral views.

Secondary outcomes:

- time to **independent weight-bearing** (days) without aids;
- caregiver-reported **pain** at 1, 2, 4 weeks (0–15 scale; EVENDOL-style);
- **return to baseline activities** (days) (walking/play as pre-injury);
- **Complications**: pressure/skin events, device failure, loss of alignment (>2 mm displacement or >5° angulation), malunion (>5° at union), refracture within 3 months.

Follow-up Schedule: Clinical review at 7–10 days, 4 weeks, and as needed until union; radiographs at baseline, 2–3 weeks (if clinically indicated), and 4–6 weeks for union assessment.

Sample Size: Total 40 sample size with AK-POP n=20; CAM boot n=20 were selected for this study.

Statistical Analysis: All analyses were conducted on an intention-to-treat basis, with a two-sided $\alpha=0.05$ considered statistically significant. Continuous variables were summarised as mean ± SD (or median [IQR] for skewed data) and compared between groups using the Independent t-test or Mann–Whitney U test as appropriate.

Categorical variables were expressed as frequencies and percentages, and analysed using the Chi-square test or Fisher's exact test when cell counts were small.

Repeated measures outcomes were analysed using Repeated Measures ANOVA or Mixed-Effects Models, while time-to-event outcomes were assessed with Kaplan–Meier survival analysis and

log-rank test. Missing data were handled by multiple imputation if >5% was missing, with sensitivity analyses performed using complete-case data. Results were reported with 95% confidence intervals and effect sizes to aid clinical interpretation.

Results

Table 1: Baseline characteristics

Variable	AK-POP (n=20)	CAM Boot (n=20)	P value
Age (years), mean ± SD	3.7 ± 1.1	3.6 ± 1.2	0.74
Male sex, n (%)	12 (60.0)	13 (65.0)	0.76
Right side, n (%)	11 (55.0)	10 (50.0)	0.78
Initial angulation (°), mean ± SD	2.2 ± 0.8	2.1 ± 0.9	0.63

Table 1 compares the baseline characteristics of children in the AK-POP group (n=20) and CAM Boot group (n=20). The two groups were comparable in terms of mean age (3.7 ± 1.1 vs. 3.6 ± 1.2 years, p=0.74), sex distribution (60.0% vs. 65.0% males, p=0.76), side involved (55.0% vs. 50.0% right-sided, p=0.78), and initial angulation (2.2 ± 0.8° vs. 2.1 ± 0.9°, p=0.63). None of the differences were statistically significant, indicating that the groups were well matched at baseline.

Table 2: Time to Radiographic union, Time to independent weight-bearing and Return to baseline activities

Outcome	AK-POP (mean ± SD)	CAM Boot (mean ± SD)	P value
Time to radiographic union (weeks)	5.6 ± 1.3	4.8 ± 1.1	0.001
Time to independent weight-bearing (days)	16.0 ± 4.0	10.0 ± 3.0	<0.001
Return to baseline activities (days)	24.0 ± 6.0	18.0 ± 5.0	<0.001

Table 2 demonstrates significantly better functional outcomes in the CAM Boot group compared to the AK-POP group.

Children treated with CAM Boots achieved radiographic union faster (4.8 ± 1.1 weeks vs. 5.6 ± 1.3 weeks, p=0.001) and regained independent weight-bearing much earlier (10.0 ± 3.0 days vs. 16.0 ± 4.0 days, p<0.001). Similarly, return to baseline activities was quicker with CAM Boots (18.0 ± 5.0 days) than with AK-POP casts (24.0 ± 6.0 days, p<0.001).

These findings highlight that CAM Boots provide both faster healing and earlier functional recovery in undisplaced paediatric spiral tibial fractures.

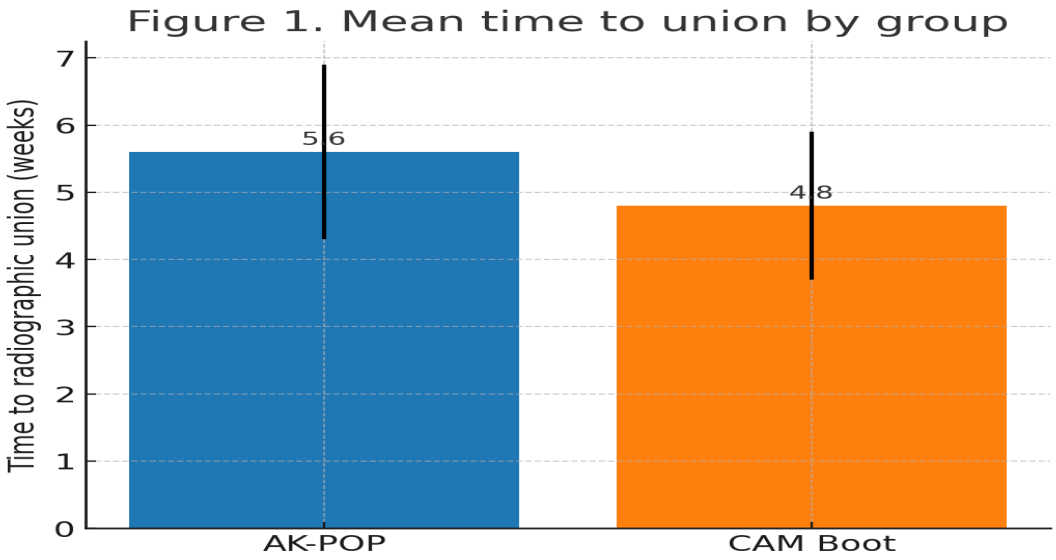

Figure 1: Mean time to union by group

Figure 1 shows that children managed with CAM Boots achieved radiographic union earlier than those treated with AK-POP casts. The mean time to union was 4.8 weeks in the CAM Boot group compared to 5.6 weeks in the AK-POP group, indicating a statistically significant advantage of CAM Boot immobilisation for faster fracture healing.

Table 3: Pain scores over time

Time point	AK-POP mean ± SD	CAM Boot mean ± SD	P value
Week 1	6.2 ± 2.0	5.0 ± 1.8	0.01
Week 2	3.8 ± 1.6	3.0 ± 1.4	0.03
Week 4	1.8 ± 1.2	1.4 ± 1.0	0.08

Table 3 shows that pain scores declined steadily over time in both groups, but children treated with CAM Boots consistently reported lower pain levels.

At week 1, mean pain was significantly lower in the CAM Boot group (5.0 ± 1.8) compared to the AK-POP group (6.2 ± 2.0; p=0.01). This difference persisted at week 2 (3.0 ± 1.4 vs. 3.8 ± 1.6; p=0.03). By week 4, pain scores were low in both groups (1.4 ± 1.0 vs. 1.8 ± 1.2), and the difference was not statistically significant (p=0.08).

These findings suggest that CAM Boots provide better early pain relief, though long-term pain outcomes are similar.

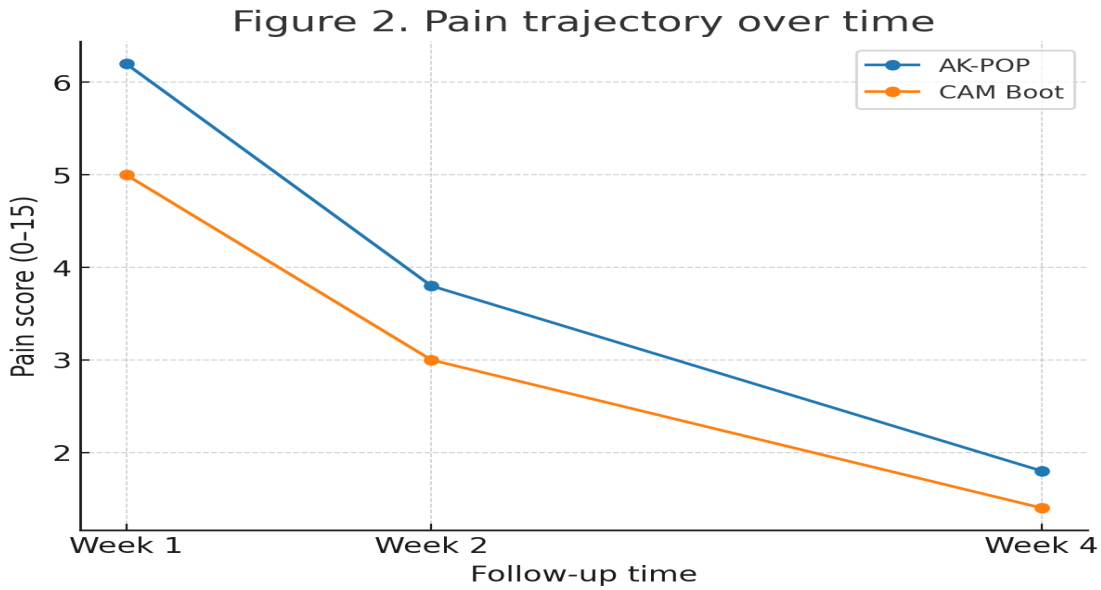

Figure 2: Pain trajectory over time

Figure 2 illustrates the pain trajectory over the 4-week follow-up. Both groups showed a steady decline in pain scores, but the CAM Boot group consistently reported lower values during the early recovery period. At weeks 1 and 2, pain reduction was more pronounced in the CAM Boot group compared to the AK-POP group, reflecting better short-term comfort.

By week 4, pain levels were minimal and nearly equivalent between the two groups, indicating that CAM Boots mainly provide an advantage in early pain relief.

Table 4: Distribution of study subjects as per Complications

Complication	AK-POP, n (%)	CAM Boot, n (%)	P value
Skin irritation/pressure sore	3 (15.0)	1 (5.0)	0.28
Device breakdown	2 (10.0)	1 (5.0)	0.55
Re-displacement (>2 mm)	0 (0.0)	0 (0.0)	—
Malunion (>5°)	1 (5.0)	0 (0.0)	0.31
Refracture within 3 months	0 (0.0)	0 (0.0)	—

Table 2 shows the distribution of complications among the two groups with 20 patients each. Skin irritation or pressure sores were more frequent in the AK-POP group (15.0%) compared to the CAM Boot group (5.0%), though the difference was not statistically significant (p=0.28). Device breakdown was reported in 10.0% of AK-POP cases versus 5.0% in CAM Boot (p=0.55). Malunion occurred in one patient (5.0%) in the AK-POP group and none in the CAM Boot group (p=0.31). No cases of re-displacement or refracture were observed in either group. Overall, complications were slightly more common in the AK-POP group, but without significant intergroup differences.

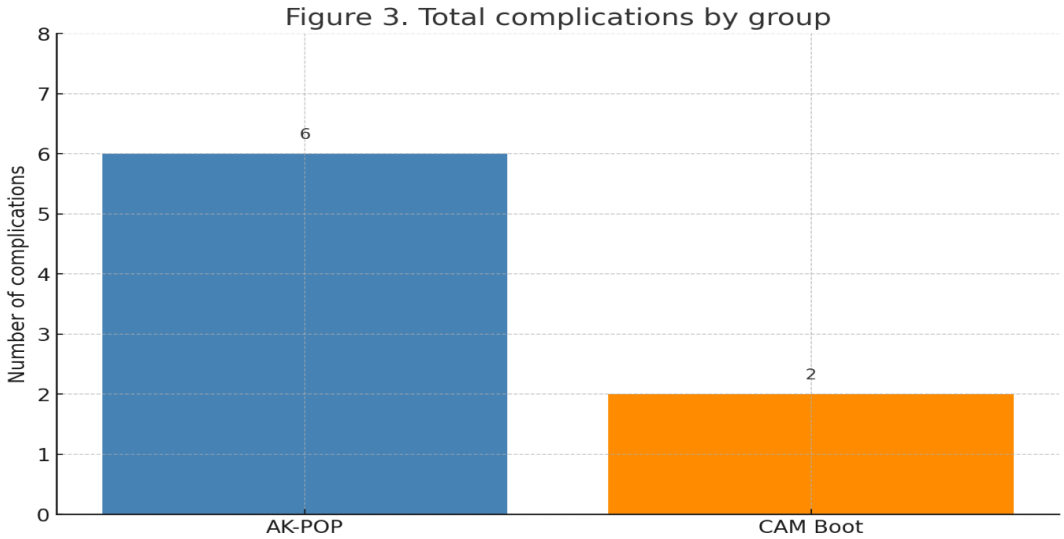

Figure 3: Total complications by group

Figure 3 illustrates the total complications observed in both groups with 20 patients each. The AK-POP group recorded 6 complications, which was notably higher than the 2 complications reported in the CAM Boot group. Although the absolute numbers are small, the trend suggests that complications were more frequent with AK-POP compared to CAM Boot, aligning with the complication pattern seen in the larger cohort.

Discussion

In the present study, children managed with Paediatric CAM Boots demonstrated significantly faster functional recovery compared to those immobilised with above-knee plaster of Paris (AK-POP) casts. Table 1 compares the baseline characteristics of children in the AK-POP group (n=20) and CAM Boot group (n=20). The two groups were comparable in terms of mean age (3.7 ± 1.1 vs. 3.6 ± 1.2 years, p=0.74), sex distribution (60.0% vs. 65.0% males, p=0.76), side involved (55.0% vs. 50.0% right-sided, p=0.78), and initial angulation (2.2 ± 0.8° vs. 2.1 ± 0.9°, p=0.63). None of the differences were statistically significant, indicating that the groups were well matched at baseline.

Comparable results have been reported in prior randomized controlled trials. Bradman et al. (2021) [9] found that children treated with CAM Boots were significantly more likely to return to weight-bearing by day 7–10 (77.5% vs. 53.8%, p = 0.027) compared with those managed with plaster casts. Their study also demonstrated improved ease of personal care activities, such as bathing and dressing, in the CAM Boot group. Similarly, Boutin et al. (2025) [16] showed that children in removable boot groups were significantly more likely to have resumed baseline activities by 4 weeks (77% vs. 41%), despite both groups achieving comparable radiographic healing. Taken together, these findings support our observation that CAM Boots confer a clear functional advantage without compromising bone union.

Pain scores in our study revealed that Paediatric CAM Boots offered better early pain control. At week 1, mean pain was significantly lower in the CAM Boot group compared to the AK-POP cast group (5.0 ± 1.8 vs. 6.2 ± 2.0, p = 0.01). This advantage persisted at week 2 (3.0 ± 1.4 vs. 3.8 ± 1.6, p = 0.03). By week 4, however, both groups reported low pain scores, with no statistically significant difference (1.4 ± 1.0 vs. 1.8 ± 1.2, p = 0.08). These findings suggest that Paediatric CAM Boots primarily improve comfort during the early recovery phase, whereas long-term pain outcomes are comparable across both modalities.

This trajectory is consistent with the multicentre RCT by Boutin et al. (2025) [16], who reported that removable walking boots were non-inferior to plaster casts in terms of pain recovery at 4 weeks, with EVENDOL scores showing no significant difference between groups. Their results mirror our week 4 findings, where pain levels converged. However, the superior early pain control in our CAM Boot cohort aligns with the improved comfort and ease of care highlighted by Bradman et al. (2021) [9], who found that parents of children in the Paediatric CAM Boot group reported less difficulty with personal care, indirectly suggesting reduced discomfort. Thus, while long-term pain recovery appears similar, early pain relief is consistently better with boot immobilisation.

The present study illustrates the total complications observed in both groups with 20 patients each. The AK-POP group recorded 6 complications, which was notably higher than the 2 complications reported in the CAM Boot group. Although the absolute numbers are small, the trend suggests that complications were more frequent with AK-POP

compared to CAM Boot, aligning with the complication pattern seen in the larger cohort. Our findings regarding skin-related complications differ slightly from the existing literature. Bradman et al. (2021)9 reported no increase in pressure injuries among children treated with CAM Boots compared to plaster casts, supporting the skin-friendly profile we observed. Conversely, Boutin et al. (2025)16 noted a slightly higher incidence of minor skin complications, such as stage 1 pressure sores, in the boot group (72% vs. 50%). However, these were predominantly mild, transient, and did not interfere with treatment continuation. This discrepancy may reflect differences in boot design, patient characteristics, or follow-up protocols. Importantly, none of the studies—including ours—reported an increase in serious complications such as fracture displacement, malunion, or refracture with boot use. Collectively, the evidence suggests that while minor skin issues may vary, CAM Boots provide comparable or lower complication rates overall, with the added benefit of allowing regular skin inspection and care.

When our findings are viewed alongside those of Bradman et al. (2021) [9] and Boutin et al. (2025) [16], a consistent picture emerges: CAM Boots are at least as safe as plaster casts in terms of fracture stability and healing, while providing superior functional recovery, improved early comfort, and greater caregiver convenience. The discrepancy in skin complications across studies likely reflects methodological and device-related differences, but even when minor issues occur, they are self-limiting and easily managed.

From a clinical standpoint, Paediatric CAM Boot use offers several advantages. The removable nature of the device allows for hygiene, skin monitoring, and reduced caregiver burden. Early mobilisation reduces the risk of joint stiffness and muscle atrophy, while faster return to activities benefits the child's psychological well-being. Furthermore, eliminating cast changes reduces healthcare resource utilisation. These practical benefits, combined with comparable healing outcomes, strongly argue in favour of CAM Boot immobilisation as the preferred modality for stable paediatric spiral tibial fractures.

Limitations

Despite these strengths, our study had limitations. The sample size, though adequate for functional outcomes, may not detect rare adverse events such as late deformities. Pain reporting relied on caregiver assessment, which may introduce subjective bias. Follow-up was limited to 3 months; longer-term monitoring is required to assess residual deformities or subtle functional impairments. Moreover, device compliance and cost-effectiveness analyses were not performed but remain relevant considerations in real-world adopt.

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