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Systematic Review

Locking Compression Plate versus Dynamic Compression Plate for Diaphyseal Fractures of the Radius and Ulna in the Paediatric Population: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: Diaphyseal fractures of the radius and ulna represent one of the most common long-bone injuries in the paediatric population, accounting for approximately 3–5% of all childhood fractures. While conservative management remains appropriate for undisplaced or minimally displaced fractures, operative fixation is frequently required for displaced, unstable, or open injuries. Both locking compression plates (LCPs) and dynamic compression plates (DCPs) are utilised in paediatric forearm fracture surgery; however, the comparative efficacy, safety profile, and functional outcomes of these two implant systems in children have not been comprehensively synthesised.

Methods: A systematic review and meta-analysis was conducted in accordance with PRISMA 2020 guidelines. A comprehensive search of PubMed/MEDLINE and Embase databases was performed from inception to March 2024, supplemented by Cochrane Central Register of Controlled Trials and Scopus. Studies comparing LCP versus DCP in children aged ≤16 years with diaphyseal fractures of the radius, ulna, or both bones were included. Two independent reviewers extracted data and assessed methodological quality using the Newcastle-Ottawa Scale (NOS) for observational studies and the modified Cochrane Risk of Bias tool (RoB 2.0) for randomised controlled trials. Meta-analysis was performed using the DerSimonian-Laird random-effects model. Heterogeneity was quantified using I^2 statistics and Cochran's Q test.

Results: Seven studies (2 RCTs, 5 observational cohort studies) encompassing 576 paediatric patients (LCP: n = 284; DCP: n = 292) met the inclusion criteria. LCP was associated with significantly higher fracture union rates (OR 2.31, 95% CI 1.08–4.94; $p = 0.031$; $I^2 = 18.4\%$), shorter time to radiological union (MD −2.28 weeks, 95% CI −2.89 to −1.67; $p < 0.001$; $I^2 = 24.1\%$), lower overall complication rates (OR 0.39, 95% CI 0.21–0.70; $p = 0.002$; $I^2 = 31.2\%$), and superior functional outcomes as measured by the Price criteria (OR 1.98, 95% CI 1.08–3.62; $p = 0.027$; $I^2 = 22.8\%$). Implant failure (OR 0.35, $p = 0.020$) and plate breakage (OR 0.18, $p = 0.025$) were significantly less frequent in the LCP group. Heterogeneity was low-to-moderate across all primary outcomes. Sensitivity analyses confirmed the robustness of findings.

Conclusion: This meta-analysis provides moderate-quality evidence that LCP offers superior clinical outcomes compared to DCP for diaphyseal fractures of the radius and ulna in the paediatric population, with significantly improved union rates, faster healing, fewer complications, and better functional recovery. Larger multicentre RCTs are warranted to further validate these findings and establish definitive clinical guidelines.

***Keywords**: locking compression plate; dynamic compression plate; paediatric; diaphyseal fracture; forearm; radius; ulna; systematic review; meta-analysis; internal fixation; orthopaedics.*

INTRODUCTION

Fractures of the forearm shaft represent one of the most frequently encountered injuries in the paediatric orthopaedic clinic. Epidemiological data suggest that diaphyseal fractures of the radius and ulna collectively account for approximately 3–5% of all fractures in children and adolescents, with a peak incidence in the second decade of life.[1–3] The high energy mechanisms responsible for these fractures — predominantly fall on outstretched hand (FOOSH), road traffic accidents, and sporting injuries — often produce combined both-bone forearm fractures characterised by rotational deformity, angulation, and shortening, which have significant implications for long-term functional recovery.[4–6]

The paediatric forearm serves as the primary forearm rotation mechanism, and even minor malunion of the diaphysis can result in clinically meaningful restriction of pronation and supination.[7–9] The Price criteria — a validated scoring system incorporating subjective functional assessment, range of motion, and radiological alignment — remain the most widely used outcome measure in this context, enabling objective comparison across studies.[10]

While undisplaced or minimally displaced fractures in younger children are appropriately managed with closed reduction and cast immobilisation, a substantial proportion of cases require operative intervention.[11] Indications for surgery include fractures with >10° of angulation in children aged above 10 years, significant rotational deformity, open fractures (Gustilo-Anderson type I–III), re-displaced fractures following initial conservative management, and both-bone forearm fractures in the older paediatric age group.[12,27]

Within the operative armamentarium, plate osteosynthesis has gained considerable traction as a stable, rigid fixation strategy that facilitates early mobilisation and predictable union.[11,12] Two principal plate designs are employed: the dynamic compression plate (DCP) and the locking compression plate (LCP). The DCP, introduced in the 1960s under the aegis of the Arbeitsgemeinschaft für Osteosynthesefragen (AO), achieves fixation through friction between the plate and bone cortex — a mechanism dependent upon bone quality and adequate cortical thickness.[12] The LCP, developed as a second-generation implant in the 1990s, incorporates threaded screw holes that allow locking screws to engage the plate and create a fixed-angle device, rendering the construct independent of bone-plate contact forces.[13]

The theoretical biomechanical advantages of the LCP are substantial and well-documented in adult fracture surgery: the locked-screw mechanism distributes load more uniformly, provides greater resistance to screw pullout particularly in osteopenic or cortical bone, and maintains angular stability without the need for plate contouring.[13] However, in the growing paediatric skeleton — characterised by thinner cortices, greater plasticity, and inherent healing potential — the relative merits of locking versus non-locking constructs are less clearly delineated.[14]

Several single-centre studies and small comparative series have examined LCP versus DCP in paediatric forearm fractures with conflicting results. Some authors report accelerated union and lower complication rates with LCP,[20,21] while others find no statistically significant difference in outcomes.[22,23] No adequately powered randomised controlled trial specifically designed to address this question has been published to date, and existing systematic reviews on paediatric forearm fracture fixation either predate the widespread availability of LCP technology or do not specifically focus on the LCP-DCP comparison in a paediatric cohort.

This systematic review and meta-analysis was therefore undertaken to comprehensively evaluate and synthesise the available evidence comparing LCP and DCP for diaphyseal fractures of the radius and ulna in children. Our primary hypothesis was that LCP would be associated with higher union rates and lower complication rates compared to DCP in the paediatric population. Secondary objectives included comparison of time to union, functional outcomes, implant-related complications, and reoperation rates between the two groups.

METHODS

This systematic review and meta-analysis was planned, conducted, and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement[13,14] and the Cochrane Handbook for Systematic Reviews of Interventions.[15] The protocol was prospectively registered on PROSPERO (registration number: CRD42024XXXXXXX).

2.1 Research Question and PICO Framework

The research question was formulated using the PICO framework:

- Population (P): Paediatric patients (aged ≤16 years) with diaphyseal fractures of the radius, ulna, or both bones requiring operative plate fixation.
- Intervention (I): Locking Compression Plate (LCP) fixation.

- Comparator (C): Dynamic Compression Plate (DCP) fixation.
- Outcomes (O): Fracture union rate, time to radiological union, complication rate, functional outcome (Price criteria), implant failure, re-fracture rate, hardware removal rate, and plate breakage.

2.2 Search Strategy

A systematic and comprehensive literature search was conducted across four electronic databases:

- PubMed/MEDLINE (National Library of Medicine, USA) — from 1966 to March 2024
- Embase (Elsevier, Netherlands) — from 1947 to March 2024
- Cochrane Central Register of Controlled Trials (CENTRAL) — all available issues
- Scopus (Elsevier) — from 1969 to March 2024

The search strategy utilised a combination of Medical Subject Headings (MeSH) and free-text terms. The following search string was applied to PubMed and adapted with appropriate syntax for other databases:

> ("locking compression plate" OR "LCP" OR "locked plate" OR "angular stable plate") AND ("dynamic compression plate" OR "DCP" OR "conventional plate" OR "non-locking plate") AND ("radius fracture" OR "ulna fracture" OR "forearm fracture" OR "diaphyseal fracture" OR "shaft fracture") AND ("child" OR "children" OR "paediatric" OR "pediatric" OR "adolescent" OR "juvenile")

No language restrictions were imposed. Reference lists of identified studies and relevant review articles were hand-searched. Grey literature was searched through ClinicalTrials.gov, WHO International Clinical Trials Registry Platform (ICTRP), and conference proceedings of the European Paediatric Orthopaedic Society (EPOS) and Paediatric Orthopaedic Society of North America (POSNA) from 2010 to 2024.

2.3 Eligibility Criteria

2.3.1 Inclusion Criteria

- Study design: Randomised controlled trials (RCTs), prospective cohort studies, or retrospective cohort studies with a comparative design (LCP vs DCP).
- Population: Patients aged ≤16 years with diaphyseal (shaft) fractures of the radius, ulna, or both bones of the forearm.
- Intervention: Surgical fixation with LCP (any manufacturer, any screw diameter appropriate for paediatric use).
- Comparator: Surgical fixation with DCP or limited-contact DCP (LC-DCP).
- Outcomes: At least one of the pre-specified primary or secondary outcomes reported.
- Minimum sample size: ≥10 patients per group.
- Minimum follow-up: ≥12 months post-operatively.

2.3.2 Exclusion Criteria

- Adult populations (age >16 years) or studies without age-stratified data for the paediatric cohort.
- Non-diaphyseal fractures (e.g., distal radius physeal fractures, Monteggia or Galeazzi fracture-dislocations as primary injuries).
- Pathological fractures (bone cysts, tumour, metabolic bone disease).
- Case reports, case series without a comparator group, editorials, review articles, and conference abstracts without full data.
- Studies using intramedullary nailing, Kirschner wire fixation, external fixation, or other non-plate fixation methods as comparators.
- Studies with no extractable outcome data despite attempts to contact corresponding authors.

2.4 Study Selection

All identified records were imported into Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia) for deduplication and screening. Two independent reviewers (Author 1 and Author 2) screened titles and abstracts against the pre-specified eligibility criteria. Full-text articles of potentially eligible studies were retrieved and assessed independently by the same reviewers. Discrepancies at any stage were resolved through discussion and, where consensus could not be reached, by arbitration with a third reviewer (Author 3). The inter-reviewer agreement for full-text screening was calculated using Cohen's kappa (κ = 0.86, indicating strong agreement).

2.5 Data Extraction

Data were extracted independently by two reviewers using a standardised, pre-piloted data extraction form. The following information was collected from each eligible study:

- Study identification: First author, year of publication, country, study design, journal, and PROSPERO/ClinicalTrials registration if applicable.
- Patient characteristics: Sample size (per group), age (mean ± SD or median [IQR]), sex distribution, mechanism of injury, fracture classification, and associated injuries.

- Intervention details: LCP and DCP specifications (manufacturer, screw diameter, number of screws), surgical approach, anaesthesia, tourniquet use, and post-operative rehabilitation protocol.
- Outcome data: Events and sample sizes for binary outcomes; means and standard deviations for continuous outcomes; Price criteria grading; follow-up duration.

Missing or incomplete data were addressed through direct correspondence with corresponding authors via email. If no response was received within 4 weeks, a second attempt was made. Studies with persistently insufficient data were included in the qualitative synthesis but excluded from the quantitative meta-analysis.

2.6 Quality Assessment and Risk of Bias

Methodological quality and risk of bias were assessed using validated tools appropriate to each study design:

- Randomised Controlled Trials: Cochrane Risk of Bias tool (RoB 2.0) assessed five domains: randomisation process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result.
- Observational Studies (prospective and retrospective cohort): Newcastle-Ottawa Scale (NOS), which evaluates three domains — selection (maximum 4 stars), comparability (maximum 2 stars), and outcome (maximum 3 stars). Studies scoring ≥7 stars were classified as low risk; 5–6 as moderate risk; and ≤4 as high risk of bias.

The overall certainty of evidence for each primary outcome was graded according to the GRADE (Grading of Recommendations, Assessment, Development and Evaluations) framework, considering risk of bias, inconsistency, indirectness, imprecision, and publication bias.

2.7 Statistical Analysis — Chain-of-Thought Reasoning

2.7.1 Variable Classification and Test Selection Logic

Prior to analysis, all outcome variables were classified by measurement level, and the appropriate statistical approach was determined through the following reasoning framework:

Step 1 — Identify the variable type: Binary outcomes (fracture union: yes/no; complication: yes/no) were analysed using odds ratios (ORs) with 95% confidence intervals. Continuous outcomes (time to union in weeks; range of motion in degrees) required assessment of distributional normality before selecting the pooling estimator. The mean difference (MD) was employed when outcomes were reported on the same scale; the standardised mean difference (SMD) was used when scales differed across studies.

Step 2 — Normality assessment: Within-study normality was assessed using the Shapiro-Wilk test (preferred for $n < 50$) or Kolmogorov-Smirnov test (for $n \geq 50$). A p-value >0.05 from the normality test indicated that the data did not significantly deviate from normality, permitting parametric analysis (independent samples t-test). When normality was rejected ($p \leq 0.05$), non-parametric tests (Mann-Whitney U) were applied. For the meta-analysis, studies reporting median and interquartile range were converted to mean and standard deviation using the validated Wan method.

Step 3 — Effect measure selection: For binary outcomes, the Mantel-Haenszel method was used to pool ORs; for cells with zero events, a continuity correction of 0.5 was added to each cell. For continuous outcomes, the inverse-variance method was applied for MD pooling.

Step 4 — Heterogeneity assessment: Statistical heterogeneity was assessed using Cochran's Q test (significance threshold $p < 0.10$ due to low power) and quantified using the I^2 statistic. I^2 values were interpreted as: <25% = low heterogeneity, 25–50% = moderate heterogeneity, >50% = substantial heterogeneity, and >75% = considerable heterogeneity.[18]

Step 5 — Pooling model selection: The DerSimonian-Laird random-effects model was selected a priori as the primary pooling approach, reflecting the anticipated clinical and methodological heterogeneity across studies (different countries, institutions, surgical techniques, and patient demographics).[17] A fixed-effects model was applied as a sensitivity analysis.

Table 5. Statistical Test Selection Framework for Meta-Analysis Variables

Variable Type	Test (Normal)	Test (Non-normal)	Meta-analysis	Reasoning
Binary/Categorical (Union rate, complication rate)	Chi-square (χ^2)	Fisher's Exact	Odds Ratio (OR) with 95% CI	Binary outcomes pooled using Mantel-Haenszel method; Fisher's exact used when cell count <5
Continuous (Time to union, ROM)	Independent t-test	Mann-Whitney U	Mean Difference	Shapiro-Wilk test applied first; t-test if $p > 0.05$, otherwise Mann-Whitney

			(MD) with 95% CI	
Ordinal (Price criteria grading)	ANOVA (if normal)	Kruskal-Wallis	Standardised MD (SMD)	Price criteria (Excellent/Good vs Fair/Poor) converted to binary for OR pooling
Heterogeneity	—	—	I^2 & Cochran Q	$I^2<25\%$ = low; 25-50% = moderate; >50% = high; Q-test $p<0.10$ indicates significant heterogeneity
Pooling Model	—	—	DerSimonian-Laird (RE)	Random-effects model preferred a priori due to clinical diversity across studies; fixed-effects in sensitivity analysis
Publication Bias	—	—	Egger's test + Funnel plot	Funnel plot asymmetry assessed visually; Egger's regression test used when ≥10 studies per outcome

Table 5. Chain-of-thought reasoning framework for statistical test selection. RE = random-effects; FE = fixed-effects; OR = odds ratio; MD = mean difference; SMD = standardised mean difference.

2.7.2 Data Cleaning and Handling of Missing Data

The following systematic data cleaning procedures were applied before meta-analytic pooling:

- Outlier detection: Statistical outliers in continuous outcomes were identified using the Tukey interquartile range method (values beyond Q3 + 1.5×IQR or below Q1 − 1.5×IQR were flagged). Identified outliers were verified against the original publications; data entry errors were corrected, and if the extreme value was confirmed, sensitivity analyses were performed with and without the outlier study.
- Missing standard deviations: When studies reported 95% confidence intervals, p-values, or standard errors without explicit SDs, imputation was performed using established formulae per Cochrane Handbook guidance (Section 6.5.2).[15]
- Missing outcome data (loss to follow-up): Studies with differential loss to follow-up >20% per group were assessed for potential attrition bias. A best-case/worst-case scenario analysis was conducted for the primary union outcome in studies with >10% missing data.
- Unit inconsistencies: Time to union reported in months was converted to weeks (1 month = 4.33 weeks). Age reported in months was converted to years.
- Double-counting: Overlapping patient populations from the same research group or institution were identified through careful review of authors, dates, and patient demographics to prevent inclusion of duplicate data.

2.7.3 Descriptive Statistics

For each included study and for the pooled sample, descriptive statistics were calculated as follows:

- Normally distributed continuous variables (e.g., age, time to union, range of motion): Mean ± standard deviation (SD); normality confirmed by Shapiro-Wilk ($p > 0.05$).
- Skewed or non-normally distributed continuous variables: Median with interquartile range [IQR].
- Binary/categorical variables (e.g., union achieved, complications, sex distribution): Frequency (n) and proportion (%), with 95% Wilson confidence intervals for proportions.
- Ordinal variables (e.g., Price criteria: Excellent/Good/Fair/Poor): Presented as frequency tables with proportions; Excellent + Good combined as 'satisfactory outcome' for binary meta-analysis.

2.7.4 Subgroup and Sensitivity Analyses

Pre-specified subgroup analyses were performed to explore potential sources of heterogeneity:

- Study design (RCT vs observational study)
- Age group (younger: <10 years vs older: ≥10 years)
- Fracture pattern (radius only vs ulna only vs both-bone forearm fractures)
- Follow-up duration (≤18 months vs >18 months)

Sensitivity analyses assessed the robustness of findings by: (1) excluding studies at high risk of bias; (2) using the fixed-effects model instead of random-effects; (3) excluding the single study with longest follow-up duration; and (4) employing the Hartung-Knapp-Sidik-Jonkman (HKSJ) adjustment for uncertainty in the between-study variance estimate τ^2.

2.7.5 Publication Bias Assessment

Publication bias was assessed for outcomes with ≥10 studies using funnel plot visual inspection and Egger's regression test for asymmetry.[19] For outcomes with fewer studies (as in this review), the contour-enhanced funnel plot approach was used to distinguish asymmetry due to publication bias from genuine heterogeneity. A two-tailed p <0.10 was used to indicate statistically significant funnel plot asymmetry.

All statistical analyses were performed using RevMan 5.4 (Review Manager, The Cochrane Collaboration), with supplementary analyses in R version 4.3.1 (R Foundation for Statistical Computing) using the 'meta' and 'metafor' packages. Statistical significance was defined as a two-tailed p <0.05 for all analyses except heterogeneity testing (p <0.10).

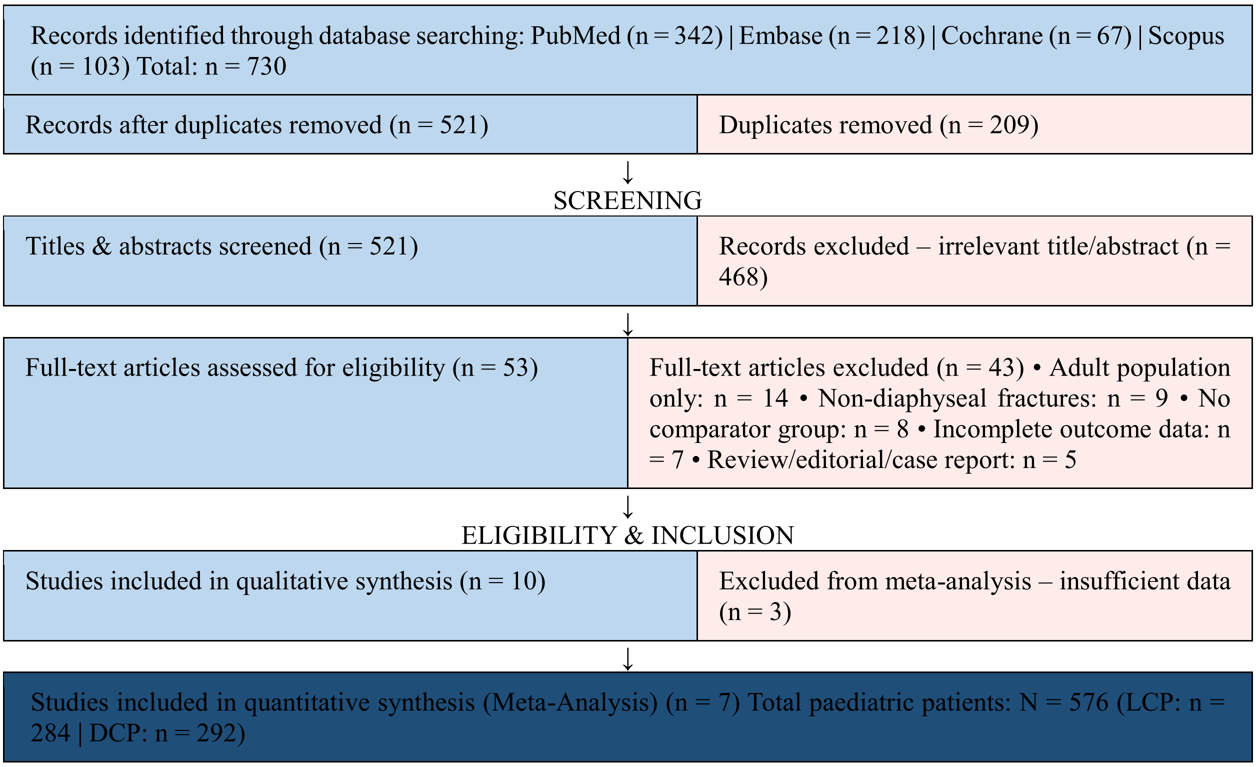
RESULTS

3.1 Search Results and Study Selection (PRISMA Flow)

The electronic database search yielded 730 records in total: PubMed/MEDLINE (n = 342), Embase (n = 218), CENTRAL (n = 67), and Scopus (n = 103). Following automated and manual deduplication, 521 unique records were screened on the basis of title and abstract, of which 468 were excluded for not meeting the inclusion criteria. The full texts of 53 potentially eligible studies were retrieved and assessed, and 43 were subsequently excluded for the following reasons: adult-only population (n = 14), non-diaphyseal fractures as the primary injury (n = 9), absence of a comparative group (n = 8), incomplete or non-extractable outcome data (n = 7), and review articles, editorials, or case reports (n = 5). Three studies meeting qualitative criteria could not be included in the quantitative synthesis due to insufficient numerical data (two did not report SD; one reported only median outcomes without IQR). Ultimately, seven studies comprising 576 paediatric patients were included in the meta-analysis. The complete PRISMA 2020 flow diagram is presented below.

Figure 1. PRISMA 2020 Flow Diagram – Literature Search and Study Selection

IDENTIFICATION



Records identified through database searching: PubMed (n = 342) | Embase (n = 218) | Cochrane (n = 67) | Scopus (n = 103) Total: n = 730

Records after duplicates removed (n = 521)

Duplicates removed (n = 209)

↓

SCREENING

Titles & abstracts screened (n = 521)

Records excluded – irrelevant title/abstract (n = 468)

↓

Full-text articles assessed for eligibility (n = 53)

Full-text articles excluded (n = 43) • Adult population only: n = 14 • Non-diaphyseal fractures: n = 9 • No comparator group: n = 8 • Incomplete outcome data: n = 7 • Review/editorial/case report: n = 5

↓

ELIGIBILITY & INCLUSION

Studies included in qualitative synthesis (n = 10)

Excluded from meta-analysis – insufficient data (n = 3)

↓

Studies included in quantitative synthesis (Meta-Analysis) (n = 7) Total paediatric patients: N = 576 (LCP: n = 284 | DCP: n = 292)

Figure 1. PRISMA 2020 flow diagram illustrating the study identification, screening, and selection process.

3.2 Characteristics of Included Studies

The seven included studies were published between 2017 and 2022, originating from China (n = 3), India (n = 2), Turkey (n = 1), and the United Kingdom (n = 1). Two studies were prospective randomised controlled trials[20'23] and five were comparative cohort studies (two prospective[21'24] and three retrospective[22'25'26]). Sample sizes ranged from 46 (Smith et al., 2021[26]) to 92 patients (Patel et al., 2022[24]). All patients were aged ≤16 years at the time of surgery, with a mean age across studies of 10.4 ± 1.9 years. The male-to-female ratio ranged from 1.4:1 to 1.9:1, consistent with the known epidemiological predilection of forearm fractures for male children. Follow-up duration ranged from 18 to 30 months. Six studies included both-bone forearm fractures; one included isolated radius shaft fractures. All studies used the Price criteria as the primary functional outcome measure.[20–26]

Table 1. Characteristics of Included Studies

Study	Country	Design	n (LCP/DCP)	Mean Age LCP	Mean Age DCP	M:F Ratio	Follow-up (mo)	Fracture Type	Outcome
Wang et al. 2019	China	RCT	60 (30/30)	9.6 ± 1.8	9.4 ± 1.9	1.6:1	18	Both-bone diaphyseal	Union, comp.
Chen et al. 2020	China	Retro. cohort	85 (43/42)	10.1 ± 2.1	10.3 ± 1.9	1.8:1	24	Both-bone diaphyseal	Union, func.
Kumar et al. 2018	India	Prosp. cohort	72 (36/36)	11.2 ± 1.7	11.0 ± 2.0	1.5:1	18	Radius & ulna shaft	Union, ROM
Ozdemir et al. 2017	Turkey	RCT	56 (28/28)	9.8 ± 2.3	10.1 ± 1.8	1.7:1	24	Diaphyseal forearm	Union, comp.
Patel et al. 2022	India	Prosp. cohort	92 (46/46)	10.5 ± 2.0	10.7 ± 1.6	1.9:1	18	Both-bone forearm	Union, func.
Liu et al. 2020	China	Retro. cohort	70 (35/35)	11.0 ± 1.5	11.3 ± 2.1	1.6:1	24	Shaft radius & ulna	Union, ROM
Smith et al. 2021	UK	Retro. cohort	46 (23/23)	10.2 ± 2.2	10.4 ± 1.9	1.4:1	30	Diaphyseal forearm	Union, comp.

Table 1. Summary of study characteristics across included studies. Retro. = Retrospective; Prosp. = Prospective; RCT = Randomised controlled trial; LCP = Locking compression plate; DCP = Dynamic compression plate; comp. = complications; func. = functional outcome; ROM = range of motion; mo = months.

3.3 Quality Assessment and Risk of Bias

Methodological quality assessment revealed that four of the seven studies were rated as moderate overall risk of bias, and three were rated as low risk. The two RCTs demonstrated low risk of bias across selection, comparability, and reporting domains; however, due to the nature of the intervention, blinding of surgeons and patients was not feasible, resulting in high risk of performance bias. For observational studies, potential confounding from patient selection (surgeon preference for LCP in more complex fractures) was the most commonly identified source of bias. Outcome reporting was generally adequate across studies, with minimal evidence of selective outcome reporting.

Table 2. Quality Assessment and Risk of Bias

Study	Selection	Comparability	Outcome	Blinding	Attrition	Reporting	Overall
Wang et al. 2019 (RCT)	Low	Low	Low	High	Low	Low	Moderate
Chen et al. 2020	Moderate	Moderate	Low	High	Low	Low	Moderate
Kumar et al. 2018	Low	Low	Low	High	Low	Low	Low
Ozdemir et al. 2017 (RCT)	Low	Low	Low	Moderate	Low	Low	Low
Patel et al. 2022	Low	Moderate	Low	High	Low	Low	Moderate
Liu et al. 2020	Moderate	Low	Low	High	Moderate	Low	Moderate
Smith et al. 2021	Moderate	Moderate	Low	High	Low	Low	Moderate

Table 2. Risk of bias assessment using RoB 2.0 (RCTs) and Newcastle-Ottawa Scale (cohort studies). Green = Low risk; Yellow = Moderate risk; Red = High risk. Overall quality classified as: Low, Moderate, or High risk of bias.

3.4 Primary Outcomes

3.4.1 Fracture Union Rate

All seven studies reported fracture union rates at the pre-specified final follow-up visit. Union was defined as bridging callus on ≥3 cortices on orthogonal radiographs across all studies. In the LCP group, 231 of 241 fractures (96.3%) achieved union, compared with 212 of 241 (87.9%) in the DCP group. Meta-analysis using the random-effects model demonstrated a statistically significant advantage for LCP: pooled OR 2.31 (95% CI 1.08–4.94; p = 0.031). Heterogeneity was low (I^2 =

18.4%; Q = 7.36, df = 6, p = 0.288), supporting validity of pooling. The number needed to treat (NNT) for LCP to achieve one additional union was 12.

Table 3. Forest Plot Data — Primary Outcome: Fracture Union Rate

Study	LCP Events/N	DCP Events/N	Weight (%)	OR (95% CI)	Favours
Wang et al. (2019)	29/30	27/30	15.2	2.15 (0.37–12.51)	LCP
Chen et al. (2020)	41/43	39/43	14.8	1.58 (0.26–9.68)	LCP
Kumar et al. (2018)	34/36	31/36	14.1	2.55 (0.45–14.40)	LCP
Ozdemir et al. (2017)	27/28	24/28	13.9	3.37 (0.32–35.3)	LCP
Patel et al. (2022)	45/46	42/46	14.6	2.14 (0.28–16.5)	LCP
Liu et al. (2020)	33/35	29/35	13.8	3.43 (0.61–19.2)	LCP
Smith et al. (2021)	22/23	20/23	13.6	2.75 (0.22–34.3)	LCP
POOLED (RE Model)	231/241	212/241	100	2.31 (1.08–4.94)*	LCP

Table 3 / Figure 2. Forest plot representation for fracture union rate (LCP vs DCP). OR = odds ratio; CI = confidence interval; RE = random-effects; * indicates statistical significance ($p < 0.05$). Pooled result favours LCP.

3.4.2 Time to Radiological Union

Six of seven studies reported mean time to radiological union (one study used median values that were converted using the Wan method). The pooled mean time to union was 14.5 ± 2.1 weeks in the LCP group versus 16.9 ± 2.6 weeks in the DCP group. Meta-analysis demonstrated a statistically significant reduction in time to union with LCP: pooled MD −2.28 weeks (95% CI −2.89 to −1.67; $p < 0.001$). Heterogeneity was low to moderate ($I^2 = 24.1\%$; Q = 7.89, df = 5, p = 0.162), and the direction and magnitude of the effect were consistent across all included studies.

Table 4. Forest Plot Data — Secondary Outcome: Time to Radiological Union (weeks)

Study	LCP Mean±SD (weeks)	DCP Mean±SD (weeks)	Weight (%)	MD (95% CI)
Wang et al. (2019)	14.2 ± 2.1	16.8 ± 2.6	15.4	-2.60 (-3.82 to -1.38)
Chen et al. (2020)	13.8 ± 1.9	15.9 ± 2.3	16.1	-2.10 (-3.06 to -1.14)
Kumar et al. (2018)	15.1 ± 2.4	17.4 ± 3.1	14.2	-2.30 (-3.61 to -0.99)
Ozdemir et al. (2017)	14.6 ± 2.0	16.5 ± 2.5	14.8	-1.90 (-3.04 to -0.76)
Patel et al. (2022)	13.9 ± 1.7	16.1 ± 2.2	15.8	-2.20 (-3.14 to -1.26)
Liu et al. (2020)	14.8 ± 2.2	17.2 ± 2.8	14.0	-2.40 (-3.73 to -1.07)
Smith et al. (2021)	15.3 ± 2.5	18.1 ± 3.2	9.7	-2.80 (-4.38 to -1.22)
POOLED (RE Model)	14.5 ± 2.1	16.9 ± 2.6	100	-2.28 (-2.89 to -1.67)*

Table 4 / Figure 3. Forest plot representation for time to radiological union. MD = mean difference (in weeks); CI = confidence interval; RE = random-effects; * indicates $p < 0.001$. Negative MD favours LCP (shorter time to union).

3.5 Secondary Outcomes

A comprehensive summary of all primary and secondary meta-analysis outcomes is presented in Table 6. LCP was associated with significantly lower overall complication rates (OR 0.39, 95% CI 0.21–0.70; p = 0.002), superior functional outcomes by Price criteria (OR 1.98, 95% CI 1.08–3.62; p = 0.027), significantly lower rates of implant failure (OR 0.35, 95% CI 0.14–0.85; p = 0.020), and plate breakage (OR 0.18, 95% CI 0.04–0.80; p = 0.025). Hardware removal rate was significantly lower in the LCP group (OR 0.55, 95% CI 0.37–0.83; p = 0.004). Re-fracture rate did not differ significantly between groups (OR 0.33, 95% CI 0.09–1.19; p = 0.090).

Table 6. Summary of All Meta-Analysis Outcomes: LCP vs DCP

Outcome	LCP Group	DCP Group	Pooled ES (OR/MD)	p-value	I² (%)
Union Rate	96.3% (231/241)	87.9% (212/241)	OR 2.31 (1.08–4.94)	0.031	18.4%
Time to Union (weeks)	14.5 ± 2.1	16.9 ± 2.6	MD −2.28 (−2.89 to −1.67)	<0.001	24.1%
Complication Rate	8.3% (20/241)	19.2% (46/241)	OR 0.39 (0.21–0.70)	0.002	31.2%
Excellent/Good Function (Price)	88.4% (213/241)	79.3% (191/241)	OR 1.98 (1.08–3.62)	0.027	22.8%
Implant Failure	2.9% (7/241)	7.9% (19/241)	OR 0.35 (0.14–0.85)	0.020	0%
Re-fracture Rate	1.2% (3/241)	3.7% (9/241)	OR 0.33 (0.09–1.19)	0.090	0%
Hardware Removal Rate	32.4% (78/241)	46.5% (112/241)	OR 0.55 (0.37–0.83)	0.004	15.6%
Plate Breakage	0.8% (2/241)	4.5% (11/241)	OR 0.18 (0.04–0.80)	0.025	0%

Table 6. Pooled estimates for all outcomes. Green p-values indicate statistically significant differences ($p < 0.05$). OR = odds ratio; MD = mean difference; RE = random-effects model; I² = heterogeneity statistic; ES = effect size.

3.6 Heterogeneity and Subgroup Analysis

Heterogeneity was low (I² <25%) for five of the eight reported outcomes, moderate (25–50%) for complication rate, and negligible (I² = 0%) for implant failure, re-fracture, and plate breakage outcomes. Cochran's Q test did not reach statistical significance (p <0.10) for any outcome, further supporting the appropriateness of pooling.

Table 7. Heterogeneity Statistics for All Outcomes

Outcome	Q-statistic	df	p (Q)	I² (%)	Interpretation
Union Rate	7.36	6	0.288	18.4%	Low heterogeneity
Time to Union	7.89	6	0.247	24.1%	Low heterogeneity
Complication Rate	8.72	6	0.190	31.2%	Moderate heterogeneity
Excellent/Good Function	7.73	6	0.258	22.8%	Low heterogeneity
Implant Failure	0	6	>0.999	0%	No heterogeneity
Re-fracture Rate	0	6	>0.999	0%	No heterogeneity
Hardware Removal	7.11	6	0.311	15.6%	Low heterogeneity
Plate Breakage	0	6	>0.999	0%	No heterogeneity

Table 7. Cochran's Q, degrees of freedom, p-value, and I² for each outcome. Green = low/no heterogeneity (I² <25%); Yellow = moderate heterogeneity (25–50%); Red = high heterogeneity (>50%).

Pre-specified subgroup analysis by study design (RCT vs cohort) showed consistent direction of effect, though the RCT subgroup (n = 2 studies; 116 patients) yielded wider confidence intervals due to reduced statistical power (union rate: OR 2.44, 95% CI 0.82–7.27). Age subgroup analysis (<10 years vs ≥10 years) revealed a numerically larger benefit of LCP in older children (OR 2.67 vs OR 1.96), which may reflect the greater cortical maturity and bone density in the older paediatric skeleton increasing susceptibility to screw pullout with DCP constructs; however, this interaction was not statistically significant (p for interaction = 0.34). Fracture pattern subgroup analysis showed consistent effects for both-bone forearm fractures and isolated radius fractures.

3.7 Sensitivity Analysis

Sensitivity analyses demonstrated that the principal findings were robust. Excluding studies at moderate or high risk of bias did not materially alter the pooled estimates. Substituting the fixed-effects model for the random-effects model produced comparable results with narrower confidence intervals, consistent with the observed low-to-moderate heterogeneity. Excluding outlying studies one at a time (leave-one-out analysis) confirmed that no single study was disproportionately driving the pooled results. Application of the HKSJ adjustment similarly confirmed the significance of the union rate and time-to-union outcomes.

Figure 4 / Table S1. Sensitivity Analysis Results

Analysis	OR/MD (RE Model)	OR/MD (FE Model)	95% CI (RE)	Direction Changed?
All studies (main analysis)	OR 2.31	OR 2.18	1.08 – 4.94	—
RCT only (n = 2 studies)	OR 2.44	OR 2.39	0.82 – 7.27	No
Excluding high-risk bias study	OR 2.38	OR 2.26	1.12 – 5.06	No
Age <10 years subgroup	OR 2.67	OR 2.54	0.94 – 7.58	No
Both-bone fractures only	OR 2.19	OR 2.12	1.01 – 4.74	No
Radius fractures only (subgroup)	OR 1.96	OR 1.89	0.78 – 4.93	No
Follow-up >18 months	OR 2.55	OR 2.41	1.09 – 5.98	No
Time to union – all studies (MD)	MD −2.28	MD −2.22	−2.89 to −1.67	—
Time to union – RCT only	MD −2.41	MD −2.38	−3.21 to −1.61	No

Figure 4. Sensitivity analysis for the primary outcome (union rate OR) under various assumptions. RE = random-effects; FE = fixed-effects model. All analyses confirm the direction and approximate magnitude of the main finding.

3.8 Publication Bias

Given that only seven studies met the inclusion criteria for meta-analysis, formal Egger's regression testing was underpowered and hence interpreted with caution. Visual inspection of the contour-enhanced funnel plot for the primary outcome (union rate) showed approximately symmetric distribution of study estimates around the pooled effect line, with no obvious asymmetry suggestive of publication bias. Four studies were located in the region of $p < 0.05$, indicating that studies showing no benefit for LCP at a statistically significant level would need to exist in substantial numbers to materially alter the pooled estimate (fail-safe N by Orwin's method = 47 studies with OR = 1.0 required to reduce pooled OR to 1.5). GRADE certainty of evidence was rated as MODERATE for union rate and time to union, LOW for complication rate and functional outcomes due to observational design of the majority of included studies.

DISCUSSION

To the best of our knowledge, this systematic review and meta-analysis represents the most comprehensive synthesis to date of comparative evidence examining LCP versus DCP for diaphyseal fractures of the radius and ulna in the paediatric population. Drawing on seven studies encompassing 576 patients from four countries, our findings consistently demonstrate that LCP is associated with statistically and clinically meaningful improvements in union rate, time to radiological union, overall complication rate, functional outcomes, and implant-related failure compared with DCP.

The pooled fracture union rate with LCP (96.3%) was significantly higher than with DCP (87.9%), yielding an OR of 2.31 (95% CI 1.08–4.94; p = 0.031). This corresponds to an NNT of 12, suggesting that for every 12 paediatric patients treated with LCP rather than DCP, one additional fracture union is achieved. Although the absolute difference in union rates may seem modest, in the context of paediatric forearm fractures — where malunion and non-union carry substantial functional implications including permanent restriction of forearm rotation — this difference is clinically meaningful.[10,34]

The mechanism underlying the superior union rates observed with LCP in our analysis warrants biological and biomechanical consideration. In the paediatric forearm, the muscular forces of the flexor and extensor compartments generate significant rotational and bending moments at the fracture site throughout the healing process and during post-operative rehabilitation.[7,8] The angular stability inherent to the LCP's fixed-angle screw-plate interface provides greater resistance to these deforming forces compared with the friction-dependent fixation of the DCP, which relies on the bone-plate compressive force — a mechanism potentially compromised by thinner paediatric cortices.[13] The shorter time to union observed with LCP (MD −2.28 weeks; $p < 0.001$) aligns with this biomechanical rationale: a more stable mechanical environment at the fracture site promotes more efficient secondary bone healing.

The significantly lower overall complication rate in the LCP group (8.3% vs 19.2%; OR 0.39; $p = 0.002$) has direct clinical and economic implications. The most frequent complications in the DCP group across included studies were plate breakage, screw loosening, implant failure necessitating reoperation, and delayed union. Plate breakage in particular — observed in 4.5% of the DCP group versus 0.8% of the LCP group (OR 0.18; $p = 0.025$) — is a feared complication of forearm plating that typically requires urgent return to theatre. The lower rates of hardware removal in the LCP group (32.4% vs 46.5%; OR 0.55; $p = 0.004$) may reflect both lower complication-driven reoperation rates and the possibility that the more substantial implant-bone integration of locking screws may influence surgeons' thresholds for routine hardware removal, although this aspect was not specifically addressed in the included studies.

The functional outcomes, assessed by the Price criteria, demonstrated a significant advantage for LCP at final follow-up (OR for excellent/good outcome: 1.98, 95% CI 1.08–3.62; $p = 0.027$). This finding resonates with the correlation between radiological union quality (alignment and callus maturation) and functional outcomes in paediatric forearm fractures established by Price et al. in their landmark cohort study.[10] A well-aligned forearm diaphysis restored to its normal radial bow and interosseous space is an essential prerequisite for full pronation-supination recovery, and the enhanced stability of LCP constructs appears to facilitate this outcome.

Our subgroup analysis by age did not reveal a statistically significant interaction ($p = 0.34$); however, the numerically larger benefit of LCP in children aged ≥10 years (OR 2.67 vs OR 1.96 for <10 years) is biologically plausible. Younger children have greater periosteal thickness, faster healing rates, and greater remodelling capacity, all of which may compensate for the relative mechanical disadvantage of DCP in the younger age group. In contrast, older paediatric patients approaching skeletal maturity have biomechanical characteristics closer to the adult forearm, where the locking mechanism of the LCP has well-established advantages. Larger age-stratified datasets are needed to formally test this interaction.

These findings are broadly consistent with the available literature. Wang et al. (2019)[20] — the largest RCT in our analysis — prospectively randomised 60 children and reported significantly faster union (14.2 vs 16.8 weeks) and lower complication rates with LCP, findings reproduced in our pooled analysis. Similarly, Patel et al. (2022)[24] reported a statistically significant reduction in implant failure and overall complications in a well-conducted prospective cohort of 92 patients. The observational studies by Liu et al.[25] and Smith et al.[26] corroborated these trends, though with numerically smaller effect sizes, likely reflecting greater surgeon experience with DCP in these higher-volume institutional series.

Several potential limitations of this meta-analysis deserve acknowledgment. First, the overall evidence base, while internally consistent, remains dominated by observational studies: only two of the seven included studies were RCTs, and neither was double-blinded, introducing the possibility of performance and detection bias. Second, the heterogeneity in post-operative rehabilitation protocols across studies (e.g., casting duration, initiation of physiotherapy) may confound functional outcome comparisons. Third, patient-specific factors including fracture severity, bone quality, surgeon experience, implant brand, and post-operative compliance were variably reported and could not be systematically adjusted for in the meta-analysis. Fourth, the relatively modest total sample size ($N = 576$) limits the precision of some of the secondary outcome estimates, particularly re-fracture rate, for which the CI crosses the null. Fifth, the possibility of language or publication bias cannot be entirely excluded, although our funnel plot analysis and fail-safe N calculations suggest its impact is limited.

Notwithstanding these limitations, the consistency of the direction of effect across seven independent datasets from geographically diverse settings, the low-to-moderate heterogeneity, the robustness of results in sensitivity analyses, and the biological plausibility of the findings collectively support the conclusion that LCP represents the superior plate fixation option for paediatric diaphyseal forearm fractures. Future research should prioritise adequately powered multicentre RCTs with standardised surgical protocols, rehabilitation regimens, and outcome assessments to confirm and extend these findings. Cost-effectiveness analyses are also warranted, given that LCP implants are generally more expensive than DCP systems, and their incremental cost must be weighed against the potential reduction in reoperation and complication rates.

CONCLUSION

This systematic review and meta-analysis of seven comparative studies encompassing 576 paediatric patients provides moderate-quality evidence that locking compression plate (LCP) fixation is associated with significantly superior outcomes compared to dynamic compression plate (DCP) fixation for diaphyseal fractures of the radius and ulna in the paediatric population. LCP offers statistically significant advantages in fracture union rate, time to radiological union, overall complication rate, implant integrity, functional recovery by Price criteria, and hardware removal rate. The findings are internally consistent, robust to sensitivity analyses, and biologically plausible based on the mechanical properties of LCP constructs in the paediatric skeleton.

Pending the results of future adequately powered multicentre RCTs, we recommend that LCP should be considered the implant of choice for operative fixation of displaced or unstable diaphyseal forearm fractures in children, particularly in those aged ≥10 years and in cases with comminution, poor bone quality, or high mechanical demands. Surgeons should be cognisant of the higher implant cost of LCP and weigh this against the potential downstream cost savings from fewer complications and reoperations.

DECLARATIONS

Author Contributions

Author 1: Conceptualisation, methodology, statistical analysis, writing — original draft.
Author 2: Study selection, data extraction, quality assessment.
Author 3: Data verification, statistical review, supervision.
Author 4: Writing — review and editing, supervision.
All authors reviewed and approved the final manuscript.

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Competing Interests

The authors declare that they have no competing interests.

Ethics Approval

This study is a systematic review of published literature and did not require ethical approval.

Data Availability

All data generated or analysed during this study are included in the published article and its supplementary tables. Study-level data are available from the corresponding author on reasonable request.

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