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Systematic Review

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Is the operative treatment of displaced diaphyseal forearm fractures in children superior to non-operative treatment? A systematic review of functional outcomes and complications

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Abstract

Background: There has been a rising tendency towards surgical intervention for diaphyseal forearm fractures in children in recent years; however, the literature lacks robust evidence for this. The aim of this systematic review was to identify and critically analyse studies examining the functional outcomes and complications of operative versus non-operative treatments for these common injuries. **Materials and Methods:** A literature search was performed, using MEDLINE, EMBASE, PubMed, Cochrane Central databases and Google Scholar for relevant articles published between January 2005 and December 2015. **Results:** 253 studies were identified, of which 23 met the rigorous inclusion and exclusion criteria. No significant differences in functional outcomes between the treatment groups were reported by any of the studies. There was a 21.4% complication rate with operative treatment and a 7.2% complication rate with non-operative treatment. **Conclusion:** This systematic review demonstrates that there is an increasing tendency towards operative management over non-operative treatment during the last decade, especially in older children and adolescents.

Keywords: Children, Pediatrics, Diaphyseal forearm fracture, Operative treatment, Conservative, Complications and Outcomes.

INTRODUCTION

Diaphyseal Forearm Fractures (DFFs) are the third most common fracture type in children: up to 5.4% of all fractures in children under 16 years of age, with a range of 3%-6% across the literature [1-6]. They are also twice as common in boys compared with girls [1].

The incidence of these fractures exhibits a bimodal age distribution, with peaks incidences between the age of 5-6 and then during adolescence at ages 10-14 [1, 7, 8]. The incidence of these injuries continues to increase [7, 9], and Ryan *et al*. [8] have postulated a link with lower bone mineralization resulting from poor nutrition, vitamin D deficiency and lack of physical activity.

Children younger than 10 years of age have a higher bone remodeling potential than adolescents [10, 11]. The majority of these fractures can be managed effectively with Closed Reduction (CR) and casting [6, 12, 13]. Approximately less than 10% of paediatric DFFs require surgical intervention [2, 14].

Residual angulation or rotational deformity can result in significant reduction in pronation and supination movements, particularly in older children approaching skeletal maturity [15]. Therefore, anatomical reduction may be of greater importance in this age group [16]. It is thought that restoration of the radial bow magnitude is the most crucial factor in preserving forearm motion and achieving better functional outcomes [15, 17, 18].

Despite the successful outcomes with conservative treatment in most cases, there has been a rising tendency towards surgical intervention for DFFs in children in recent years [2, 18-21]. However, the literature

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lacks robust evidence of the superiority of operative treatment over non-operative treatment in these fractures [10, 22, 23]. Schmittenbecher[18] reported an increase in the frequency of DFFs treated surgically from 1% to 40.4%. Another study showed a sevenfold rise in the number of surgically managed fractures from 1997 to 2008 [19].

The rate of re-displacement following CR of these fractures can vary between 10% and 60% [4, 21]. Another rare complication is re-fracturing, which can occur up to 6 months after initial injury [10]. In rare circumstances CR may result in malunion that affects functional outcome [4, 10]. The decision of whether to proceed with surgical intervention depends on several factors including: child age, fracture location and displacement, rotation and angulation [7, 24-27].

The method of surgical intervention remains controversial [12, 21, 30]. The most common surgical options include Elastic Intramedullary Nailing (EIMN) and Open Reduction and Internal Fixation (ORIF) with dual or single plate screw fixation [2, 11, 12, 22, 31]. Also, single bone fixation of either the radius or ulna in children has been reported in the literature [32-34].

Several studies have shown that EIMN has become more popular in the management of DFFs in children [19, 29, 31, 35, 36]. The advantages of EIMN include limited soft tissue dissection, better cosmesis, shorter operative time, reliable maintenance of fracture alignment and length, and easier implant removal. However, recent studies have reported several complications associated with EIMN fixation, including delayed union and nonunion of the ulna, implant migration, skin irritation over prominent hardware, pin site infection and Compartment Syndrome (CS) [19, 29, 31, 35, 36]. The rate of these complications was higher in children over than the age of 10 than in younger children [2, 19].

ORIF has been considered for older children, where rigid fixation and direct anatomic reduction of the fracture are essential for resorting forearm rotation [6, 31, 37]. This surgical option carries some disadvantages, including significant soft tissue dissection, periosteal stripping which increases the risk of nonunion, and the risk of re-fracture following implant removal [6, 31, 38].

The purpose of this comprehensive systematic review of the literature is to identify studies examining the functional outcome and complication of non-operative and operative treatment for both DFFs in children under the age of 18. We also aimed to critically appraise the evidence and describe the findings in light of the published studies from 2005 to 2015. Therein, we hope to determine if there is an advantage in the operative treatment over non-operative treatment that supports the rising trend towards operative treatment.

MATERIALS AND METHODS

Search Methodology

A comprehensive search of the literature with Medline, EMBASE, PubMed, Cochrane Central databases and also the Google Scholar searcher was performed, examining the functional outcomes and complications of non-operative and operative treatment for both DFFs in children under the age of 18.

All electronic online databases were searched for articles written in English or with an available English translation between January 2005 and December 2015. The literature search terms are outlined in (Table 1).

Table 1: Search terms used for literature review

#1 ('forearm'/exp OR 'forearm' OR 'forearm injuries'/exp OR 'forearm injuries')
#2 ('radius' OR 'ulna')
#3 (#1 OR #2)
#4 ('radius fracture')
#5 ('ulna fracture')
#6 (#4 AND #5)
#7 (#3 OR #6)
#8 ('shaft' OR 'diaphysis fracture' OR 'diaphysis' OR 'diaphyses' OR 'diaphyseal')
#9 (#7 AND #8)
#10 ('nonsurgical treatment' OR 'non-operative treatment' OR 'noninvasive method' OR 'Conservative treatment' OR 'closed treatment')
#11 ('surgical' OR 'operative intervention' OR 'fixation' OR 'invasive')
#12 (#10 OR #11)
#13 (#9 AND #12)
#14 ('Complication' OR 'outcomes')
#15 (#13 AND #14)
#16 (#13 AND #14 AND ([infant]/lim OR [child]/lim OR [preschool]/lim OR [school]/lim OR [Adolescent]/lim))
#17 (#13 AND #14 AND ([infant]/lim OR [child]/lim OR [preschool]/lim OR [school]/lim OR [Adolescent]/lim) AND [english]/lim AND [humans]/lim AND [2005-2015]/py)

Data assessment and eligibility criteria

Duplicate articles and those not related to our review were excluded. We reviewed all of the titles and abstracts of articles regarded as potentially eligible for further consideration. Subsequently, eligible studies were selected and analysed. References were individually reviewed for possible additional articles that could be eligible for inclusion. Thereafter, 2 reviewers selected eligible studies for final assessment according to explicit inclusion and exclusion criteria (Table 2).

Table 2: Summary of eligibility criteria

Inclusion criteria	Exclusion criteria
▪ Clearly assessed functional and/or clinical outcome and complication following non-operative or operative treatment ▪ Defined data in children younger than 18 years (skeletally immature) ▪ Included at least ten patients ▪ Examined both DFFs ▪ Complete/displaced/unstable fractures ▪ Human studies ▪ Published in English language ▪ RCT's or observational studies	▪ Duplicate studies ▪ Single bone forearm fracture ▪ Pathological fracture ▪ Complex forearm fractures (Galeazzi, Monteggia, intra-articular fractures, Greenstick fracture) ▪ External fixation ▪ Skeletally mature (>18) ▪ Isolated case reports, case series with sample size < 10, comments to editors, technical notes, epide-miological and radiological studies, anatomical or cadaveric studies, unpublished studies, review articles

Data extraction

The studies were systemically reviewed using a data extraction proforma. Data extraction was performed by one reviewer and checked by a second reviewer. Relevant information was extracted from each study: authors, year of publication, design of study, study population (population size, sex, age), treatment, and follow-up. Further information included union rate and time to union, functional outcome in terms of range of movement, and complications in terms of nonunion, malunion, delayed union, re-fracture, failure of metal work, re-operation, scar problems, soft tissue and wound complications.

Critical appraisal

Each study included in this systematic review was critically appraised independently using the Critical Appraisal Skills Programme checklist (CASP) [39]. Disagreements between reviewers were resolved by consensus or by the decision of a third independent reviewer.

RESULTS

Search results

An initial electronic search identified 253 potentially relevant studies. 69 were retrieved from Medline, 139 from EMBASE, 3 from Cochrane Central, 12 from PubMed publisher, and 30 from Google Scholar. We excluded 143 studies, as they were clearly unrelated to our study goals. 44 articles were found to be duplicated, leaving 65 articles of potential interest. 16 papers were excluded by reviewing the abstracts.

The remaining 49 studies were retrieved for more detailed assessment of full text, of which 28 articles were excluded. Two further articles were retrieved after checking the references of included studies. Consequently, a total of 23 studies met inclusion criteria (Fig. 1).

Characteristics of included studies

Sixteen of 23 selected studies were retrospective case-series [10, 27, 31, 35-37, 40-49]. Five studies had a prospective design [33, 50-53], one was a case-control study [54] and one was an RCT [55]. Overall, there were 1222 patients with both DFFs. The number of patients in each study ranged from 18 to 168. Of these, 1210 who were followed up and had enough data to be included in the individual studies. There were 836 males and 339 females. The mean patient age for the studies included ranged from 8 to 15.3 years, and the mean follow up time ranged from 3.9 to 132 months. In Tables 3 and 4 study characteristics and outcomes are summarized.

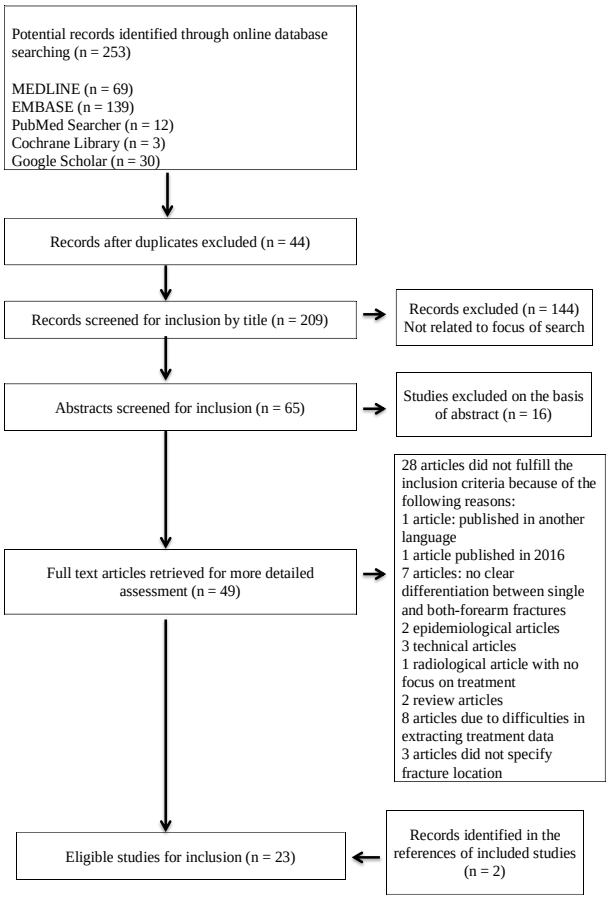

Figure 1: Flow chart for the process of selecting and reviewing the articles

Table 3: Study characteristics

Authors	Year	Study design	Total n (n with adequate f/u)	Average age, years (range)	Males/ Females	Average follow up months (range)	Operative	Non-operative
Fernandez *et al.* (35)	2005	Retrospective Comparative	64 (60)	ORIF 11.16 (5-14) IMN 9.3 (3-14)	47/17	ORIF 32.3 (8-44) IM Nail 20.6 (6-40)	19 ORIF 45 EIMN (Both)	0
Jubel *et al.* (50)	2005	Prospective	51 (43)	8 (3-13)	37/14	38 ± 21	51 EIMN (Both)	0
Zionts *et al.* (51)	2005	Prospective	25 (25)	13.3 (8.8-15.5)	21/4	10.8 (3-31)	0	25
Smith *et al.* (40)	2005	Retrospective Comparative	53 (53)	9.6 (2-17)	37/16	No data	15 ORIF 21 EIMN (Both)	17
Houshian & Bajaj (33)	2005	Prospective	20 (20)	10 (6-15)	14/6	20 (6-30)	17 R EIMN 3 U EIMN	0
Al-Sabbagh *et al.* (52)	2007	Prospective Comparative	50 (50)	10.42 (4-15)	37/13	27 (10-40)	26 EIMN 24 ORIF (Both R&U)	0
Hammad *et al.* (41)	2007	Retrospective	18 (18)	10 (8-14)	13/5	27.7 (30-55)	18 U ORIF	0
Kose *et al.* (27)	2008	Retrospective Comparative	32 (32)	12 (10-15)	27/5	24 (13-40)	21 EIMN 11 ORIF (Both)	0

Reinhardt *et al*. (31)	2008	Retrospective Comparative	31(31)	13.2 (10-16)	23/8	27 (6-45)	19 EIMN 12 ORIF (Both)	0
Teoh *et al*. (43)	2009	Retrospective Comparative	34 (34)	11.6 (7-15)	22/12	IMN 31 (24-45) ORIF 31.8 (23-44)	17 EIMN 17 ORIF (Both)	0
Ali *et al*. (36)	2010	Retrospective	20 (20)	12 (6-15)	11/9	24 (12-30)	20 EIMN (Both)	0
Flynn *et al*. (2)	2010	Retrospective Comparative	149 (149)	11.2 (3-17)	111/38	5.1(1-26)	103 EIMN (both) 44 ORIF (26 single, 16 both) 2 Hybrid	0
Shah *et al*. (37)	2010	Retrospective Comparative	61 (61)	13.9 (11.5-16.9)	47/14	No data	15 EIMN 46 ORIF (Both)	0
Dietz *et al*. (47)	2010	Retrospective	38 (38)	9 (4-14)	18/20	3.9 (1.1- 12)	38 U EIMN	0
Parajuli *et al*. (46)	2011	Retrospective Comparative	50 (50)	10.4 ± 3.09	38/12	11.8 (6-16)	50 EIMN (Both)	0
Alnaib *et al*. (48)	2011	Retrospective	29 (29)	9 (5-17)	20/9	6.8 (4-12)	29 R EIMN	0
Wall *et al*. (47)	2012	Retrospective	32 (32)	14.1 (12.1-17.6)	28/4	9 (1.5-20)	32 EIMN (Both)	0
Sinikumpu *et al*. (10)	2013	Retrospective Comparative	168 (168)	8.6 (<16)	117/51	No data	66 EIMN 5 ORIF (Both)	97
Antabak *et al*. (46)	2013	Retrospective	88 (88)	10.5 ± 2.59 (4-16)	42/46	No data	88 EIMN (Both)	0
Colaris *et al*. (55)	2013	RCT	24 (24)	10.4 (No data)	14/10	9 (No data)	11 Single EIMN (7 R, 4 U) 13 EIMN Both (11 Both, 2 U)	0
Ali A. (53)	2013	Prospective	35(35)	15.3 (14-17)	20/15	31 (24-48)	35 EIMN (Both)	0
Hassan W. (49)	2014	Retrospective Comparative	103 (103)	8.5 (2.5-13)	92/11	Up to 6	23 EIMN 2 ORIF (Both)	78
Sinikumpu *et al*. (54)	2014	Case-control	47 (47)	8.5 (3-16)	No data	132 (108-168)	0	47

EIMN; elastic intramedullary nailing, ORIF; open reduction and internal fixation, R; radius, U; ulna, RCT; randomized controlled trial

Table 4: Study Outcomes

Author	**Total n**	**Union rate**	**Average time to union; weeks (range)**	**Functional and/or clinical outcome**	**Complications**
Fernandez *et al*. (35)	64	100%	No data	No significant difference in functional outcome between the two groups (p = 0.303) EIMN is superior in terms of better cosmesis & shorter operative time	ORIF 2 refractures 1 SRN neuropraxia EIMN1 refracture 1 pseudoarthrosis 3 SRN neuropathy 2 delayed union 2 superficial infection
Jubel *et al*. (50)	51	No data	13 (No data)	Forearm pro-supination 40 excellent, 3 good No fair/poor outcomes	2 SRN neuropraxia 8 soft tissue irritation 3 shortening of nail
Zionts *et al*. (51)	25	100%	8.4 (4-12)	Price criteria; 16 excellent, 6 good, 3 fair outcomes	2 Required repeat CR
Smith *et al*. (40)	53	No data	No data	Not mentioned - More complications in ORIF group	Non-op 1 decrease supination EIMN 4 prominent hardware 1 loss of thumb ext. 2 delayed union 1 non-union 1 SRN neuropraxia 1 painful ulna bursitis ORIF 2 postop CTS 1 CS 1 loss of thumb ext. 1 restriction in pro/sup 1 no fingers extension

					Significant difference in immediate & long-term complications between non-op group compared to op group (p = 0.012, p = 0.046, respectively). No difference between ORIF & EIMN groups
Houshian & Bajaj (33)	20	100%	8.4 (4-12)	All achieved full ROM of elbow, wrist & forearm	No complications mentioned
Al-Sabbagh *et al.* (52)	50	No data	No data	EIMN 88.5% excellent/good outcomes ORIF 87.5% excellent/ good outcomes Operative time and LOS were significantly shorter in EIMN group (p<0.001)	EIMN 1 pin track infection ORIF 2 superficial infection 1 deep infection 1 delayed union 1 CS
Hammad *et al*. (41)	18	100%	11.4 (8-16)	Daruwalla criteria; 13 excellent, 4 good, 1 fair. No limitations in daily activities.	1 superficial infection
Kose *et al*. (27)	32	100%	IMN 8.8 (8-16) ORIF 9 (8-16)	Price criteria; All had excellent outcomes, except 1 in the ORIF group with good outcome	EIMN 1 delayed union 1 pin difficult to remove 5 superficial infection 2 SRN neuropraxia 2 poor cosmesis ORIF 1 superficial infection 3 poor cosmesis
Reinhardt *et al*. (31)	31	90%	No data	No significant difference in forearm ROM between the groups (p=0.174)	EIMN 4 major (2 refractures, 1 ulnar non-union, 1 CS) 8 minor (4 delayed union, 3 superficial infection, 1 bursitis over olecranon) ORIF 4 majors (2 refractures, 1 nonunion, 1 broken plate) 4 minors (4 delayed union) No significant difference in minor & major complications between both groups (p = 0.676 and 0.716, respectively)
Teoh *et al*. (43)	34	100%	No data	No significant differences in the loss of forearm motion and grip strength between both groups. No difference in PSONA score. ORIF group had significantly worse Manchester scar score (p=0.012)	EIMN 1 osteomyelitis ORIF 1 ulna nerve palsy 1 loose ulnar screw
Ali *et al*. (36)	20	100%	10 (7-12)	Price criteria; 14 excellent, 5 good, 1 fair. All achieved full elbow ROM	2 local tissue irritation 1 superficial infection 1 SRN neuropraxia
Flynn *et al*. (2)	149	96.59%	IMN OR 8.6 (4-12) IMN CR 6.9 (4-11) ORIF 9.2 (6-16)	EIMN 80 excellent, 15 fair, 8 poor. ORIF no outcome data.Older children > 10 years had poorer outcomes and higher rate of delayed union	EIMN 6 delayed union 2 CS 2 superficial infection 2 EPL tendon laceration ORIF 1 CS 11 minor pro/sup deficit
Shah *et al*. (37)	61	No data	IMN 8.5 (5-16) ORIF 8.9 (6-33)	83% achieved full forearm rotation. No significant difference in forearm ROM	EIMN 3 minor (2 SRN neuropraxia, 1 olecranon bursitis) ORIF 8 minor (3 SRN neuropraxia, 1 UN neuropraxia, 3 hypertrophic scars, 1 superficial infection) 5 Majors (1 ulnar malunion, 1 radial delayed union, 1 radial nonunion, 1 refracture, 1 hematoma)
Dietz *et al*. (47)	38	No data	8 (3.6-15.86)	92% achieved 160º or greater forearm rotation, 5% mild restriction, 3% 80º forearm sup & 30º pro at final F/U	1 superficial infection 1 re-fracture
Parajuli *et al*. (44)	50	100%	8 (6.5-13)	Price *et al*. 47 excellent, 3 good outcomes	4 skin irritation 1 backing out of ulnar pin 3 superficial skin breakdown and exposure of hardware 1 delayed union
Alnaib *et al*. (48)	29	100%	No data (6-8)	All achieved full forearm ROM	2 superficial infection 2 re-fracture
Wall *et al*. (45)	32	98%	Radius 9 Ulna 10.5	Anderson criteria; 30 excellent, 1 satisfactory, 1 failure due to non-union	1 radial non-union 2 re-fracture
Sinikumpu *et al*. (10)	168	96.4%	4 (no data)	Not mentioned - Complications were 2.3 fold higher in the non-op group	Op (6 delayed union, 2 non-union, 6 re-fracture, 4 nerve palsy, 1 unsightly scar) Non-op (5 delayed union, 6 re-fracture, 5 nerve palsy)
Antabak *et al*. (46)	88	No data	No data	Price criteria; 76 excellent, 11 good, 1 poor outcomes	1 myositis ossificans 3 superficial infection 9 soft tissue irritation 6 SRN neuropraxia 1 re-fracture 1 delayed union

Colaris *et al*. (55)	24	95.8%	No data	Daruwalla; single-bone (3 excellent, 6 good, 2 fair, 2 poor), both-bone (5 excellent, 4 good, 2 fair, 2 poor). Price; single-bone (5 excellent, 4 good, 3 fair, 1 poor), both-bone (5 excellent, 2 good, 4 fair)	Single 4 re-displacement 2 transient neuropraxia 1 re-fracture 1 excoriation skin 1 non-union of ulna Both 1 re-fracture 1 superficial infection 1 transient neuropraxia 1 hardware problem
Ali (53)	35	100%	12 (8-15)	Price *et al*. 21 excellent, 12 good, 2 fair. All achieved full elbow ROM	2 hardware pain 1 delayed union 1 SRN neuropraxia 1 partial EPL rupture 1 superficial infection
Hassan (49)	103	No data	No data	Price criteria; Non-op 70 excellent, 8 good. Op 20 excellent, 4 good, 1 fair	Op 2 superficial infection 1 joint stiffness Non-op 2 mal-union
Sinikumpu *et al*. (54)	47	100%	No data	All achieved full ROM Excellent long term outcome	1 visible deformity

EIMN, elastic intramedullary nail; ORIF, open reduction and internal fixation; OR, open reduction; CR, close reduction; SRN, superficial radial nerve; CTS, carpal tunnel syndrome; CS, compartment syndrome; non-op, non-operative; op, operative; LOS, length of stay; ROM, range of movement; F/U, follow-up; Ext. extension; UN, ulnar nerve; pro-supination, pronation-supination

Treatment methods

Two studies reported outcomes on non-operative treatments [51-54]. A total of 264 patients were treated non-operatively. Three studies compared non-operative with operative treatment [10, 40, 49]. Nineteen studies had patients treated solely with operative means. Eight studies directly compared EIMN with ORIF [2, 27, 31, 35, 37, 43, 52]. One study compared single-bone fixation with both-bone fixation [55]. Six studies reported EIMN of both-bone fixation [37, 44-46, 50, 53, 56]. Four studies reported single-bone fixation [33, 41, 47, 48]. In total, 958 patients received operative treatment.

Closed reduction and Cast Application

Outcomes- Two studies report non-operative treatment of both DFF's. Zionts *et al*. [51] classified outcome according to Price *et al*. [57] criteria. They reported a high proportion of excellent to good results in patients who showed an angulation of up to 15º compared with those who showed more than 15º of angulation in radiographs. Three patients only had a fair outcome and healed between 6-17º angulation of the radius and 13-20º angulation of the ulna, resulting in 20-40º loss of pro-supination. Although the patients were not concerned about the appearance and reported no functional limitation, one of the patient's parents was not pleased with cosmetic outcome. In their long-term follow-up, Sinikumpu *et al*. [54] found that all patients achieved excellent ROM and grip strength was similar to control cases and uninjured side. There was no significant difference between both groups in terms of decreased tolerance of physical activity (p=0.09) and symptoms disturbing daily activities (p=0.8).

Complications- Zionts *et al*. [51] reported no complications related to the non-operative treatment of DFF's, however, two patients underwent a repeat manipulation during the follow-up period. Sinikumpu *et al*. [54] had one patient with visible deformity of the forearm and five patients who required re-manipulation during the short-term follow-up.

Fracture Union- Both studies were associated with a union rate of 100%.

Comparative studies (Operative versus Non-operative treatment)

Outcomes- Three studies directly compared operative with non-operative treatment outcomes. Hassan [49] measured outcome according to Price *et al*. [57] criteria. They reported no statistical significant differences in the functional outcome between both groups (p=0.296). Both Smith *et al*. [40] and Sinikumpu *et al*. [10] did not report on functional outcome.

Complications- There was a 21.4% complication rate with operative treatment and a 7.2% complication rate with non-operative treatment. Two patients in Hassan [49] series of non-operatively treated fractures developed malunion and subsequently required re-operation. Smith *et al*. [40] found significantly higher immediate and long-term complication rate in the operative groups (33% for ORIF and 42% for EIMN) compared to 5% complication rate with non-operative treatment. There was no significant difference between both operative groups. However, Sinikumpu *et al*. [10] reported that the overall complications were 2.3-fold more common in the non-operative group (56%) compared to the EIMN group (24%) and ORIF group (40%). Also, they found that the risk of re-operations were more higher among the non-operative group (37.1%) compared to the operative group (14.1%). Cosmetic outcome scoring was not formally used but one child left with an unacceptable scar in the Sinikumpu *et al*. [10] series, and subsequently required re-operation.

Bone Union- Delayed union occurred in 2.6% (n=5) of the non-operative group compared to 6.2% (n=8) of the operative group. Nonunion was seen in 2.31% (n=3) of the operative group.

Perioperative Variables- Length of Hospital Stay (LOHS) was significantly shorter for those treated non-operatively compared to those treated operatively (p=0.005) [49].

Comparative studies (Elastic Intramedullary Nail versus Open Reduction and Internal Fixation)

Outcomes. Seven studies directly compared EIMN with ORIF. Al-Sabbagh *et al*. [52] and Kose *et al*. [27] used Price *et al*. [57] criteria to evaluate the functional outcome. They found that the majority of patients had excellent to good outcomes. Flynn *et al*. [2] used Forearm Fracture Fixation Outcome Classification to assess outcome. 77.7% of patients who had EIMN achieved excellent outcome, however, the outcome was poorer in children older than 10 years. The ORIF functional outcome was not reported. Kose *et al*. [27] classified cosmesis according to patient satisfaction. ORIF resulted in significantly worse cosmetic outcome. Similarly, Fernandez *et al*. [35] reported that 82% of children and parents were satisfied with scars from EIMN, whereas only 45% were satisfied with scars from ORIF.

Only one study reported on parent-reported functional scores [43]. Teoh *et al*. [43] used The Pediatric Orthopaedic Society of North America (POSNA) validating functional tool [58], subjective contentment and dynamometric grip strength. They demonstrated excellent results in

terms of restoration of forearm function. There was no significant difference in grip strength and POSNA score between both groups.

Complications- There was a 19.9% (49/246) complication rate with EIMN and a 27.2% (47/173) complication rate with ORIF. Reinhardt *et al*. [31] reported no significant difference in minor and major complication rates between both groups (p=0.676 and p=0.716, respectively). Shah *et al*. [37] showed a trend toward a higher rate of total and major complications in the ORIF group.

Bone Union- Flynn *et al*. [2] demonstrated an increasing risk of delayed union with IMN as age increases. It was evident in children over the age of 10 years. In contrast, delayed union did not occur in any patients below the age of 10. Shah *et al*. [37] reported no statically significant difference between both groups in terms of time to fracture union.

Perioperative variables- Most of the studies reported that operative time and LOHS were shorter in EIMN compared to ORIF. Also, Reinhardt *et al*. [31] demonstrated shorter tourniquet time in EIMN.

Elastic Intramedullary Nailing

Outcomes- Six studies reported on EIMN of both DFF's. Five studies measured outcomes according to Price *et al*. [57] and one study used Anderson *et al*. [59] classification. The majority of children had excellent to good outcomes following EIMN. None of the studies reported on cosmesis.

Complications- Four patients sustained re-fracture; three of them were sustained with EIMN in place.

Bone union- The overall rate of nonunion and delayed union was 0.36% and 1.2%, respectively.

Comparative studies (single-bone versus both-bone forearm fixation)

Outcomes- One RCT compared between single and both-bone forearm fixation outcomes. Colaris *et al*. [55] reported outcome in 11 cases of single-bone fixation compared with 13 both-bone fixation with IMN. They identified a large number of children with limitation of pronation-supination compared to other studies according to Price *et al*. [57] and Daruwalla [15]. The authors used visual analog scale cosmetics of the fractured arm [60]. The orthopaedic surgeon and parents completed this scale. No significant difference was identified between the groups.

Complications- Single-bone fixation associated with a higher rate of re-displacement and overall complications.

Bone union- One child who was treated with single-bone fixation developed ulnar nonunion.

Perioperative variables- The operative time was similar in both groups.

Single-bone fixation of both-bone DFF's

Outcomes- Four studies reported on single-bone forearm fixation. Dietz *et al*. [47] reported that 35 patients had achieved ≥ 160º of forearm ROM, two patients lacked the terminal 20º of supination, and one patient had 80º of supination and 30º of pronation. Hammad *et al*. [41] reported excellent to good results with single-bone fixation according to Price *et al*. [57] and Daruwalla [15]. The rest of the studies reported excellent to good outcomes, according to subjective measurement of forearm ROM. The authors did not report on the cosmesis.

Complications- There were 3 cases of re-fracture after initial injury.

Bone union- All patients achieved a union rate of 100%.

DISCUSSION

The purpose of this systematic review was to determine if there is an advantage in operative treatment, which would justify its rising trend. We found that the total incidence of operative treatment was increasing. The rationale behind this increasing trend is due to the potential failure of non-operative management and the importance of reducing the angular deformity to preserve normal forearm function [4, 21]. Yang *et al*. [61] reported that re-displacement is close to 10 times more in the presence of a complete fracture of both DFF's. Orthopaedic surgeons should be familiar not only with different methods of treatment but also with the functional forearm anatomy and injury mechanism to decide which treatment option is feasible [62].

Despite the existing debate as to whether operative fixation of paediatric DFF's is justified, no high level of evidence exists to guide treatment [2, 10, 20]. Two studies have shown good outcome with CR and casting. Sinikump *et al*. [54] conducted a population-based age and sex matched case-control study. They have shown excellent 11-year functional outcome of non-operative management of displaced DFF's and age of patients was not a limiting factor. Zionts *et al*. [51] examined DFF's treated non-operatively in 25 children with age ranging between 8.8 and 15.5 years old and found that loss of pro-supination averaged 4º and 6.8º, respectively, with all patients achieving full ROM. However, this contradicts Sinikumpu *et al*. [10] and Hassan [49] results, who reported a higher rate of complications associated with non-operative management of displaced DFF's.

Based on the results of the included studies, it was not possible to determine any significant difference in functional outcome between EIMN and ORIF for both DFF's. Small sample sizes may have prohibited detection of statistically significant differences between both groups. Cosmetically, EIMN provided significantly better results in terms of the smaller incision and scar length than ORIF as examined by three studies [27, 35, 43]. For both healing problems and complications, rates varied significantly between the included studies and did not routinely favor one fixation method over the other. The overall complication rate was higher in ORIF group (27.2%) compared to EIMN group (19.9%). Shah *et al*. [37] reported a trend towards a higher overall complication with ORIF. We found the overall rate of complications to be higher than expected. This could be secondary to some element of selection bias in the studies presented.

Six studies had older series of children that they compared [2, 27, 31, 35, 37]. These studies showed a nearly of 5.3% delayed union rate with EIMN compared to 3.5% rate with ORIF. Although not statistically significant, these findings suggest that EIMN may carry a higher rate of delayed union as age increases. Most of these studies demonstrated shorter operative time, LOS and intra-operative tourniquet usage with EIMN [31, 35, 37, 52].

Flynn and Walters [63] reported in 10 of the 17 children who underwent single-bone fixation of the ulna. They showed that all fractures healed without evidence of complications or functional limitations. The authors concluded that this method provides a safe and effective option for displaced DFF's.

To date only one RCT has investigated single-bone fixation versus both-bone fixation and the rest of the studies have prospectively or retrospectively investigated single-bone fixation in both DFF's [33, 41, 47, 48]. Colaris *et al*. [55] conducted an RCT comparing the outcomes of single-bone fixation versus both-bone fixation. They reported a higher rate of

Table 5: Critical appraisal of studies. Observational studies

Study	Clear statement of aims?	Appropriate qualitative methodology?	Appropriate study design to address the aims?	Appropriate sampling strategy?	Appropriate data collection?	Adequate consideration of researcher/participant role?	Ethical considerations?	Rigorous data analysis?	Clear statement of findings?	How valuable is research?
Fernandez *et al*. (36)	Yes	Yes	• Yes • Clinician-reported outcome score used • Patient cosmetic-reported outcome score used	• Inclusion/exclusion criteria clearly mentioned • No significant differences between the two groups for age and sex • Indications for surgery not mentioned	• Retrospective non-randomised comparative study • Perioperative variables were clearly mentioned • Duration of hospital stay and follow-up mentioned clearly • Surgical techniques mentioned clearly • Time for fracture union not stated	• Number of surgeons and their role not mentioned • No differences between the groups in the level of training of the surgeons • Subjective opinion of patient and parent were considered	• Not stated	• Small sample size • No power calculation • No depth in description of the statistical analysis • Limitations not identified	• Clear statement of findings • Outcomes well-defined • Rationale for EIMN or ORIF with dual-plating fixation discussed	• Study linked to current practice and knowledge • Mention of relevant literature
Jubel *et al*. (51)	Yes	Yes	• Yes • Clinician-reported outcome score used	• Inclusion/exclusion criteria clearly mentioned • Clear indications for surgery • Rationale for EIMN choice not clearly defined	• Retrospective non-randomised study • Perioperative variables were mentioned • Duration of LOS and follow-up mentioned clearly • Surgical technique mentioned • Time for fracture union stated clearly	• Number of surgeons and their role not mentioned • Radiological findings clearly defined • Subjective opinion of patient and parent were considered	• Not stated	• Small sample size • No statistical analysis performed • Limitations not identified	• Clear statement of findings • Outcomes well-defined • Discussion of the evidence both for and against the researchers argument	• Study linked to current practice and knowledge
Zionts *et al*. (52)	Yes	Yes	• Yes • Clinician-reported outcome score used	• Inclusion criteria clearly mentioned • Rationale for non-surgical treatment clearly defined	• Prospective non-randomised study • Follow-up duration was stated • Long term follow-up was not stated • Time for fracture union stated clearly	• Number of surgeons and their role not mentioned • Radiological findings clearly defined • Subjective opinion of patient and parent were considered	• Not stated	• Appropriate statistical analysis • Small sample size • No power calculation or mention of confidence interval • Limitations not identified	• Clear statement of findings • Outcomes well-defined • Discussion of the available evidence	• Study linked to current knowledge
Smith *et al*. (41)	Yes	Yes	• Yes • Functional outcomes score was not used	• Inclusion/exclusion criteria clearly mentioned • Rationale for surgical fixation was not stated • Indications for surgery was not mentioned	• Retrospective non-randomised comparative study • Follow-up period was not stated • No data on fracture union	• Number of surgeons and their role not mentioned • Subjective opinion of patient and parent was not stated	• Not stated	• Small sample size • No depth in description of the statistical analysis	• Brief discussion of available evidence • Clear statement of findings	• Findings linked to current knowledge and practice
Houshian & Bajaj (34)	Yes	Yes	• Yes • Subjective measure of range of motion • Patient-reported outcome score was not used	• Inclusion/exclusion criteria were not stated • Indications for surgery clearly defined • Rationale for EIMN use was not stated	• Prospective non-randomised study • Follow-up duration was mentioned • Time for fracture union clearly stated • Surgical technique mentioned • Perioperative variables clearly mentioned	• Number of surgeons and their role not mentioned	• Not stated	• Small sample size • No statistical analysis performed • Limitations not identified	• Rationale for single-bone fixation discussed • Clear statement of findings	• Study linked to current knowledge

Al-Sabbagh *et al*. (53)	Yes	Yes	• Yes • Clinician-reported outcome score used • Patient-reported outcome score was not used	• Inclusion/exclusion criteria clearly mentioned • Rationale for surgical fixation was not stated • Indications for surgery was mentioned • Patients were divided randomly into two groups	• Prospective comparative study • Follow-up duration clearly mentioned • Time for fracture union not stated • Surgical techniques mentioned • Perioperative variables clearly mentioned	• Number of surgeons and their experience not mentioned • Does not adequately explain the randomization process	• Not stated	• Small sample size • No depth in description of statistical analysis Ÿ No power calculation • No mention of confidence interval • Limitations not identified	• Outcomes well-defined • Clear statement of findings • Rationale for EIMN or ORIF with dual-plate fixation discussed	• Study linked to current knowledge • Brief discussion of available evidence
Hammad *et al*. (42)	Yes	Yes	• Yes • Clinician-reported outcome score used • Patient-reported outcome score was not used	• Inclusion/exclusion criteria were not stated • Indications for surgery not defined • Rationale for plate use was not stated	• Prospective non-randomised study • Follow-up period clearly mentioned • Time for fracture union stated • No mention of surgical technique • Perioperative variables clearly mentioned	• Number of surgeons and their experience not mentioned Ÿ Radiological findings not defined	• Not stated	• Small sample size • No statistical analysis performed • Limitations not identified	• Outcomes well-defined • Clear statement of findings	• Study linked to current knowledge • Rationale for single-bone fixation discussed
Kose *et al*. (28)	Yes	Yes	• Yes • Clinician-reported outcome score used • Patient cosmetic-reported outcome score used	• Inclusion/exclusion criteria clearly mentioned • Indications for surgery clearly defined • Rationale for plate or EIMN use was not stated • No significant differences between the two groups for age, sex, and fracture level	• Retrospective non-randomised comparative study • Follow-up period clearly mentioned • Time for fracture union not stated • Surgical technique stated • Perioperative variables clearly mentioned	• Number of surgeons stated, but their experience not mentioned • Radiological findings not defined	• Not stated	• Small sample size • Appropriate statistical analysis • Limitations identified • No power calculation • No confidence interval	• Outcomes well-defined • Clear statement of findings	• Study linked to current knowledge • Further work identified
Reinhardt *et al*. (32)	Yes	Yes	• Yes • Clinician-reported outcome score used	• Inclusion/exclusion criteria clearly mentioned • Indications for surgery not defined • Rationale for surgery based on surgeon's preference • Age discrepancy between the groups	• Retrospective non-randomised comparative study • Follow-up period clearly mentioned • Time for fracture union stated • Surgical technique stated • Perioperative variables clearly mentioned	• Number of surgeons and their experience clearly mentioned • Radiological findings defined	• Not stated	• Small sample size • Appropriate statistical analysis • Limitations identified • No power calculation • No confidence interval	• Outcomes well-defined • Clear statement of findings	• Study linked to current knowledge • Further work identified
Teoh *et al*. (44)	Yes	Yes	• Yes • Clinician-reported outcome score used • Validated patient-reported outcome score used (POSNA) • Patient cosmetic-reported outcome score used (Manchester scar score)	• Inclusion/exclusion criteria clearly mentioned • Indications for surgery clearly defined • Rationale for surgery based on supervising consultant surgeon's preference	• Retrospective comparative study • Randomly matched for sex and age for each group • Follow-up period clearly mentioned • Time for fracture union not stated •Surgical technique stated • Perioperative variables clearly mentioned • All received post-operative rehab regime	• Number of surgeons and their experience clearly mentioned • Radiological findings clearly defined and verified • Patients who returned for the research clinic were assessed by independent clinical researcher who had not been involved in the treatment phase	• Ethical approval by Regional Ethics Committee	• Appropriate statistical analysis • Age and Sex matched study • Limitations identified	• Outcomes well-defined • Clear statement of findings	• Study linked to current knowledge • Further work identified • Relevant literature search

Ali *et al.* (37)	Yes	Yes	• Yes • Clinician-reported outcome score used	• Inclusion/exclusion criteria were not stated • Indications for surgery defined • Rationale for EIMN use was not stated	• Retrospective non-randomised comparative study • Follow-up period clearly mentioned • Time for fracture union stated • Surgical technique stated	• Number of surgeons and their experience not mentioned	• Not stated	• Small sample size • No statistical analysis performed • Limitations not identified	• Outcomes well-defined • Clear statement of findings	• Study linked to current knowledge
Flynn *et al.* (2)	Yes	Yes	• Yes • Clinician-reported outcome score used • Patient cosmetic-reported outcome score not used	• Inclusion/exclusion criteria clearly mentioned • Indications for surgery clearly defined • Rationale for surgery based on surgeon preference	• Retrospective non-randomised comparative study • Follow-up period clearly mentioned • Time for fracture union stated • Surgical techniques for both not stated • Perioperative variables not mentioned	• Number of surgeons and their experience not clearly mentioned • Radiological findings not defined	• Approved by Institutional Review Board	• Appropriate statistical analysis • No mention of power calculation or confidence interval • Limitations identified	• Outcomes well-defined • Clear statement of findings • ORIF complications were briefly mentioned	• Study linked to current knowledge • Relevant literature search • Further work identified
Shah *et al.* (38)	Yes	Yes	• Yes • Subjective measure of range of motion • Patient cosmetic-reported outcome score not used	• Inclusion/exclusion criteria clearly mentioned • Patients with either single-bone or both-bone fixation were included • Indications for surgery not clearly defined • Rationale for EIMN or ORIF use was determined by the treating surgeon	• Retrospective non-randomised comparative study • Follow-up period clearly mentioned • Time for fracture union stated • Surgical techniques for both stated • Perioperative variables mentioned	• Number of surgeons and their experience not clearly mentioned • Pre-op and post-op radiological findings were defined and verified by an independent Paediatric radiologists	• Approved by Institutional Review Board	• Appropriate statistical analysis • No mention of power calculation or confidence interval • Small sample size • Limitations identified	• Outcomes well-defined • Clear statement of findings • EIMN complication clearly stated and compared to ORIF	• Study linked to current knowledge • Relevant literature search • Further work identified
Dietz *et al.* (48)	Yes	Yes	• Yes • Subjective measure of range of motion • Patient-reported outcome score not used	• Inclusion/exclusion criteria clearly mentioned • Indications for surgery clearly defined • Rationale for EIMN use was determined by the treating surgeon	• Retrospective non-randomised study • Follow-up period clearly mentioned • Time for fracture union stated • Surgical technique not stated • Perioperative variables not stated	• Number of surgeons not stated but their experience clearly mentioned • Pre-op and post-op radiological findings were defined	• Approved by Institutional Review Board	• Appropriate statistical analysis • Confidence interval stated • Small sample size • Limitations identified	• Clear statement of findings • Assess the ability of single-bone fixation with EIMN to maintain alignment	• Study linked to current knowledge • Relevant literature review • Further work identified
Parajuli *et al.* (45)	Yes	Yes	• Yes • Clinician-reported outcome score used • Patient-reported outcome score not used	• Inclusion/exclusion criteria clearly mentioned • Indications for surgery not defined • Rationale for EIMN use not stated	• Retrospective non-randomised study • Follow-up period clearly mentioned • Time for fracture union stated • Surgical technique stated • Perioperative variables not mentioned	• Number of surgeons and their experience not clearly mentioned • Radiological findings not defined	• Not stated	• No depth in description of the statistical analysis • No confidence interval • No power calculation • Small sample size • Limitations identified	• Outcomes well-defined • Clear statement of findings	• Study linked to current knowledge • Relevant literature search • Further work identified

Alnaib *et al*. (49)	Yes	Yes	• Yes • Subjective measure of range of motion • Patient-reported outcome score not used	• Inclusion/exclusion criteria were not stated • Indications for surgery defined • Rationale for single-bone EIMN use not stated	• Retrospective non-randomised study • No comparative group • Follow-up period mentioned • Time for fracture union stated • Surgical technique stated • Perioperative variables briefly mentioned	• Number of surgeons and their experience not clearly mentioned • Radiological findings not defined	• Not stated	• No depth in description of the statistical analysis • No confidence interval or power calculation • Small sample size • No limitations identified	• Outcomes well-defined • Clear statement of findings • Rationale for single-bone fixation mentioned	• Study linked to current knowledge • Relevant literature search
Wall *et al*. (46)	Yes	Yes	• Yes • Clinician-reported outcome score used • Patient-reported outcome score not used	• Inclusion/exclusion criteria stated • Indications for surgery mentioned • Rationale for EIMN use not stated	• Retrospective non-randomised study • No comparative group • Follow-up period mentioned • Time for fracture union stated • Surgical technique stated • Perioperative variables mentioned	• Number of surgeons stated but their experience not clearly mentioned • Pre and post-op radiological findings clearly defined	• Not stated	• No statistical analysis performed • Small sample size • No limitations identified	• Outcomes well-defined • Clear statement of findings	• Study linked to current knowledge • Relevant literature search
Sinikumpu *et al*. (10)	Yes	Yes	• Yes • Functional outcomes score was not used	• Inclusion/exclusion criteria not mentioned • Indications for surgery not clearly defined • Rationale non-op or operative treatment was determined by the treating surgeon	• Retrospective non-randomised comparative study • Follow-up period not mentioned • Time for fracture union stated • Surgical techniques not stated • Perioperative variables not mentioned	• Number of surgeons and their experience not clearly mentioned • Pre-op radiological findings were defined	• No approval from Ethics Committee was needed	• Appropriate statistical analysis • Confidence interval used • Small sample size • Factors affecting the choice of either treatment were analysed • Limitations identified	• Outcomes well-defined • Clear statement of findings • Non-op complication clearly stated and compared to operative treatment	• Study linked to current knowledge • Relevant literature review • Further work identified
Antabak *et al*. (47)	Yes	Yes	• Yes • Clinician-reported outcome score used	• Inclusion/exclusion criteria clearly mentioned • Indications for surgery clearly defined • Rationale for EIMN use was determined by the treating surgeon	• Retrospective non-randomised study • No comparative group • Follow-up period not mentioned • Time for fracture union not stated • Surgical techniques briefly stated • Perioperative variables not mentioned	• Number of surgeons and their experience clearly mentioned • Radiological findings not defined	• Approved by Local Ethics Committee	• No statistical analysis performed • Moderate sample size • No Limitations identified	• Outcomes well-defined • Clear statement of findings	• Study linked to current knowledge • Relevant literature review
Ali A. (54)	Yes	Yes	• Yes • Clinician-reported outcome score used	• Inclusion/exclusion criteria clearly mentioned • Indications for surgery clearly defined • Rationale for EIMN use not stated	• Prospective non-randomised study • No comparative group • Follow-up period mentioned • Time for fracture union stated • Surgical techniques stated	• Number of surgeons and their experience not mentioned • Pre and post-op radiological findings clearly defined and verified	• Not stated	• No statistical analysis performed • Small sample size • No Limitations identified	• Outcomes well-defined • Clear statement of findings	• Study linked to current knowledge • Relevant literature review

Hassan W. (50)	Yes	Yes	• Yes • Clinician-reported outcome score used	• Inclusion/exclusion criteria clearly mentioned • Indications for surgery clearly defined • Rationale for EIMN or ORIF use not stated	• Retrospective non-randomised comparative study • Follow-up period mentioned • Time for fracture union not stated • Surgical techniques stated • Perioperative variables mentioned	• Number of surgeons and their experience not mentioned • Radiological findings not defined	• Not stated	• No depth in description of the statistical analysis • No confidence interval and power calculation • Small sample size • No Limitations identified	• Outcomes well-defined • Clear statement of findings • Non-op complication clearly stated and compared to operative treatment	• Study linked to current knowledge • Very Brief mention of relevant literature
Sinikumpu *et al*. (55)	Yes	Yes	• Yes • Subjective measure of range of motion	• Inclusion criteria clearly mentioned • Rationale for non-surgical treatment clearly defined	• Case-control study • Sex and age matched control group included • Control selected randomly • Follow-up duration was stated • Long term follow-up was not stated • Time for fracture union not stated • Age did not affect clinical and radiological outcomes	• Number of surgeons and their role not mentioned • Pre-op and post-op radiological findings clearly defined and verified by clinicians	• Approved by local Ethics Committee	• Appropriate statistical analysis • Small sample size • Post hoc power analysis performed • No mention of confidence interval • Limitations not identified	• Clear statement of findings • Outcomes well-defined • Generalizable findings	• Study linked to current knowledge • Population-based study with full participation • Mention of relevant literature

Table 5: Critical appraisal of studies. Randomized Controlled Trial

Study	**Clearly focused research question?**	**Assignments of patients to treatment were randomised?**	**Study participants blinded?**	**Groups similar at start of the trial?**	**Groups treated equally?**	**Accountability?**	**How large is the treatment effect?**	**How precise was the estimate of the treatment effect?**	**Can the results be applied locally?**	**All clinical outcomes considered?**	**Are the benefits worth the harms and costs?**
Colaris *et al*. (56)	Yes	• Yes • Assignment was performed by a clinician who was not involve in the treatment • Children were randomization by sealed envelope with varied block sizes	• No • Children and parents were not blinded • Surgeon examined the children after initial trauma without masking	Yes	• No • 11 treated with single-bone fixation whereas 13 treated with both-bone fixation	Children were analysed in the groups to which there were randomised	• Outcomes were clearly specified and measured • Higher complication rates with single-bone fixation	• Statistical analysis under-utilized • Small sample size • Results were underpowered • No confidence interval used	• The results are not precise enough to make a decision	The results caution against the use of single-bone fixation. This method may increase the risk of re-displacement and reduced clinical results	• Higher complication rates with single-bone fixation • It is likely that the benefits are worth the costs and harms

complications with single-bone fixation; this is mainly caused by the re-displacement of the fracture without fixation. Also, they found that the fractures stabilised with one EIMN were immobilized in a cast for a longer duration.

Critical appraisal of the studies showed considerable variation in the methodological quality (Table 5). All studies provided adequate descriptions of their participants and intervention. All studies had adequate descriptions of inclusion and exclusion criteria, except for 5 studies [10, 33, 36, 41, 48]. Two studies had independent clinicians that assessed their functional and radiological outcomes [37, 43]. Seven studies used no statistical analysis [33, 36, 41, 45, 46, 50, 53]. Seven studies described their statistical methods but did not include nonparametric statistics where they would be appropriate [35, 40, 44, 48, 49, 52]. The remainder of the studies had appropriate statistical analysis [2, 10, 27, 31, 37, 43, 47, 51, 54].

There was one RCT with concealed allocations to limit allocation bias. However, children and parents were not blinded. The study was statistically unpowered and did not use confidence intervals. Also, the sample size was small and follow-up period was limited to 9 months, affecting the external validity of the study. Therefore, the results should be interpreted with caution [55].

In two studies the comparator groups were age and sex matched [43, 54]. A general perception of matching procedures in population-based studies is that it controls for potential confounding factors. As a result, there was no selection bias, and the findings can be generalizable [64].

There were a variety of outcome measure scores amongst the twenty-four studies assessing patient and clinician outcomes, post-operative complications, perioperative variables, and radiographic findings. Although most studies used scoring systems to measure clinical, functional or cosmetic outcome, only one study used validated scoring systems [43].

A number of other methodological flaws were pervaded in the studies included being retrospective, small sample sizes, no controlling for confounding factors, poor methodological methods, no power calculation and no use of confidence intervals. Most studies stated that the operating surgeon decided the choice of implant. Selection bias and confounding factors could probably only be controlled by large prospective, RCT investigating the different treatment methods and determine which treatment method is optimal. Outcome measures should include clinician and patient-reported evaluation scores using validated research tools.

This review has limitations. First, search of a large body of literature may still have over-looked some relevant studies but we believe it is unlikely that they would significantly affect our conclusions. Secondly, the inclusion of retrospective studies was not avoidable; therefore, our study shares the limitations of all retrospective studies including investigator bias and uncontrolled possible confounding factors. Thirdly, the small sample sizes of most of the studies, which were included, may predispose to a type-II error, owing insufficient power. Finally, only English-language studies were included; thus, potentially relevant studies in the non-English-language literature may have been missed.

The strength of this systemic review is the aggregation of the previous studies to provide insights into who may benefit from each method.

CONCLUSION

There is no doubt that DFF's are potentially harmful and challenging to manage. They are one of the few fractures that demonstrate a real risk of complications and potential prolonged morbidity. This systematic review demonstrates that there is an increasing tendency towards operative management during the last decade as an alternative to non-operative treatment especially in older children and adolescents. However, the rates of fixation-related complications vary greatly among different studies indicating that these procedures may be highly operator-dependent in terms of success and complications. On the basis of the current available low-level evidence studies, robust prospective studies with a large sample size investigating the outcome of different treatment methods could greatly aid in evidence-based decision-making for DFF's.

Compliance with ethical standards

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