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REVIEW ARTICLE

Single-bone fixation of paediatric diaphyseal both-bone forearm fractures : A systematic review

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Unstable paediatric diaphyseal both-bone forearm fractures that fail conservative management are usually treated with fixation of both radius and ulna. This systematic review aimed to establish if single-bone fixation achieves results comparable to both-bone fixation and which bone should be fixed and by what method. A systematic review of the published literature was performed, searching Medline for English language studies that reported functional or radiographic outcome following single-bone fixation of either bone by any method. Eight studies met the inclusion criteria (Level of Evidence III or IV). Three studies compared single- with both-bone fixation, showing comparable functional and radiographic outcomes. Redisplacement of the radius fracture is common following fixation of the ulna, particularly with intramedullary K-wires. Flexible nails achieve better results than K-wires in intramedullary stabilisations. Outcome is good following radius fixation with plating or nailing. Plating achieves good results in either bone. Few complications are seen when the second bone was left unfixed only if reduced and stable. Single-bone fixation achieves results comparable to both-bone fixation. Fixing the radius rather than the ulna provides better outcome, regardless of the method. The second bone should only be left unfixed if reduced and stable intra-operatively.

Keywords : child, fracture fixation ; radius fracture ; ulna fracture ; treatment outcome.

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INTRODUCTION

Diaphyseal forearm fractures are common injuries and represent between three and six percent of all paediatric fractures. Only distal radius fractures are more common among adolescents (*5,6, 23,40*). Closed reduction and casting is a successful treatment in 85% of cases but loss of forearm rotation can occur following conservative management (*7,30,32*). Internal fixation is indicated when cast treatment fails to maintain alignment, in cases of associated humeral fracture ('floating elbow'), and in displaced fractures in children nearing skeletal maturity (*31,39*). Compared to more distal metaphyseal fractures, diaphyseal forearm fractures remodel poorly and mal-union is common (*17*). Residual angulation or rotational deformity can cause a loss of pro-supination (*9*). It has been

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suggested that restoration of the radial bow is key to preserving forearm rotation (*35*).

Internal fixation of unstable paediatric forearm fractures traditionally involved open reduction and rigid internal fixation with plate and screws (ORIF), with reports of good functional outcome and restoration of anatomy (*30,31*). Intramedullary nailing has risen in popularity, offering smaller scars, shorter procedures and easier removal, with encouraging results reported (*4,18,24*). While it may not achieve the anatomical reduction possible with plating, alignment and length are maintained whilst micro-movement of the fracture encourages callus formation (*26*).

Standard treatment entails fixation of both radius and ulna, whichever method is chosen. Single-bone fixation can reduce surgical insult, operative time, and hence complications but may reduce stability. The purpose of this review was therefore to examine the published literature on single-bone fixation in paediatric both-bone diaphyseal forearm fractures to establish if this achieves comparable functional and radiographic outcome to both-bone fixation and to establish which bone should be fixed and by what method.

METHODS

A literature search was performed using OvidSP to interrogate the Medline database on 4th October 2011 by the first author and repeated one month later by the second author. The search strategy is detailed in Table I. The inclusion criteria were [1] English language [2] acute diaphyseal both-bone forearm fracture [3] study population with average age less than 18 years [4] any internal fixation method of either bone [5] functional or radiographic results reported [6] identifiable results specific to at least ten patients in which the same bone was fixed with the same method. Any study with a potentially relevant abstract underwent full-text assessment. The process by which studies were selected is detailed in Figure 1. Any disagreement regarding inclusion was resolved by consensus with the third author. Data was extracted by one author and verified by a second.

Table I. — Medline Search Strategy

Medline (1948 – present)		
1	Child/	1254978
2	Radius Fractures/su [Surgery]	3268
3	Ulna Fractures/su [Surgery]	1307
4	Forearm Injuries/su, th [Surgery, Therapy]	1136
5	Fracture Fixation, Intramedullary/	6532
6	Bone Plates/	10866
7	Fracture Fixation, Internal/	21486
8	2 or 3 or 4	4780
9	5 or 6 or 7	32525
10	1 and 8 and 9	406
11	limit 10 to (English language and humans)	225

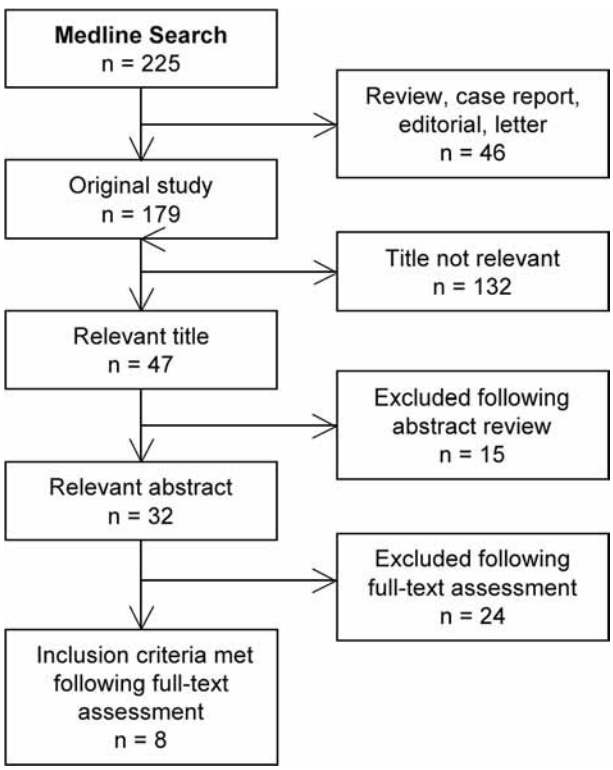

Fig. 1. — Flowchart demonstrating the process of article selection.

RESULTS

Eight studies met the inclusion criteria ; they are summarised in Table II. All studies were retrospective case series or comparative studies (Level III or IV). Three studies were excluded because too few patients were treated with the same method (*8,13,18, 37*). Nine studies were identified in which some patients were treated with single-bone fixation but

Table II. — Details of the included studies. ROM = range of motion, DCP = dynamic compression plating, ESIN = elastic stable intramedullary nails

Study	Bone Fixed	Fixation Method	Mean Age	Follow-up	Comparison Group	Findings
Lee *et al* 2002 (*25*)	22 Ulna 3 Radius	1.6 mm K-wires	11		24 both-bone fixations	7 of 22 ulna fixations had re-angulation of the radius
Dietz *et al* 2010 (*10*)	38 Ulna	32 K-wires 4 flexible nails 2 Rush pins	9	4 months	None	11 with 10-20° of radial redisplacement, 2 with > 20°
Bhaskar & Roberts 2001 (*3*)	12 Ulna	Plating (DCP)	11	12 months	20 both-bone fixations	Same function and ROM, 8° of AP radial angulation in single-bone group
Hammad *et al* 2007 (*15*)	18 Ulna	Plating	10.7	27.7 months	None	17 pts good or excellent
Myers *et al* 2004 (*29*)	18 Radius 7 Ulna	ESIN (C-nail)	10.75	10.5 months	25 both-bone fixations	Same function, ROM and complications.
Houshian & Bajaj 2005 (*16*)	17 Radius 3 Ulna	Nancy nails	10	20 months	None	Full ROM elbow, wrist and forearm in all cases. All united by 9 weeks
Alnaib *et al* 2011 (*1*)	29 Radius	Titanium elastic nail	9	6.8 months	None	No loss of prono-supination
Kirkos *et al* 2000 (*20*)	50 Radius	Plating (1/3 tubular)	11	4 years	None	12% had < 10° loss of forearm rotation

they were excluded after full-text assessment because the reporting of results did not allow for outcomes specific to these cases to be differentiated from the both-bone fixations (*12,14,22,27,28,31,33,36, 41*). Pooled analysis of the data from the included studies was not performed due to heterogeneity among them with regards to the treatment protocols, fixation techniques and outcome reporting.

Comparative studies

Three studies directly compared single-bone fixations with both-bone fixations. Bhaskar and Roberts treated 32 both-bone diaphyseal forearm fractures with dynamic compression plating (DCP) (*3*). The ulna was fixed first and the radius was not fixed if the fracture ends were hitched and there was less than 10° angulation in two planes (this was the case in 12 patients). The both-bone fixations had a shorter time to union and the single-bone fixations had an average of 8° AP angulation of the radius. Despite this, there was no difference in function or range of motion. They recommended that the radius need not be stabilised if it reduces with ulnar fixation.

Lee *et al* treated 49 both-bone diaphyseal forearm fractures in a specialist paediatric centre (*25*). The ulna was fixed in 22 cases, the radius in three, and both bones in 24, using 1.6 mm Kirschner wires. The treatment protocol was unclear but the authors state that in general the ulna was fixed first before deciding if the radius required fixation. The radius fixations all healed with < 5° of ulnar angulation. Seven of the 22 ulna fixations had re-angulation of the radius. One was accepted, four were treated with cast moulding, while two cases required plate fixation. A further two cases displaced late after removal of the ulnar wire at five weeks. On the basis of this, the authors suggest burying the wires to negate the need for early removal. Functional outcome was not reported.

Myers *et al* reported outcome in 25 cases of single-bone fixation with flexible nails (18 radius, seven ulna), compared with 25 both-bone fixations (*29*). The bone with greater deformity was nailed first and the second bone was not fixed if it

was reduced and stable through a full range of pro-supination. There was no difference in range of motion, function or pain between the single and both-bone fixations. Radiological outcome (angulation) was not reported.

Ulnar Nailing

Two studies report intramedullary stabilisation of the ulna. As previously described, Lee *et al* reported re-angulation in seven of 22 unfixed radial fractures following ulnar fixation with K-wires (*25*).

Dietz *et al* performed single bone intramedullary fixation of the ulna in 38 children, using Kirschner wires in 32 cases, flexible nails in four, and Rush rods in two (*10*). Eleven (29%) had 10-20° of radial redisplacement. Two had over 20°, one of which was treated with repeat closed reduction, while one required ORIF. They identified open fracture as a risk factor for redisplacement. Despite the radiological mal-unions, 92% of patients had 160° of pro-supination. One patient had only 30° of pronation, associated with 20° of radial redisplacement.

Ulnar Plating

Two studies report plating of the ulna. As described earlier, Bhaskar and Roberts reported slight angulation of the unfixed radius following DCP plating of the ulna alone but there was no difference in functional outcome when compared to plating both bones (*3*).

Hammad *et al* reported outcome of 18 cases of ulnar plating (*15*). The selection criteria and treatment protocol were not explained. There were no non-unions and all patients had a good or excellent outcome by the criteria of Price *et al* and Daruwalla (*9,32*). There was a mean loss of 12° of pronation and 5° supination. There was a mean of 5.8° AP angulation of the radius.

Radial Nailing

Three studies report intramedullary stabilisation of the radius predominantly. As previously described, Myers *et al* reported similar function, range of motion and complications in 18 radial nailings (and seven ulnar nailings), compared with an equal number of both-bone nailings.

Houshian and Bajaj performed single-bone fixation with elastic stable intramedullary nails in 20 cases (17 radius, three ulna) (*16*). The bone with the greater deformity was nailed first and the forearm screened through the full range of pro-supination. The second bone was only fixed if reduction was lost. All cases united by nine weeks with a full range of movement of the elbow, wrist and forearm.

Alnaib *et al* treated 29 simple transverse diaphyseal fractures with titanium elastic nailing of the radius (*1*). Cases with an ulnar wedge fracture or comminution had both bones nailed. All united in eight weeks with full pro-supination.

Radial Plating

Kirkos *et al* reported 50 cases in which the radius alone was fixed with a 1/3 tubular plate (*20*). The treatment protocol is unclear. All fractures united by nine weeks. Twelve percent of children had a loss of forearm rotation but none lost more than 10°.

DISCUSSION

These studies suggest single-bone fixation of paediatric both-bone diaphyseal forearm fractures to be a suitable treatment option. Functional and radiographic outcomes comparable to both-bone fixations are possible.

If the surgeon is considering single-bone fixation, the temptation will be to fix the ulna rather than the radius. When performing plating, the approach to the subcutaneous midshaft of the ulna involves less soft tissue dissection than a volar or dorsal approach to the radius. The introduction of a nail at the proximal olecranon is technically easier than at the distal radius. However, these studies suggest single-bone fixation of the ulna to be associated with high rates of re-displacement of the associated radial fracture, especially if intramedullary stabilisation is performed. It should be noted that no study met the inclusion criteria that reported the use of flexible elastic nails in the ulna, although there were three cases in the study by Houshian and Bajaj (*16*). These nails have been

shown to be more biomechanically stable than Kirschner wires in this type of injury (*2*). This reduced stability was often compounded by the fact that they were not buried in these studies, resulting in late displacement after their removal at three to five weeks post-operatively. The results of flexible elastic nailing of the radius in these studies were more encouraging, with results comparable to both-bone fixation. Fixation of the radius rather than the ulna may infer such benefit due to the proposed importance of restoration of the radial bow in preserving forearm rotation (*35*).

All the studies reporting plating demonstrated good outcome, regardless of the bone fixed. Intramedullary stabilisation has grown in popularity over plating in recent years due to improved cosmesis, shorter operative time, and ease of removal (*11,21,34,38*).

Intra-operative assessment of the stability of the unfixed bone may be as important as the fixation method or choice of bone. Some of the best results were seen in the three studies that stated an explicit treatment protocol in which the second bone was only left unfixed if adequately reduced and stable (*3, 16,29*).

It should be remembered that these studies have short follow-up in general and therefore do not address the issue of remodelling or refracture. We must also note that radiographic and functional outcome are not necessarily related.

Being retrospective, there are important methodological shortcomings inherent among these studies, most notably that of selection bias. The process by which the fixation method was decided is rarely clear, although some studies explain the grounds upon which single-bone was considered adequate. The inclusion criteria were rarely explained, particularly with regards to fracture type. Some more unstable fracture configurations may not be amenable to single-bone fixation. Post-operative protocols were rarely explained. Prospective randomised non-inferiority studies of both plating and intramedullary nailing techniques are required to ascertain if single-bone fixation is a suitable alternative to both-bone fixation. Studies comparing single-bone fixation of the radius with that of the ulna would also be of great interest.

CONCLUSIONS

Single-bone fixation is a suitable treatment method for paediatric diaphyseal both-bone forearm fractures, with results comparable to both-bone fixations. Better results can be expected from fixation of the radius. Plating achieves good results with fixation of either bone. If intramedullary stabilisation is undertaken, flexible elastic nails may be preferable to Kirschner wires to prevent re-angulation and loss of forearm rotation. The second bone should only be left unfixed if reduced and stable.

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