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Treatment outcomes of both-bone diaphyseal paediatric forearm fractures

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ABSTRACT

Background: Elastic-stable intramedullary nailing (ESIN), is an accepted method for stabilization of unstable forearm shaft fractures in children. This study analyzed the radiographic and functional outcomes of intramedullary nailing of forearm diaphyseal fractures in children.
Materials and methods: A retrospective analysis was performed of children with forearm shaft fractures and open epiphyseal plates, treated with ESIN between 2000 and 2012 in our institution. Evaluation of cases was conducted minimum 14 months after osteosynthesis. Clinical results were evaluated according to the criteria developed by Price et al. and Flynn et al.
Results: The study included 88 (42 boys) children. The average age of children at day injury was 10.5 ± 2.59 years (range 4-16), and at the review clinic was 13.4 ± 1.85 years (range 7-18). Forty six (52.3 %) had right forearm and 42 (47.7%) had left fracture respectively. Open reduction was required in 20 (22.7%) children. Primarily surgically were treated 62 (70.5%) children and 26 (29.5%) were operated as a second procedure after failed conservative management. There was one delayed union. Rotational forearm restriction with values between 11 and 20 degrees was present in nine children. Six children developed radial nerve hypoesthesia which eventually resolved with time. After removal of the implant one child sustained a re-fracture. The overall complication rate was 25%. Complete recovery to the original condition was noted in 76 (86.4%) children, eleven children (12.5%) had good and only one (1.1%) had poor outcome.
Conclusion: Our study suggests that ESIN osteosynthesis for diaphyseal forearm fractures remains a valid technique with very good functional results.

Introduction

Forearm fractures are the most common injuries in children and adolescents. Their incidence is thought to be increasing during the last decade.[1–6] Diaphyseal forearm fractures in particular are among the most common injuries treated in children.[7] The main goal of treatment is to achieve reduction and maintain appropriate position of the rotational displaced fragments. The majority of these fractures is successfully treated non-operatively by closed reduction and cast immobilization. When operative intervention is indicated different techniques can be employed such as intramedullary nailing (IM), osteosynthesis with plate and screw fixation, and external fixators. Flexible intramedullary nailing has been shown to produce excellent clinical results and in contrast to plate fixation is considered as a minimal invasive procedure.[8,9]

In this study our goal was to evaluate late outcomes of diaphyseal forearm fractures in children treated with elastic-stable intramedullary nailing (ESIN).

Patients and Methods

A retrospective analysis was performed of children with forearm shaft fractures and open epiphyseal plates, treated with ESIN between January 2000 and December 2011 in the Zagreb University Hospital Centre (KBC Zagreb). Our center provides the trauma service for local population, with a catchment of about 150,000 children. Exclusion criteria were Montaggia, Galeazzi, and pathological fractures as well as children with polytrauma, neuromuscular paralysis and injuries of the central nervous system. Approval for the study was obtained from the local ethical committee.

Indications for surgical treatment were unsuccessful reduction and/or poor retention of fragments. Standard operative technique as described by Lascombes et al.[10] was applied in all cases. Radial fracture was fixed retrograde with a titanium elastic nail, advanced through a drill hole just proximal to the distal radial epiphysis. Ulnar fracture was fixed with a lateral approach through the olecranon. All surgery was performed by five specialists of pediatric traumatology. The average age of children at the day injury was 10.5 ± 2.59 years (range 4-16 years), and at the review clinic was 13.4 ± 1.85 years (range 7-18). After the ESIN procedure the forearm was immobilized in a splint. One week after surgery, the above elbow splint was removed and

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Table 1
Grading of results according to the criteria of Price et al.[13] and Flynn et al.[14]

Outcome	Rating	Loss of motion in affected versus unaffected forearms (in degrees)		Symptoms
		Pronation and supination	Flexion and extension	
Satisfactory	Excellent	<10	0-5	No complaints with strenuous physical activity
	Good	11-30	6-10	Mild complaints with strenuous physical activity
	Fail	31-90	11-15	Mild complaints with daily activity
Unsatisfactory	Poor	All other results	> 15	All other results

plain radiographs were obtained. Two weeks after surgery all children, were encouraged to start active mobilization of both the elbow and wrist joints. Three months later, the function of the affected elbow and forearm was assessed new radiographs were taken and the implants were removed. The final review was conducted at a minimum of 14 months after osteosynthesis and included clinical and radiological assessment. Clinical review included grip strength and range of movement of the wrist (radial and ulnar deviation, palmar and dorsal flexion) forearm (pronation, supination) and elbow (flexion and extension). Sets of radiographs (anteroposterior and lateral) were measured for residual deformities (angulation, shortening and translation). Nonunion, malunion or other complications were noted. An active forearm pronation and supination motion was measured by goniometer with the elbow flexed at 90 grad's (hand-held pencil method). The arm was adducted. Flexion and extension of the elbow were measured by a flexible goniometer, also the same conventional goniometry was used by measured movement of the wrist. Grip strength was assessed using a handle hydraulic dynamometer, Marsden MG-4800 (KERN & SOHN GmbH Balingen–Deutschland). The average strength from two grip measurements was recorded and compared to normative values (dominant hand, sex and age) as described by Mathiowetz.[11] Radial bowing was measured according to the method previously described[12] (60.39% (SD ± 3.74%) for the site of maximum bowing, and 7.21% (SD ± 1.03) for maximum of radial bow of the total radial length). Clinical results were evaluated according to the criteria developed by Price et al.[13], and Flynn et al.[14] (Table 1).

Results

In total out of 97 children, 88 (52 males and 36 females) with mean age of 10.5 ± 2.59 years of age met the inclusion criteria. Forty six (52.3%) children had right forearm fracture and 42 (47.7%) had left forearm fracture. Close manipulation and intramedullary titanium elastic nail fixation was possible in 68 (77.3%) children. Out of the 88 children, 26 (29.5%) were operated as a second procedure after failure of non-operative management (loss of reduction). All fractures were classified according the AO Pediatric Classification[15] with the majority of them being type 22-D/5.1. There were seven open fractures; five of them had a fracture type 22-D/5.1. The radiographs at the review clinic showed complete healing and angular deformities in all children <5°. Table 2 shows all 22 children who had some complications or failures during treatment with ESIN. One patient who had ORIF developed traumatic myositis ossificans of the radius. Six of the children had maximum radial bow values greater than normal figures outlined. Three of them had reduced hand value grip strength. Except in three girls, the rest of the children had a difference in the range of wrist motion between affected and unaffected forearms of less then 6°. The highest measured difference was noted in a 13 year old girl who at the time of injury sustained a fracture type 22-D/5.2 (a break in the distal third in two levels with ulnar free bone fragment). In nine children we measured difference in the range a rotary motion in affected and unaffected forearms with values between 11-20°. Only in one child, difference in the range of motion was >20°, (pronation forearm deficit of 26°). A full range of elbow and wrist movements were found in 58 (65.9%) children.

In three children superficial wound infections following ESIN were seen, all of whom had been treated with open reduction. These infected wounds were treated with change of wound dressings and oral antibiotics. In a 12 years old girl, who required open reduction for ulnar fracture due to soft tissue interposition, no healing was achieved by 12 weeks. Fracture consolidation (spontaneously) became manifested after 16 weeks. We did not see any pseudarthroses. In nine children, skin irritation over prominent ulnar hardware were founded, in one of them ulnar pin required early removal. In six children, hypoesthesia in the area of the superficial radial nerve occurred but this was a temporary finding. In one child, 5 weeks after the operative procedure a re-fracture occurred without dislocation of fragments. A refracture after removal of titanium nails took place in one 13 years old boy. The implant removal was made 4 months after trauma. This case was treated non-operatively with excellent final result. Removal of the nails was undertaken in all 88 children at a median of 15 weeks (range 9–20 weeks) post-operatively.

In 84 children there were no subjective symptoms, as complains with physical or daily activity. Subjective symptoms were found in four children, three of them reporting mild complains with strenuous physical activity and one mild complaint with daily activity.

Complete recovery to the original condition was recorded in 76 (86.4%) children. There were no subjective or measurable deficits in both the clinical and radiological assessment.

Discussion

Achieving a good functional result following fractures of both diaphyseal paediatric forearm bones is the objective for both operative and non-operative management of these injuries. Because of a high rate of re-displacement noted after conservative treatment, not surprising a move towards an increased open reduction surgery has been advocated[2]. In a comparison with the series by Bowman et al.[16] (7%) and Voto et al.[17] (19%) we found a higher incidence of failed closed reduction. In our study, a third (29.5%) of all children ESIN treated, had a complication of closed fracture reduction and immobilization, usually as result of additional displacement of fragments. Our result supports the findings of Sinikumpu at al.[18]

Two thirds (59.1%) of the fractures in our children were the type 22D/5.1. This type of fractures along with type 22D/5.2 were primarily surgically treated. For fracture-type 22D/4.1 (20.5%) and type 22D/4.2, (4.5%), typically we operate only after unsuccessful repositioning or other complications of conservative treatment. The primary goal of fracture treatment is to restore normal radioulnar length, to re-establish muscle length, to restore rotational alignment that is essential for forearm rotation, and to restore the normal radial bow.[19] According to many authors ESIN ideally achieve these goals.

Table 2
Patient's characteristics and complications intramedullary fixation of forearm fractures

P	Sex	Age	S	AO Type	OR	OF	Union (wk)	Rem (wk)	Complication	Rating
1	F	12	D	22-D/5.1	-	-	8	16	Radial deviation wrist deficit 10 °, pronation 18° and supination forearm deficit 12°	Good
2	M	11	D	22-D/5.1	U	-	6	12	Max. radial bow greater, pronation forearm deficit 14 °	Good
3	M	8	S	22-D/5.2	B	-	6	12	Wound infection, hypoesthesia radial nerve	Excellent
4	F	11	D	22-D/5.1	-	-	7	12	Mild complaints with strenuous physical activity, pronation 8°and supination forearm deficit 12°	Good
5	M	13	S	22-D/5.1	B	U	8	14	Max. radial bow greater, less grip strength, supination forearm deficit 18 °	Good
6	F	9	S	22-D/5.1	B	R	7	12	Radial deviation wrist deficit 10°, pronation 18° and supination forearm deficit 12°d	Good
7	M	14	S	22-D/5.1	-	-	8	20	Mild complaints with strenuous physical activity, pronation forearm deficit of 16 °	Good
8	M	12	D	22-D/5.2	R	-	7	12	Hypoesthesia radial nerve	Excellent
9	M	11	S	22-D/5.1	-	-	7	12	Max. radial bow greater, pronation forearm deficit 18°	Good
10	M	9	D	22-D/5.1	-	-	6	8	Migration ulnar hardware, early removal	Excellent
11	F	15	D	22-D/5.1	R	-	8	20	Max. radial bow greater, less grip strength, pronation forearm deficit 26°, supination forearm deficit of 19° mild complaints with daily activity	Fair
12	M	10	D	22-D/5.1	B	R	7	16	Mild complaints with strenuous physical activity	Good
13	F	8	D	22-D/5.1	-	U	6	12	Max. radial bow greater, pronation forearm deficit 16°, mild complaints with strenuous physical activity	Good
14	M	12	S	22-D/5.1	B	R	8	12	Wound infection, Hypoesthesia radial nerve	Excellent
15	F	10	S	22-D/5.1	R	-	8	14	Hypoesthesia radial nerve, pronation forearm deficit 10°	Excellent
16	M	10	D	22-D/5.1	B	-	7	12	Hypoesthesia radial nerve	Excellent
17	F	13	L	22-D/5.2	B	-	8	18	Wrist ulnar deviation deficit of 18°, pronation forearm deficit 12°	Good
18	F	12	S	22-D/5.1	U	-	16	20	Deleted union in the middle third of ulna	Excellent
19	M	9	D	22-D/5.1	-	-	8	14	Max. radial bow greater, less grip strength, supination forearm deficit of 18°	Good
20	M	8	D	22-D/5.1	-	-	8	12	Myositis ossificans of radius	Excellent
21	F	9	S	22-D/5.1	-	-	8	12	Wound infection, Hypoesthesia radial nerve	Excellent
22	M	13	D	22-D/5.1	-	-	8	16	Refracture	Excellent

P:patient; S:side; OR:open reduction; OF:open fracture; Rem:removal; wk:week; M:male; F:female; D:right; S:left; U:ulna; B:both; R:radius.

For a more complete evaluation of the late effects of ESIN for both-bone forearm fractures in children, in this study, we measured all the relevant indicators of the forearm functions. Bowing of the radius is of crucial importance to the normal range of rotation of the forearm, and to the strength generated by the muscles[20]. To evaluate the radial bow of our children, we have used the method of Firl,[12] based on the measurement of three basic distances of the radius on the anteroposterior radiograph. Studying the radial bow in 100 healthy children, Firl[12] calculated that mean value of maximum radial bow is 7.21 % of total radial length (SD±1.03 %). In our study, only six of the children had maximum radial bow values greater than normal figures outlined. Three of them had less value hand grip strength affected forearms, another three had the proper values of grip strength for their age with a correction applied for sex and the dominant hand as suggested by Mathiowetz et al.[11] We could not find any relationship between increased radial bow and hand grip strength. The same conclusion was reached by Teoh et al.[21] in a similar treated group of children.

Both bone fractures of the forearm particularly in the distal-shaft, with residual angulation can lead to disruption of wrist joint movement.[22] In our group of children, only three of the children had significant restricted wrist motion. The remaining children had a difference in the range of wrist joint motion in affected and unaffected forearms of less than six degrees.

The most common functional deficit after malunited forearm fractures is particularly reduced motion of pronation and supination. More authors[23-26] came to a similar conclusion, as Price et al.[24] have suggested that when malnunion is greater than 10° degrees in the middle third, rotation can be limited by 20-30°. Daruwalla[21] recommended 10° degrees as the maximum acceptable angulation for older children and proximal shaft fractures. Matthews et al.[26] found similar results in a cadaveric study. Rotation contracture is more functionally limiting than loss of wrist flexion and extension.[27,28]

In our study we noted a reduced range of motion (>10°) in 14 cases (pronation in eight cases, supination in six cases) (Table 3). All these rotational deficits were measured in nine children. Six of these nine children had an increased radial bow more than 10° and two children between 5-10°. All children we studied had appropriate movement of flexion and extension or disturbances were less than 10°. This study did not aim to evaluate correlations between the rotatory deficit and the radial bow, but data indicate that all children with radial bow greater than 10° had also rotation disturbances of greater than 10°.

According to the criteria of Price at al. and Flynn et al, we recorded in 76 (86.4%) of children an excellent result (complete recovery to the original condition).[13,14] In nine children a rotatory deficit was the cause of the bad outcome, and represents two thirds of all adverse outcomes. One of them reported subjective complaints with daily activities, and lack of supination and pronation of nearly 50°.

In our series 98.8% of children were found to have good and excellent results. It is of note however, that the overall complication and failure rate reported in the literature can be as high as 50%.[29] Cullen et al.[30] reported also a complication rate of 50%. Eighteen complications occurred in 10 of 20 patients, including hardware migration, infection, loss of reduction, reoperation, nerve injury, significant decreased range of motion, synostosis, muscle entrapment, and delayed union. [30]

Superficial wound infections following ESIN of forearm fractures in children are very rare. Fernandez[31] reported on five

Table 3
Success rate depending on the subjective symptoms and the measured deviations from normal values

Outcome of 88 children Rating	Symptoms	Maximum radial bow	Grip strength	Wrist extension and flexion	Wrist ulnar and radial deviation	Flexion and extension elbow	Pronation forearm	Supination forearm
Excellent	84	82	85	86	86	88	80	82
Good	3	6	3	-	3	-	8	6
Fail	1	-	-	-	-	-	-	-
Poor	-	-	-	-	-	-	-	-

superficial infections in 553 children. In our study, we saw three superficial infections in 88 children. Soft tissue damage generally occurs during insertion of the nail, therefore the traumatized skin should be excised before suturing.

There are only a few reports on delayed union following ESIN of forearm fractures in children. Schmittenbecher et al.[32] reported on ten delayed unions (seven in the ulna and three in the radius) in 532 children. Lieber et al.[33] reported in a multicenter study with 400 patients two cases of delayed union. In our study, we saw one delayed union (no healing was achieved by 12 weeks) in 88 children. The cause should be sought in the extensive soft tissue damage and due to soft tissue interposition. In any case, the open reduction does not additionally damage the periosteal perfusion, especially in fractures of the ulna.

Loss of reduction while the ESIN being in place is most commonly seen in the distal radial fragment. Too short fragment is not ideal for treatment with ESIN. Lascombes et al.[10] reported in a study of 85 children a 5% incidence a loss of reduction. In eight children of our series, a loss of correction was seen as greater radial bow. Incorrectly placed wires or selection of too small wire diameter are the main causes of this complication. Our experience with ESIN though suggests that a forearm immobilization splint that is applied in addition to the ESIN in the first ten days is sufficient to prevent or reduce the risk of loss of correction.

Hypoesthesia in the area of the superficial radial nerve is a common complication in forearm shaft fractures treated with ESIN. Lesions of the superficial radial nerve occur in the primary fracture treatment or at the time of material removal. Fernandez at al.[31] reported on 15 lesions of superficial radial nerve in 553 children with forearm shaft fractures treated with ESIN. In 13 children, hypoesthesia was temporary and in two cases persisted after all. Yalcinkaya at al.[34] reported in a study of 45 children that three of them had transitory hypoesthesia of the superficial radial nerve. In our study, all six lesions of the superficial radial were made in the primary fracture treatment and quickly subsided. We suggest that for the prevention of this injury, a sufficient incision of minimal 2 cm and careful blunt subcutaneous preparation in the region of the surgical approach should be carried out. Mandatory identification of the nerve is not necessary. Although 22 (25%) children during treatment had some complication or failure, good and excellent results were found in 87 (98.8%) of the children. Complications are mainly caused by technical errors including too-thin nails, asymmetry of the frame, and mal-orientation of the implants.

In conclusion, our study suggests that good indications for operative treatment and adequate techniques of ESIN osteosynthesis give excellent functional results in treatments of both-bone diaphyseal paediatric forearm fractures.

Conflict of interest

All authors declare no conflict of interest and confirm that no funding was used to carry out the project.

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