

Elastic stable intramedullary nailing for the treatment of forearm refractures in children

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Received on December 29th, 2017; accepted after evaluation on March 25th, 2018 • JAVIER MASQUIJO, MD • jmasquijo@gmail.com 

How to cite this article: Eamara P, Masquijo JJ. Elastic stable intramedullary nailing for the treatment of forearm refractures in children. Rev Asoc Argent Ortop Traumatol 2018;83(4):242-247. doi:10.15417/issn.1852-7434.2018.83.4.813

ABSTRACT

Introduction: In children the commonest refracture location is forearm diaphysis. These injuries usually occur in the forearm proximal or mid-third within the one year consecutive to the initial fracture. There is little information about treatment in these kinds of injuries. The aim of this study was to evaluate results and complications in patients with forearm refracture who required internal fixation with elastic intramedullary nails.

Materials and Methods: We registered the following information: demographic data, mechanism of injury, classification, the time passed between the original fracture and the re-fracture, type of reduction and bone healing timing. Results were evaluated by the scale set out by Martus and, complications, by an adaptation of the Clavien-Dindo classification.

Results: We evaluated 17 patients (14 males) with 17 refractures in forearm (15 closed and 2 open). Age was 11 years old (7 IQR, 5-15 min-max). The lesion occurred 12 weeks after the initial fracture (4.7 IQR, 4-28 min-max). Forty-seven percent required open reduction. Bone healing took 8 weeks (4 IQR, 6-28 min-max). Average follow-up was 43 months (47 IQR, 12-103 min-max). It was possible to assess 16 patients (1 was lost to follow-up). Results were excellent in 15 cases and regular in one. One patient suffered ROM loss (15°); one, bone healing delay (ulnar bone) and 3, a second refracture.

Conclusions: Internal fixation with elastic intramedullary nailing was an effective technique to treat forearm refracture in children. Although high percentages of patients require open reduction, bone healing timing and complication rates may be similar to those in primary fractures treated with the same technique.

Key words: Refracture; forearm; elastic intramedullary nailing; children; adolescents.

Level of evidence: IV

ENCLAVADO ENDOMEDULAR ELÁSTICO PARA EL TRATAMIENTO DE REFRACTURAS DE ANTEBRAZO EN NIÑOS

RESUMEN

Introducción: La diáfisis del antebrazo es el sitio más frecuente de refracturas en niños. Estas lesiones suelen ocurrir en el tercio medio o proximal antes del año de la fractura inicial. Hay poca información sobre el tratamiento de este tipo de lesiones. El objetivo de este estudio fue evaluar los resultados y las complicaciones en pacientes con refracturas de antebrazo que requirieron fijación interna con clavos elásticos endomedulares.

Materiales y Métodos: Se registró la siguiente información: datos demográficos, mecanismo de lesión, clasificación, tiempo desde la consolidación de la fractura original hasta la refractura, tipo de reducción y tiempo de consolidación.

Conflict of interests: The authors have reported none.

Los resultados fueron evaluados según la escala propuesta por Martus y las complicaciones, con una adaptación de la clasificación de Clavien-Dindo.

Resultados: Se evaluaron 17 pacientes (14 varones) con 17 refracturas de antebrazo (15 cerradas y 2 expuestas). La edad era de 11 años (RIC 7, mín.-máx. 5-15). La lesión ocurrió a las 12 semanas de la fractura inicial (RIC 4.7, mín.-máx. 4-28). El 47% requirió reducción abierta. El tiempo de consolidación fue de 8 semanas (RIC 4, mín.-máx. 6-28). El seguimiento fue de 43 meses (RIC 47, mín.-máx. 12-103). Fue posible evaluar clínicamente a 16 pacientes (1 pérdida en el seguimiento). El resultado fue excelente en 15 casos y regular en uno. Un paciente tuvo pérdida del rango de movilidad (15°); uno, retraso de la consolidación (cúbito) y 3 sufrieron una segunda refractura.

Conclusiones: La fijación interna con clavos elásticos endomedulares fue una técnica eficaz para tratar las refracturas de antebrazo en niños. Si bien un alto porcentaje necesita reducción abierta, el tiempo de consolidación y la tasa de complicaciones serían similares a los de las fracturas primarias tratadas con la misma técnica.

Palabras clave: Refracturas; antebrazo; enclavado elástico endomedular; niños; adolescentes.

Nivel de Evidencia: IV

Introduction

Forearm fractures are frequent injuries among children and adolescents. They occur in approximately 1 per 100 children,¹ and they represent the third commonest long-bone fracture among the most frequent ones in children, with maximal incidence between 12 and 14 years of age. The diaphysis of the radial and ulnar bones is the most frequent area for refracture in children,² Refracture usually occurs in up to 5% of the patients with forearm fracture. These lesions usually involve the proximal or mid-third of the forearm, and they occur between 6 weeks and 10 months after the initial fracture.^{3,4}

The aim of the treatment in refracture consists of getting bone healing while preserving function and minimizing complications.² Although some patients who suffer recurrent fractures can be treated non-operatively, many of them usually show unstable fracture patterns which require stabilization. Internal fixation with elastic titanium nails has become the method of choice for skeletally-immature patients. By avoiding extensive tissue-dissection, this technique preserves soft tissues and promotes fast bone healing. Although there are numerous series of patients evaluating results with elastic intramedullary nailing in forearm unstable fractures,⁵⁻⁸ there is little information about its application in patients with recurrent forearm fracture.^{9,10}

The aim of this study was to evaluate results and complications in patients who suffered forearm refracture and required internal fixation with elastic intramedullary nails.

Materials and Methods

We analyzed retrospectively all the patients with diagnosis of forearm refracture who were operated on with elastic intramedullary nailing between January 2008 and January 2016 at the Sanatorio Allende Orthopedics Department. Surgery was indicated in patients skeletally

immature with recurrent unstable fractures who had been subject to whichever (conservative or surgical) therapeutic method and who had an intramedullary canal wide enough so as to receive 2mm-elastic nails.

Surgical technique

Under general anesthesia and with intra-operative monitoring, the patient goes in supine position with abducted arm and supinated forearm on hand-operating table. We prepare the patient in anti-septic conditions and display surgical drapes as technically outlined. The C-arch goes parallel to the patient from their feet, and the monitor goes in front of the surgeon. When both forearm bones are affected, we prefer to start operating on the radial bone because usually it is the most difficult to carry out fracture reduction in. With intra-operative fluoroscopy we assess the size of the nail we are going to use, which should occupy at least two thirds of the narrowest part of the bone canal (usually 2 or 2.5 mm-nails in children forearms).

We perform a skin 2-cm incision in the distal radial bone, 2 cm proximally to the growth plate. We identify and protect the superficial branch of the radial nerve. We drill the distal radial bone—the hole should be oblong to facilitate the introduction of the nail. Previously we curve the selected nail some 40° at the level of the fracture and we introduce the nail by hand. If the intramedullary canal is obliterated or if after three reduction attempts it is not possible to introduce the nail into the proximal fragment, a surgical approach for open reduction should be carried out. We perform a palmar 3-cm longitudinal incision. We identify both ends of the fracture and re-open the intramedullary canal by drilling, taking care of avoiding false pathways. In the ulnar bone we introduce a nail of the same diameter as the one we used in the radial bone. In ulnar diaphyseal or proximal fractures we prefer that the ulnar nail goes in distal-proximal direction, because this alternative allows us to get better fluoroscopic visualization during the manipulation of the fracture. Should open

reduction be necessary, we perform a 3-cm longitudinal incision on the subcutaneous edge of the ulnar bone. Once we have verified by fluoroscopy that the fracture is properly aligned and the nails skids are in front of each other (orientated towards the inter-osseous membrane), the nails are cut under fluoroscopic control. Ideally the nails should end up at the same level and parallel to the metaphysis 2 cm outside the intramedullary canal, beneath the skin.

Then we carry out washing with saline solution, we infiltrate with a bupivacaine solution and close the wound with intradermal 4.0 Vicryl Rapide stitches. We put the patient in a cast dorsal splint during two weeks to decrease soft tissues inflammation.

Evaluation of patients

We excluded from the analysis those patients who required other kinds of treatments (casting, plate with screws, etc.), those with closed growth plate, with <12-month follow-up and lack of information in medical histories. We documented demographic data, mechanism of injury, classification,¹¹ time passed since the bone healing of the original fracture up to refracture, type of re-

duction (closed/open), time taken by bone healing, and postoperative complications. Information was taken from radiologic registry and electronic medical histories in files.

Results were evaluated in accordance with the scale set out by Martus et al.¹² and the complications, by and adaptation of the Clavien-Dindo classification for orthopedic surgery.^{3,4} (Tables 1 and 2). Considering as normal a 70°-pronation and 85°-supination forearm rotation,¹⁵ we considered results as excellent if ROM was complete and there were no complications greater than grade I. We considered results as good when the patient had a slight movement loss (<10°) and grade II complications or beyond. Results were classified as regular if mobility loss was between 10° and 30° and, complications were grade III or more serious, and if mobility loss was >30° or complications were grades IV or V, results were considered as bad.

Statistical analysis

The analyzed variables showed non-parametric distribution; therefore, they were described as median, interquartile range (IQR) and min-max values.

Table 1. Modified Clavien-Dindo classification for surgical complications in forearm fracture^{13,14}

Grade	Definition	Examples
I	Deviation from postoperative routine with no need for intervention	Asymptomatic bone healing delay Prominent implants
II	Resolution after ambulatory management, pharmacological treatment or close follow-up.	Superficial infection Transitory nerve palsy
III	Requirement of hospital management or resurgery	Deep infection Migration of implants requiring early removal
IV	Complications which represent risks for patients' lives or limbs, or result in permanent deficit.	Compartment syndrome Permanent nervous palsy Radio-ulnar fusion Tendon rupture
V	Patient's death	Death after the surgery due to anesthetic reaction

Table 2. Results classification system by Martus et al.¹²

Results	ROM	Complication grade
Excellent	Complete	Grade I or nothing
Good	<10° loss Pronation or supination	Grade II or more
Fair	10°-30° Pronation or supination	Grade III or more
Poor	>30° Pronation or supination	Up to Grade 5

Results

We analyzed 17 patients (14 males) with 17 forearm refractures. Fifteen refractures were closed and two, open (Table 3). The most frequent pattern was transverse complete fracture (22-D/4.1 and 22-D/5.1), 76% (n=13) with refracture in the bone mid-third and, in 70.5% (n=12), the affected bone was in left forearm. Only one patient showed preoperative ulnar paresthesia and recovery was complete two weeks after the surgery. The most frequent mechanism of injury was fall from own height (13 patients). Age at the time of refracture was 11 years old (7 IQR, 5-15 years of age min-max). The injury occurred 12 weeks after the initial fracture (4.7 IQR, 4-28 weeks). Eight patients required open reduction (47%): six, only in radial bone; one, only in ulnar bone, and another one, in both bones (Table 3). Bone healing took eight weeks (4 IQR, 6-20 weeks min-max). Follow-up was 43 months (47 IQR, 12-103 months min-max).

In sixteen patients we were able to carry out clinic assessment (1 of them was lost during follow-up). Fifteen had excellent results and, in one patient, results were regular.

Two patients showed $>10^\circ$ -residual angle. There were two grade 1 complications: a slight loss of supination (15°) and ulnar delayed bone healing. This one underwent bone healing with no need for additional treatment 28 weeks after the surgery. Three patients suffered grade 3 complications: second refracture with *in situ* nails. They occurred three months (case 1), seven months (case 2) and one month (case 17) after fixation. Case 1 was treated by open reduction and internal fixation with plates and screws. Case 2 was treated by intramedullary nails change into other ones of greater diameter, and bone healing took place three months afterwards. Case 17 was subject to closed reduction to re-align the elastic nail, and it healed in good position three months after the surgery.

Nails removal of the elastic nails was routinely indicated 12 months after the surgery once we verified complete bone remodeling in radial and ulnar bones. However, it was carried out in just 13 out of the 17 patients in the series by their choice.

Discussion

Approximately 4-8% of the children who suffer forearm fracture can develop refracture during the first 12 months consecutive to the lesion.² Surgical treatment is usually indicated when it has not been possible to get re-alignment for the fracture (or keep its alignment) by closed manipulation and cast. Published reports on surgical results in forearm refracture are few in skeletally-immature patients. Therefore, the aim of our study was to assess results and complications in pediatric patients who

suffered forearm refracture and required internal fixation with elastic intramedullary nails.

Ninety-four percent of the patients in our series got excellent results with complete ROM. Only one patient suffered a slight supination loss. Because of the previous fracture callus, almost half the cases required open reduction and new opening of the intramedullary canal to allow nails to go through. Some authors have associated this surgical gesture with bone healing delay.¹⁶ Differently from adult populations, bone healing delay and non-union are not frequent in children (0-4%).^{17,18} In general, these complications occur in the ulnar bone diaphysis and they are associated with open fracture or open reduction. In our series, median bone healing was eight weeks and only one patient suffered healing delay in their ulnar bone (20 weeks), although reduction and fixation were closed in this case. Bone healing timing and complication rates (29%) in this series can be compared with those in other studies which evaluate primary fractures using the same method.^{12,19-21}

Some authors suggest that, since many patients with forearm refracture require open reduction, stabilization by plates with screws may be a simpler and more effective alternative.² Although plates give fractures absolute stability and earlier mobilization, they have a disadvantage in that they may imply a more extensive surgery (for plate insertion and removal), more time before returning to sports after removal, and more chances of refracture through screw holes.

Removal of elastic nails is controversial in specialized literature. Lascombes et al.¹⁷ recommend elastic nails removal three or four months after fixation in all long bones fractures, except forearm fracture. In their series of 85 forearm fractures treated with elastic intramedullary nails, nails were removed four months after the initial surgery in the first 50 patients, and there were three cases of re-fracture. Therefore, they recommend nails removal between 10 months and one year after the surgery. Although there are no recommendations for osteosynthesis removal in refracture cases, we recommend removal between one and two years after the surgery, once remodeling has been completed in both forearm bones. In isolated cases, we have had difficulties in varied-location elastic nail removal two years after insertion; thus, we suggest earlier removal. Following these guidelines, no patient in our series who was subject to material removal suffered a new re-fracture.

Three patients in this study suffered a second refracture with *in situ* elastic nails. In one case, traumatism occurred four weeks later, what resulted in loss of correction before bone healing. In two cases, refracture was already completely healed and the patient suffered a true second re-fracture. The patient's age at the time of refracture was similar to that in the rest of the patients in the series, and the three of them had suffered closed injuries. Reduction

Table 3. Demographic data

n	Age	Sex	Side	Affected bone	Mechanism	Type of fracture	Neurovascular injury	Pediatric AO classification	Time until refracture weeks)*	Treatment	Nails diameter (mm)	Reduction
1	12	M	L	RU	Skate	Closed	No	22-D/4.1	13	EIN RC	2.5	Closed
2	14	M	L	RU	Skate	Closed	No	22-D/5.1	8	EIN RC	2	Closed
3	6	M	R	RU	Fall from own height, Swimming-pool	Closed	No	22-D/5.1	8	EIN RC	2	Open RU
4	6	F	L	RU	Fall from own height, Dancing	Closed	No	22-D/4.1	30	EIN RC	2.5	Open R
5	13	M	L	RU	Football	Closed	No	22-D/4.1	13	EIN R	2	Open R
6	9	M	R	RU	Fall from own height	Closed	No	22-D/4.1	4.3	EIN RC	2	Closed
7	9	F	L	RU	Fall from own height	Closed	No	22-D/4.1	4.3	EIN RC	2.5	Closed
8	6	F	L	RU	Fall from slide	Closed	No	22-D/4.1	8	EIN R	2.5	Closed
9	13	M	L	RU	Fall from own height	Open Gustilo I U	No	22-D/5.1	26	EIN RC	2.5	Open R
10	7	M	R	RU	Fall from own height	Closed	No	22r-D/4.1	4.3	EIN RC	2.5	Open R
11	7	M	L	RU	Fall from own height	Closed	No	22-D/5,1	4.3	EIN RC	2.5	Closed
12	11	M	R	R	Fall from own height	Closed	No	22r-D/4.1	13	EIN R	2	Closed
13	14	M	L	RC	Fall from own height	Open Gustilo I R	No	22-D/5.1	26	EIN R	2	Open R
14	15	M	L	RU	Fall from own height	Closed	Ulnar paresthesia	22-D/5.1	NC	EIN RC	2.5	Closed
15	14	M	L	R	Fall from own height	Closed	No	22r-D/5.1	26	EIN R	2	Closed
16	12	M	L	RU	Fall from own height	Closed	No	22-D/4.1	30	EIN RC	2	Open R
17	5	M	R	U	Fall from own height	Closed	No	22u-D/4.1	21	EIN C	2	Open U

*Time from primary fracture bone healing up to refracture.

M = male, F = female, L = left, R = right, R = radial bone, C = ulnar bone, NMH = no in medical history, EIN = elastic intramedullary nail.

was closed in two cases and open in one. We did not find mistakes in surgical techniques for the new lesion to take place. Fernández et al.¹⁶ published a series of 14 refracture cases with *in situ* nails. These authors could not identify technical problems facilitating refracture either.

Results in this study should be interpreted in the context of the limitations it has. The size of the sample and the study design represent limitations for a more rigorous statistical analysis. Some of the patients come from the suburbs or the provinces and, therefore, clinical and ra-

diographic follow-up was conditioned by their possibilities to come back for follow-up. This may have affected bone healing timing. Lastly, the classification we used for complications is validated in adult patients but not in children, although it has been previously used in other studies.¹² In spite of these limitations, we believe that this study gives us original information because, as far as we know, there are no other series that have evaluated the use of elastic nails exclusively in forearm refracture in children.

In this study, internal fixation with elastic intramedullary nailing resulted in an effective technique for the treatment of forearm refracture in children. Although high per-

centages of patients require open reduction, bone healing timing and consolidation rates may be similar to those in primary fractures treated with the same technique.

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