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A PROSPECTIVE STUDY OF FUNCTIONAL OUTCOME, SAFETY AND EFFICACY OF FLEXIBLE NAILING IN UNSTABLE FRACTURES OF BOTH BONES OF FOREARM IN PAEDIATRIC AGE GROUP

Orthopaedics

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ABSTRACT

AIM OF THE STUDY: To assess Safety, Efficacy and Functional outcome of flexible nailing with (ESIN) in unstable fractures of both bones of forearm in children.

OBJECTIVES

- To determine the clinical spectrum of paediatric patients who shall undergo ESIN for both bones forearm fractures.
- To assess the functional outcome based on clinical parameters, Daruwalla's grading, Price et al; grading and the scores obtained by the Upper Extremity and the Functional Index (UEFI).
- To assess fracture union, time to union, fracture alignment and verify re-establishment of the natural radial bow (based on radiographs).

KEYWORDS

Forearm Fracture, Both bone fracture, Elastic Nail, Paediatric fracture

INTRODUCTION:

Forearm diaphyseal fracture is one of the three common upper limb fractures in the pediatric population[1,2,3]. Unlike the adult forearm diaphyseal fractures, which has undergone major changes in its treatment concepts[4,5,6,7]. Though the possibility of complications in paediatric forearm diaphyseal fractures are relatively rare, they are certainly not negligible[15,16,17,18]

Though the concept of instability in forearm diaphyseal fracture is not new, it has acquired better acceptance and understanding with our growing knowledge[6, 13, 18]. Various options have been put forward to internally stabilize the so called 'unstable' fractures. They include Kirschner wires, Steinmann's pins, Rush rods, rigid plate osteosynthesis and even SS wires [6, 19, 20, 21]Metaizeau, from Nancy, France, had popularized the concept of using two pre-bent intra-medullary flexible Titanium nails to recreate the inter-osseous space and provide three-point fixations, while simultaneously providing for biological fracture healing and more convenient hardware removal [22].Flexible Titanium nails are physis-sparing because they are introduced through the meta-physeal flare in order avoid any physeal damage.

MATERIALS AND METHODS

The prospective descriptive study was carried out in the Orthopaedics Department of Sree Balaji Medical College and Hospital, Chrompet, Chennai from March 2017 to February 2018. The follow-up study continued till 0ctober 2018. Thus, the recruitment period was of 12 months and the follow-up period was a mean of 12. 8 months (range: 8 to 19 months). The study was approved by the Institutional review board of our hospital.

Inclusion criteria:

1) Completely displaced and unstable dia-physeal fracture of either or both bones of the forearm in children of the age group 5 to 14 years were all included.
2) Oblique, transverse and short spiral dia-physeal fractures were included.
3) Fractures presenting within 2 weeks of injury, alone were included.
4) Closed dia-physeal fracture and Type-I Gustillo-Anderson open fractures were included.

Exclusion criteria:

1) Pathological fractures were excluded.
2) Open-fractures were excluded, except for Type-I Gustillo-Anderson.
3) Nailing done for non-union and delayed-union were excluded.

CLASSIFICATION: AO Paediatric Comprehensive Classification of long-bone Fractures (PCCF) was adopted in this study

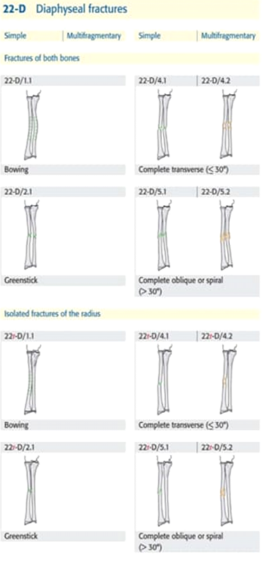


FIGURE: 1

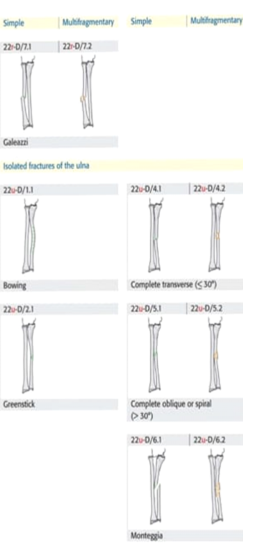


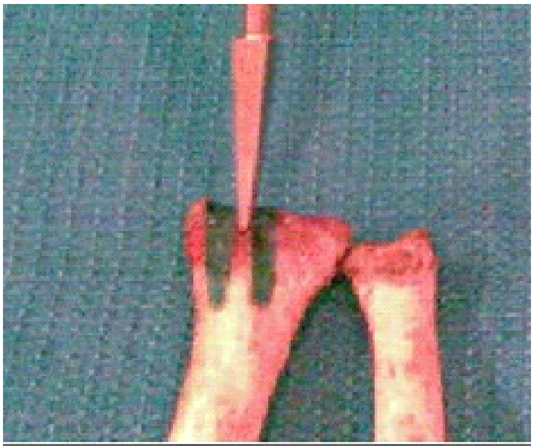
FIGURE: 2

Pre-op protocol

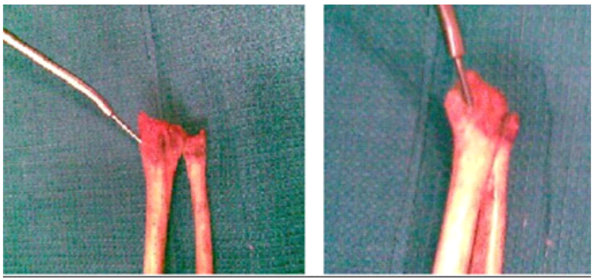
All the children underwent routine blood investigation. X-ray chest PA and X-rays AP/Lat of both the injured forearm and the healthy forearm. Anaesthetic fitness for GA/RA was sought. On the day of surgery, parentral third-generation cephalosporin was started at a dose as assigned by the paediatrician, depending on the child's weight in kgs. In the ward, the forearm and arm with injury, were sanitized with betadine and the limb with injury was draped in a sterile cloth, prior to shifting to the operation theatre. Inj. TT was administered routinely.

Intra-op protocol

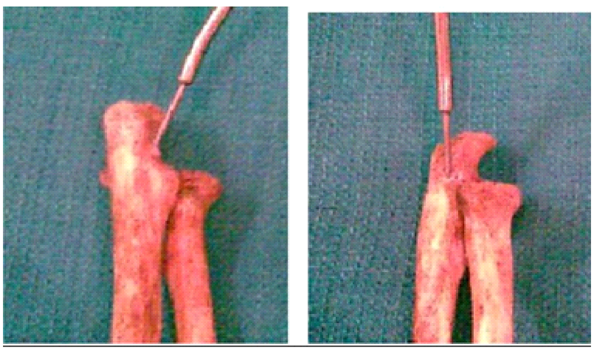
On shifting to OT, anaesthesia as deemed fit by the anaesthetist, was given (either general or regional anaesthesia). The child was positioned supine. A radio-lucent arm extension was used. The arm was again prepared and draped with 10% povidone iodine solution and then later with sterilium. On the X-ray the medullary diameter was checked in both the injured and the healthy forearm and appropriate size of nail selected. Titanium elastic nails are available in six diameters:1.5mm, 2.0mm, 2.5mm, 3.0mm, 3.5mm and 4.0mm.The 1.5mm diameter nail is 300mm long. The 2.0mm through 4.0mm diameter nails are 440mm long. The nails are colour coded for easy identification. The proper nail diameter is not more than forty percent of the narrowest width of the medullary canal.



[IMAGE:1] Dorsal Entry Point for Radius.



[IMAGE:3] Surgical Approach to Ulna.



Forearm fractures typically require a single nail inserted in each bone. Nails may be used either ante-grade or retro-grade depending on fracture location and the surgeon's preference. It is usually recommended to place the radial nail from a distal approach. The most commonly used nail diameter in the Indian children are 1.5mm to 2.5mm. For a better and delicate control, instead of the nail inserter, a light weight universal chuck with a T-handle is used. The image intensifier is positioned perpendicular to the arm, entering from the foot-end of the table. While imaging, we move the beam of the c-arm and not the arm. The distal entry point of radius is either just proximal to the radial styloid or through the Lister's tubercle.

Be aware of the extensor tendons and superficial radial nerve. Care is taken not to penetrate the contra-lateral cortex. The use of the hammer is not recommended, since hammering may produce further fracture fragments.

The ante-grade entry point in the ulna can be either at the posterior aspect of the olecranon or by a lateral approach through the proximal meta-physis. The retro-grade entry point in the ulna if opted for, is through the distal meta-physis.

Nailing of ulna alone, may in some instance permit the radius to be treated closed. If the retro-grade ulnar entry is opted for, the sensory branch of the ulnar nerve should be protected. In the retro-grade technique for radius, we over-drill the starting point to allow for ease of nail insertion. The pre-nail is bent 15 to 20 degrees to both facilitate insertion

Post-op protocol:

Post-operative splinting with a POP slab is done. IV antibiotics are continued for 72 hours after surgery. No DT removal is required, as none was introduced. Early mobilization has been advocated [Verstreken JPO 1988 and Ritcher JPO 18, 1998] and had proved that there is a good 3-point fixation, which leads to the tighting the inter-osseous membrane and hence early mobilization is executable

Nail removal:

The nail removal is usually planned by 16 to 24 weeks of the initial surgery. Too early a removal could cause a re-fracture, leading to some authors recommending a retention period of atleast 6 to 9 months.

Complications:

ESIN is a simple surgical method, but failures do occur when basic principles are not heeded to. Though the corrective potential of a child's skeleton contributes to fracture healing despite sub-optimal fixation, it is not an excuse for poor surgical technique and performance

Most failures with ESIN occur due to wrong indication, incorrect nail size, wrong technique and failure by omission. Common post-operative complications, as reported in the literature include:

1. Soft tissue irritation due to sharp nail ends (3%).
2. wound infection.
3. Secondary rupture of tendons (3.7%).
4. Re-fracture with nail in situ (2.5%).
5. Axial deviation > 10 degrees (1.8%).
6. Delayed healing (1.2%).
7. Migration of nail (0.6%).
8. Technical failure (0.6%).
9. Functional rotational restriction (limitation of movement > 10 degrees) 1.8% cases.
10. Distal radio-ulnar joint subluxation (0.9%).

Common errors

1. Using too narrow nail (<60% of forearm bone diameter).
2. Inadequate 3-point contact with the diaphysis.
3. Inadequate pre-bending.
4. Improper nail insertion.
5. Soft tissue irritation.

RESULTS:

26 children in the age group of 5 to 14 years of age and conforming to our inclusion criteria, qualified for Titanium Elastic Nailing of the forearm bones, in the ear-marked recruitment period from March 2017 to February 2018. Recruitment of fresh patients stopped by February 2018, in order that the minimum follow-up period would be 8 months [Mean 12.8 months; range: 8 to 19 months]

[Table:1] Age And Sex Distribution:

Age (in years)	Male		Female	
	(No:of patients)'n'	% age	(No:of patients)'n'	% age
5-6	2	7.70	0	00
7-8	4	15.40	2	7.70
9-10	9	34.62	4	15.40
11-12	2	7.70	1	3.85
13-14	1	3.85	1	3.85
Total	18	69.20	8	30.80

[Table:2]average Injury To Surgery (I To S) And Surgery To Discharge(S To D) Time Distribution:

No:of days	Injury to Surgery		Surgery to Discharge	
	'n' No:of patients	%age	'n' No:of patients	%age
1–2	20	76.9	0	0.0
3–4	4	15.4	0	0.0
5–6	2	7.7	15	57.7
7–8	0	0.0	7	26.9
9–10	0	0.0	4	15.4
Total	26	100%	26	100%

Mean I to S = 2.7 days.
Mean S to D = 7.3 days

[TABLE:3] AVERAGE UNION PERIOD DISTRIBUTION:

Radiological Union By The End Of Week	MALE		FEMALE	
	(No:of patients) 'n'	% age	(No:of patients) 'n'	% age
4	1		0	
5	4		1	
6	7		1	
7	3		1	
8	2		3	
9	1		1	
10	0		1	
Total	18	69.20	8	30.80

Highlight:
Union within 2 months:23/26=88.46%
Union between 2 months and 2 and a ½ months: 3/26=11.54% Non-union=nil=0%

[Table:4] Clinical Outcome Distribution Chart As Assessed By Upper Extremity Functional Index [UEFI] Questionnaire:

Outcome Grading And Score Range	(No:of patients) 'n'	%age
Excellent 80-66	11	42.31
Good 65-51	14	53.85
Fair 50-36	1	3.84
Poor 35 and below	0	
Total	26	100%

Thus, the excellent to good results as per UEFI questionnaire was 96.16%

We used the modified Schemitsch and Richard's method to calculate the location of the radial bow in the children who underwent flexible nailing. The mean distance of the site of the radial bow was located at 66.32% (SD +/- 4.7%) of the radial length. The mean value of maximum radial bow was 5.13% (SD +/- 0.26%). It is comparable to Firl's criteria which specifies that the mean distance of the radial bow should be around 60% and the maximum radial bow should be less than 10% of the radial length. There was no limb length discrepancy between the operated and non-operated limbs in our group.

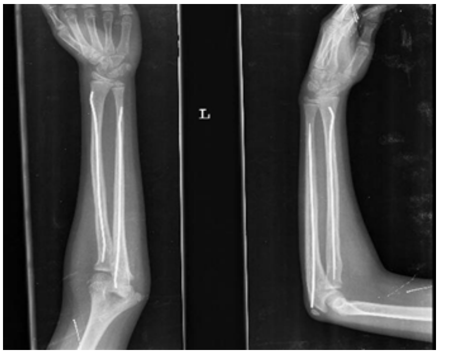
The average cost of two intra-medullary nail varied between INR12,000.00 to INR 16,000.00. The analysis revealed that the total expenses incurred during the hospitalization were approximately INR38, 500.00. This cost can be justified considering the fact that the surgery was offered to only carefully selected patients with relevant indications for operative management, who other-wise might have ended up with resultant deformity requiring corrective osteotomy or significant life style modification and altered self-perception. There was no observed case of refracture in our study group.

With regard to clinical and functional outcomes:

- As per the Daruwala criteria; we had 92.31% excellent to good outcomes and no poor outcomes.
- As per the price et al; criteria; we had 96.16% excellent to good outcomes and no poor outcomes.
- As per the (UEFI) upper extremity functional index questionnaire outcomes; we had again a 96.16% excellent to good outcomes and no poor outcomes.
- The mean average considering all the above criteria and questionnaire, brings the tally of good to excellent results to 94.88%.

CASE ILLUSTRATION
CASE1:
RADIOLOGICAL OUTCOME:

[Fig:4] Pre -OPX-ray showing proximal third of both bones fracture left forearm. Type I open GA.



[Fig:5] Post-OP X-ray showing bony union at 6 weeks.

FUNCTIONAL OUTCOME:
[Fig:6] Forearm Supination

[Fig:7] Forearm Pronation.

DISCUSSION

The management of forearm fracture in children has undergone a sea change with the realization that closed reduction with some deformity in children is not acceptable and will not remodel as was earlier perceived. This holds true for the age group beyond 9 to 10 years. The literature has shown that the results of closed reduction irrespective of instability and higher degree of deformity and mal-alignment have caused un-acceptable cosmetic and functional results [15,17]. With the available information the present criteria for acceptable angulation, dis-placement and rotation are much stringent[3]. The acceptable limits of angulation and mal-rotation for completely displaced both bones of forearm fractures are 15 and 45 degrees respectively in children under age of 9 years and in the age above 9 years are 10 degrees and 30 degrees respectively [3]. The complications of correcting a mal-united, functionally compromised paediatric forearm far out-weighs those of primary internal fixation of unstable forearm fracture [32,34,37]

The listed indications in literature for internal fixation for paediatric both bones forearm fracture are fracture instability, mal-reduction, loss of reduction and in children older than 10 years. Instability, mal-reduction and loss of reduction account for about 50% to 90% of cases in whom internal fixation for paediatric both bone forearms are described in the literature[19,36,44,45]. In our series of 26 patients, 80.82% (n=21) cases were of age group below 10 years of age, remaining

19.18% (n=5) cases were in the age group between 11 to 14 years. the water shed zone! Were rules of acceptability of angulation and mal-rotation take a sweeping change.69.20% (n=18) of these were male and 30.80% (n=8) were females. There was a clear male preponderance in our series as the M:F ratio was 21:5.In 69.23% (n=18) cases, both the radius and ulna were fractured, in 23.08% (n=6) cases ulna alone was fractured and in 7.69% (n=2) cases radius alone was fractured. By far the commonest mode of injury 65.40% (n=17) were due to fall on an outstretched hand. In all, 44 nails were surgically deployed for as many fractured forearm bones. The most widely used nail diameter in 47.70% (n=21) cases were the 2.5mm variant. However, in the entire study range from 1.5mm diameter TENS to 3.0 mm diameter TENS were deployed.

The pattern of fracture in the unstable group is usually complete, transverse, oblique or short oblique. Literature has shown that approximately 10 % of all paediatric forearm both bones fractures are unstable and warrant internal fixation[37,12]. As a corollary, 80% of internal fixation in the paediatric forearm both bones fractures are secondary to instability. According to Price's criteria over 30 degrees of angular malalignment is un-acceptable[3]. The young children with thick periosteum and relatively elastic bones tend to sustain Green stick fractures and stable fractures, whereas the older children are prone to sustain complete, un-stable, angulated and mal-rotated fractures which require to be treated with reduction and internal fixation, as was warranted in the present study.

[Table:5] Our Good To Excellent Clinical And Functional Outcomes Were As Follows:

Daruwalla Criteria	Price et al; criteria	UEFI criteria
% age / 'n'	'n' % age	'n' / % age
92.31 (n=24)	96.16 (n=25)	96.16 (n=25)

Lyons et al; in a review of literature involving 68231 children sited a male to female propensity of 63.7%:39.1%. Lyons et al;[65]and Ceroni et al;[66] cited that the majority of fracture of the paediatric forearm occurred in the distal third. In our study 73.10 % (n=19) cases were those of the middle third forearm, 15.38% (n=4) cases were of proximal third forearm and 11.52 % (n=3) cases were of the distal third forearm.

A review of literature, is inconclusive in defining precise guidelines for acceptable deformity.

Franklin et al;[70] defines successful treatment of paediatric forearm fractures should result in painless and complication free outcome with good functional prono-supination. Our study had generated 92.31 % good and excellent outcome by Daruwala criteria, 96.16% by Price et al; criteria and 96.16 % as per UEFI questionnaire. Hence the functional end results of operated TENS nailing were credibly good. It has been shown by Shah AS et al;[71] that 15 to 20 degree of angulation the middle third of the forearm can lead to a major loss of forearm rotation. Price CT;[72] stated that closed reduction is indicated in children aged 0 to 8 with a fracture angulation of greater that 10 degree and mal-rotation greater than 30 degree. In patients with angulation less than 10

CONCLUSION

Mostly both bone fractures that are indicated to be fixed with plate / plates or may also be surgically treated with flexible nails, through closed / open reduction techniques accordingly. In last decade fracture fixation with flexible nails has gained momentum with proponents arguing that flexible nailing results in decreased surgical dissection with retention of biological factors at the fracture exudate site. Generally, both titanium and stainless-steel flexible nails are being used for fixation. In most circumstances titanium nail is being used rather than stainless steel because of the flexible elastic properties which are unique to titanium which helps in convenient and improved insertion and rotation while still providing adequate stabilisation for the fracture.

The diameter of available Titanium Elastic Nail (TEN) implants ranges in sizes 1.5mm, 2mm, 2.5mm, 3mm, 3.5mm and 4mm. All the nails measures about 440 mm in length. The size selection of the implant is dependent on the diameter of the medullary canal. The nails are colour coded for easy identification.

The ideal diameter is a nail which is 40% of the medullary diameter. Length is determined by placing the implant over the injured forearm and measuring against bone length under fluoroscopic guidance. Nails should be pre-bent, with maximum curvature at the site of the fracture which helps to ensure restoration of the inter-osseous space

Similar to plate fixation, several authors have sought out to determine if dual nail fixation is truly necessary. Some advocate for dual fixation, as ulnar fixation alone may lead to an unacceptable rate of loss of reduction of the unfixed radius. Duration and method of post-operative immobilization amongst studies is variable, ranging from practically no immobilization to six weeks of long arm casting. Nails are routinely removed at 6 months post-operatively, requiring a second operative procedure. Complications secondary to intra-medullary fixation include infection at the site of implantation, skin irritation, re-fracture after removal, implant failure, nerve/tendon injury, decreased range of motion and compartment syndrome. The cause of these complications is difficult to determine. All cases of compartment syndrome developed within 24 hours of initial fixation and in the literature treated with fasciotomy and delayed wound closure, and no patient developed permanent neurologic injury after treatment. Other studies have reported a 0-1% incidence of compartment syndrome, with notably a shorter tourniquet times. It appears that a longer tourniquet time can be correlated with the risk for compartment syndrome. Despite the complication risk inherently associated with operative insertion of flexible nails, intra-medullary nailing can be an effective strategy for treatment of forearm fractures with acceptable complication rates. Careful attention to the length tourniquet time is warranted.

Our series is too small to draw high end conclusions for paediatric forearm fracture management. Having said that, the general trends that we witnessed during the course of this study points to the following conclusions:

1. Elastic stable intra-medullary nailing is a safe and reliable method for internal fixation of unstable forearm fractures.
2. Deviation from the basic principles of ESIN which includes choosing the suitable size and material of flexible nail, suitable nail entry point and surgical approach, will lead to avoidable complications
3. Lateral entry point for radial nail puts the superficial radial nerve at risk.
4. The functional results at 1 year are maintained and uncomplicated cases may be discharged from regular follow-up at this period.
5. Immobilization during the immediate post-operative period for 4 to 6 weeks is advisable.
6. Hardware exit is desirable and probably timed at about 6 months from the time of surgery.

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