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SAFETY, EFFICACY AND FUNCTIONAL OUTCOME OF FLEXIBLE NAILING (ESIN) IN UNSTABLE FRACTURES OF BOTH BONES OF FOREARM IN CHILDREN

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ABSTRACT

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 treatment of dia-physeal forearm fractures using open reduction and plate fixation is generally accepted as the best choice in many studies. However, periosteal stripping, hematoma evacuation may result in delayed union, non-union and infection. Re-fracture after plate removal is another concern. To overcome these problems intra-medullary nails with different designs had been used with various outcomes. However previous IM nails have some short comings such as rotational instability and inter - locking difficulties.

Keywords:bone fractures, Titanium nails, paediatric corollary, ossification centre, Forearm, Osteology

Introduction

Forearm dia-physeal fracture is one of the three common upper limb fractures in the paediatricpopulation[(1,2,3)]. Unlike the adult forearm dia-physeal fractures, which has undergone tectonic shift in its management concepts[(4,5,6,7)], its paediatric corollary continues to be viewed more cautiously. Having said that, the interest of the Orthopaedic surgeon has been piqued by the subtle but pragmatic encroachment of the operative interventions in an area hitherto considered as a stronghold for conservative management [(8,9,10,11)].

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 torecreate 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.

In an attempt to define the indications for operative management, we propose to highlight the learning curve in optimization of surgical technique, quantify the desired outcomes and address the complications of internal fixation of unstable paediatric forearm dia-physeal fractures with intra-medullary flexible nails by prospectively studying paediatric patients who shall undergo

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flexible nailing for both bones dia-physeal forearm fractures. Here we shall attempt to assess the outcome parameters and complications associated with this procedure, with intentions to look at the safety and efficacy of elastic stable intra-medullary nailing and establish if any evidence-based outcome measures for the operative management in paediatric forearm dia-physeal fractures.

Elastic stable intra-medullary nailing (ESIN) is a relatively established minimally invasive technique for the treatment of paediatric fractures. It approximates the physiological healing process of bone, without opening the fracture site. Also, the fracture operative stress is minimal because of the minimally invasive nature of the procedure, and the volume of the implants is small, offering a relatively very good stability, which may not be achieved with a simple cast immobilization.

Elastic stable intra-medullary nailing (ESIN) is a minimally invasive technique. According to this technique, one or two elastic nails are introduced through the meta- physis into the medullary canal, advanced through the fracture site and impacted into the opposite meta-physis. These nails are pre-formed in a C-shaped manner, which allows for their precise orientation and the creation of an elastic system that resists the forces of deformation. The bone remodelling capacity in children corrects residual deformations through growth, while the classical methods of osteo-synthesis may encounter many complications.

Spontaneous bone remodelling is subject to rules referring to the fracture site, the type and the degree of displacement. When these conditions are not met, osteo- synthesis is needed. The technical procedures that are currently available for the treatment of children, are far different from those which are applicable for the adults.

Plate osteo-synthesis requires extensive periosteal stripping, in conditions in which the periosteum plays an essential role in the consolidation of fractures in children, intra-medullary osteo-synthesis, with the penetration of the growth cartilage, induces endosteal circulation disorders and severe growth problems, because of epiphysiodesis or growth stimulation through the complete obstruction of the medullary canal.

Currently, the most common operative interventions are open reduction with plate fixation versus closed or open reduction with intra-medullary fixation. Plating has advantages of being more familiar to many surgeons, being theoretically superior in the ability to restore the radial bow, and providing the possibility of hardware retention.

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.

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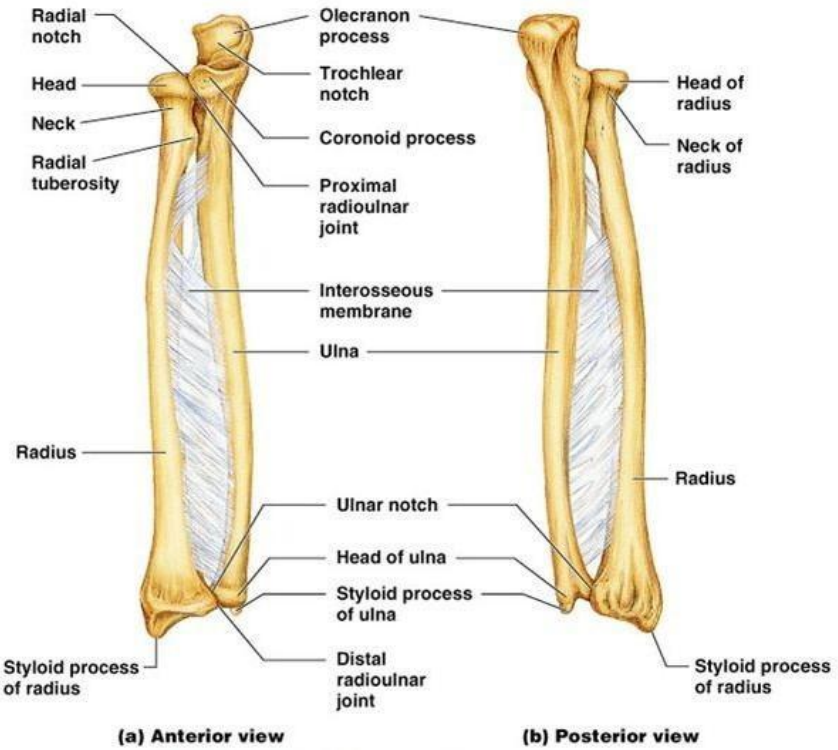
- To assess the functional outcome based on clinical parameters, Daruwalla's grading, Price et al; grading and the scores obtained by the Upper Extremity and the Functional Index (UEFI).
- To assess fracture union, time to union, fracture alignment and verify re-establishment of the natural radial bow (based on radiographs).

APPLIED ANATOMY[1,2,24]

Several anatomic differences distinguish paediatric forearms from those of adults. The paediatric radial and ulnar shafts are proportionately smaller, with narrow medullary canals, and the metaphysis contains more trabecular bone. In addition, the periosteum in children is much thicker than that in adults; this feature can both hinder as well as help in the management of paediatric fractures.

Fig 11: Anatomy of Radius and Ulna.

The ulna is a straight, triangular shaped bone but the radius is rectangular distally, triangular in the middle third and cylindrical in the proximal third. The radius has a gentle bow along its shaft, which facilitates its rotation around the ulna during the pronation and supination movement of theforearm. The two bones are held together by the annular ligament at the proximal end, the triangular fibro-cartilage complex in the distal end and the inter-osseous membrane in the middle. This inter-osseous membrane is attached to the medial border of the



radius and the lateral border of the ulna and extends from below the radial tuberosity to just proximal to the distal radio-ulnar joint. The inter-osseous membrane is stretched to its full length when the forearm is in neutral and up to 30 degrees supination. As the forearm is pronates, the radius rotates around the ulna and the membrane is relaxed.

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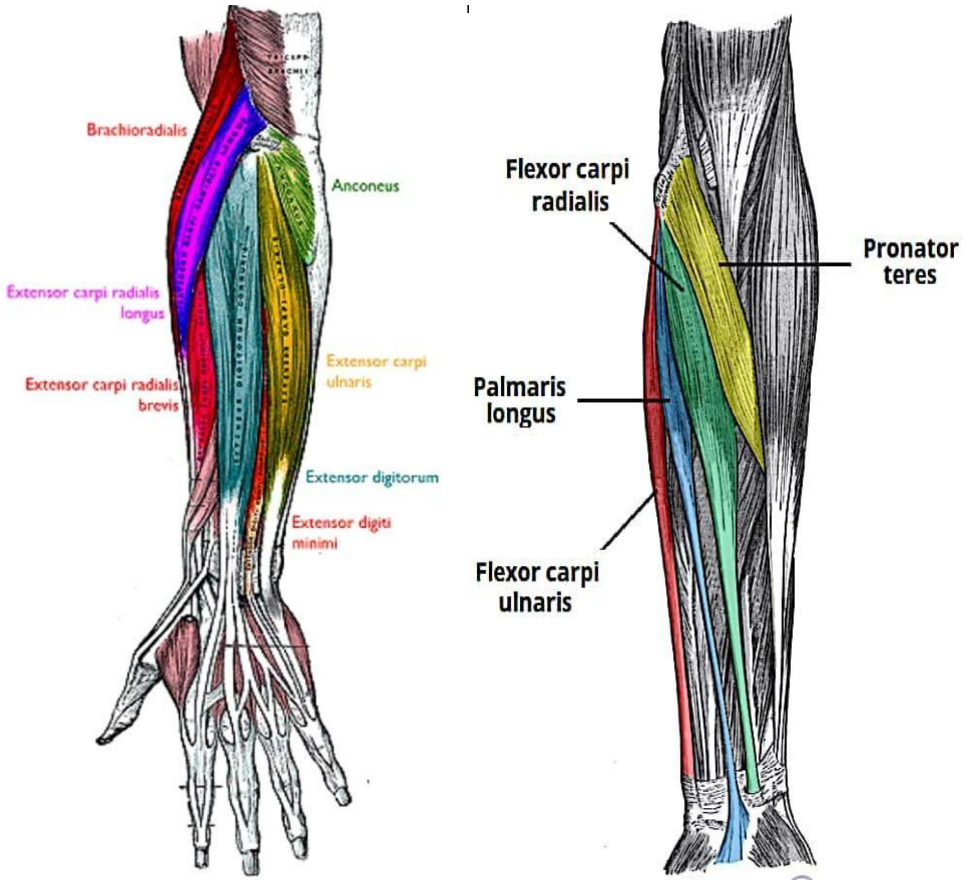

Fig 12: Posterior Forearm Fig 13:The Superficial Muscle Superficial Muscle. Ofthe Anterior Forearm.

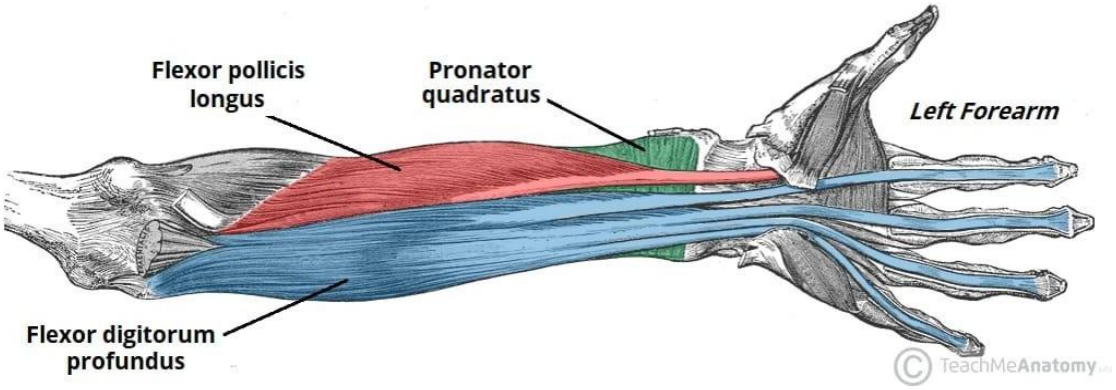

Fig 14: Deep Muscles of the Anterior Forearm.

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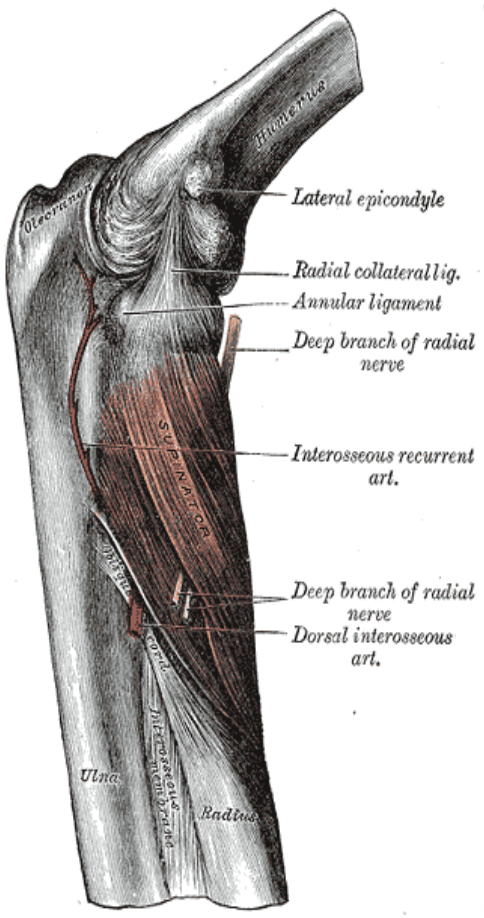

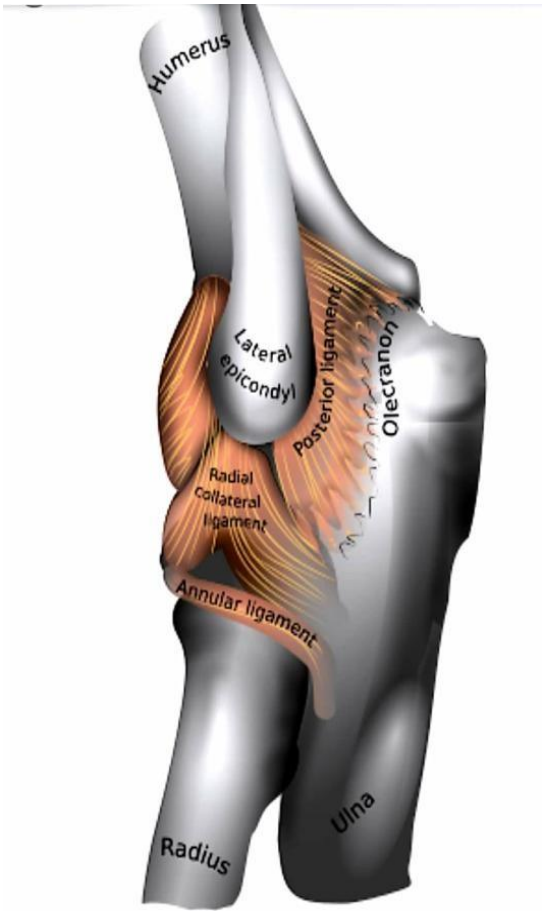

Fig 15: Inter-Osseous Membrane. **Fig 16: Annular Ligament.**

The radial tuberosity located just below its neck provides attachment for the Biceps tendon and is located exactly opposite to the radial styloid process. This fact can be used as an intra-operative guide to assess rotational alignment. The radius and ulna articulate distally and proximally and functionas a two-bone complex. Hence a displaced injury to one bone is associated with an injury to the other. Forearm flexor muscles are divided into three groups. The superficial group includes the Pronator teres, Flexor carpi radialis, Palmaris longus and Flexor carpi ulnaris. The intermediate group includes Flexor digitorumsuperficialis and the deep group includes Flexor digitorumprofundus, Flexor policislongus and Pronator quadratus.

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1	C	Capitulum
3	R	Radial Head
5	I	Internal Epicondyle
7	T	Trochlea
9	O	Olecranon
11	L	Lateral Epicondyle

Fig 18: Ossification Centre Elbow and Proximal Forearm.

While both proximal and distal physis provide growth potential to the forearm long bones, the distal radial and ulnar physis contribute 75% and 81% of the longitudinal growth of the long bones, respectively

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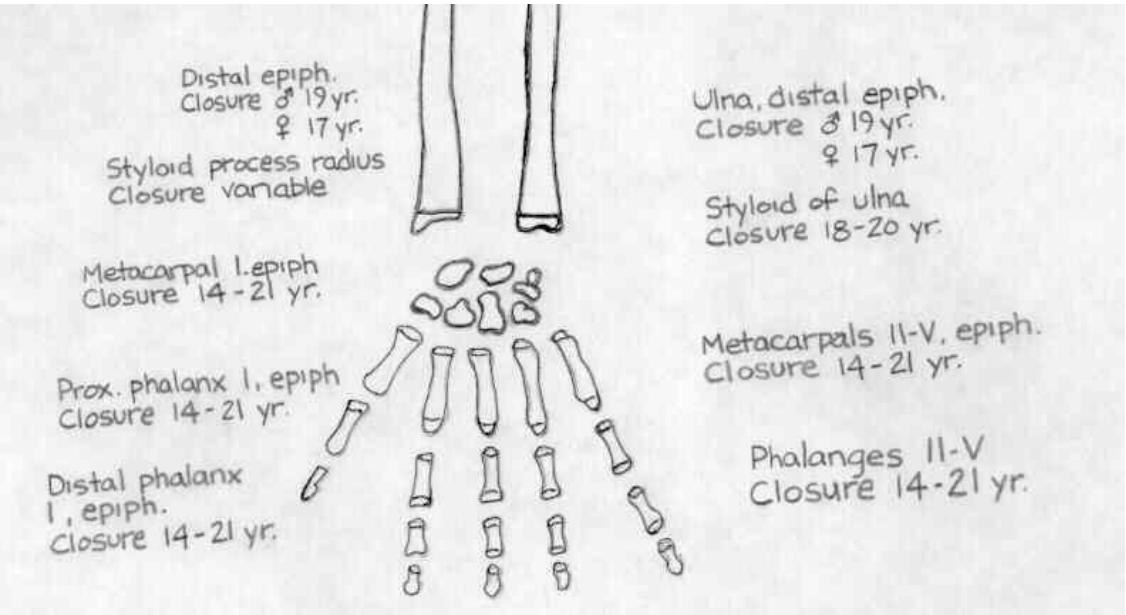
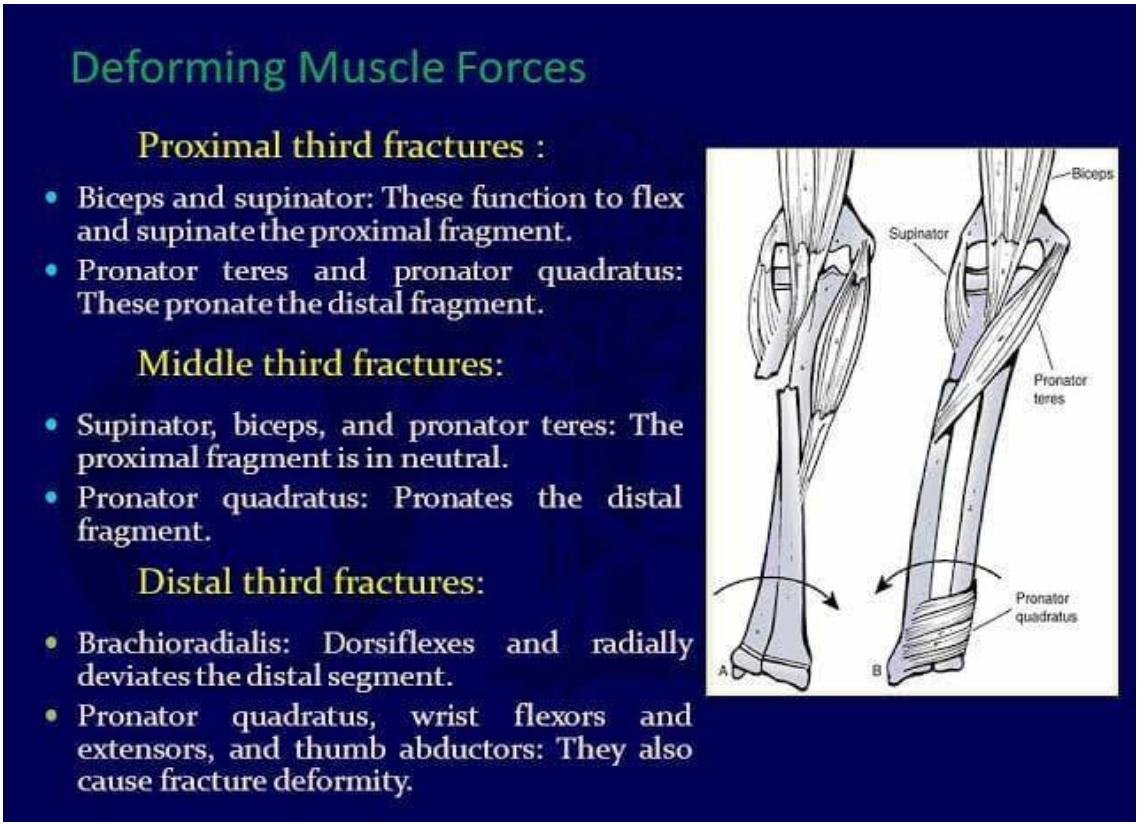


Fig 19: Ossification Centre Wrist and Distal Forearm.



Typical closure ofphysis is about 17 years in girls and 18 years in boys. The distal ulna physis closes about a year earlier than the distal radial physis. The proximal ulnar ossification centre appears around age 10.**Mechanism of injury:**

Fig 20: Mechanism of Injury.

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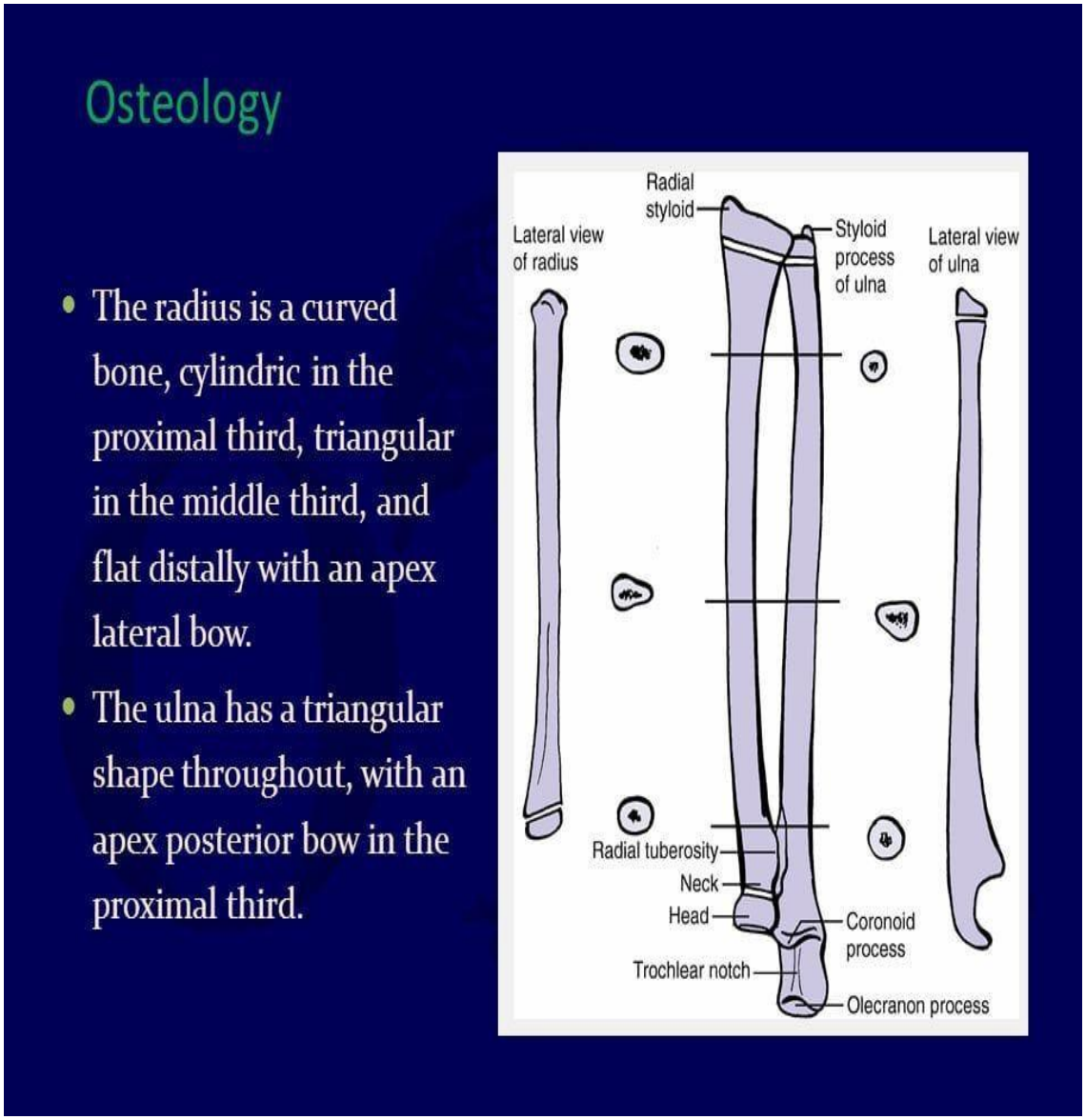

Fig 21:Osteology and variable medullary size from Proximal to Distal Forearm Bone.

Pronated or supinated forearm and its impact onthe nature of injury:
Themechanismisafallonto anoutstretched hand.Forearm rotation determines the direction of angulation. Pronation: flexion injury (dorsal angulation).
Supination: extension injury (volar angulation). Direct: direct trauma to the radial or ulnar shaft.

MATERIALS AND METHODS

The prospective descriptive study was carried out in the Orthopaedics Department of SreeBalaji 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.

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Inclusion criteria:

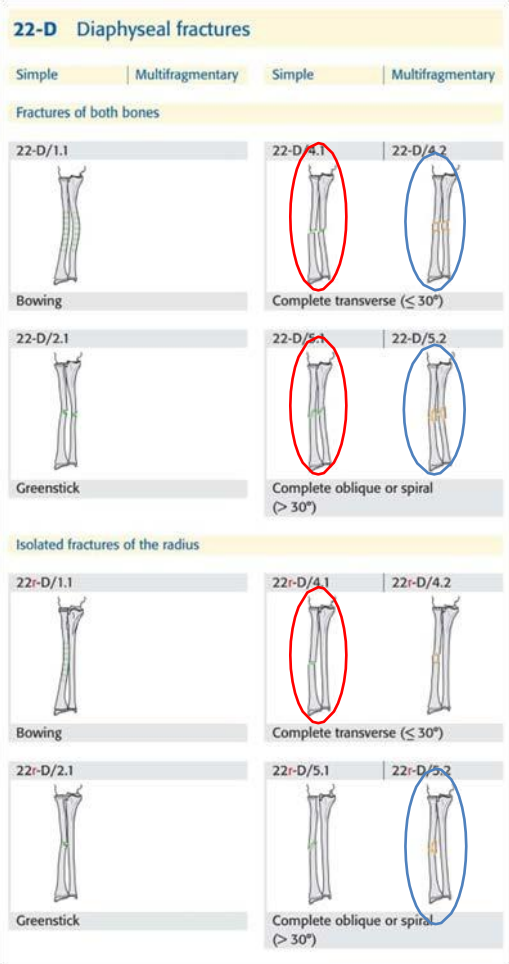
a) Completely displaced and unstable dia-physeal fracture of either or both bones of the forearm in children of the age group 5 to 14 years were all included.
b) Oblique, transverse and short spiral dia-physeal fractures were included.
c) Fractures presenting within 2 weeks of injury, alone were included.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

Exclusion criteria:

a) Pathological fractures were excluded.
b) Open-fractures were excluded, except for Type-I Gustillo-Anderson.
c) Nailing done for non-union and delayed-union were excluded.

Classification system:

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



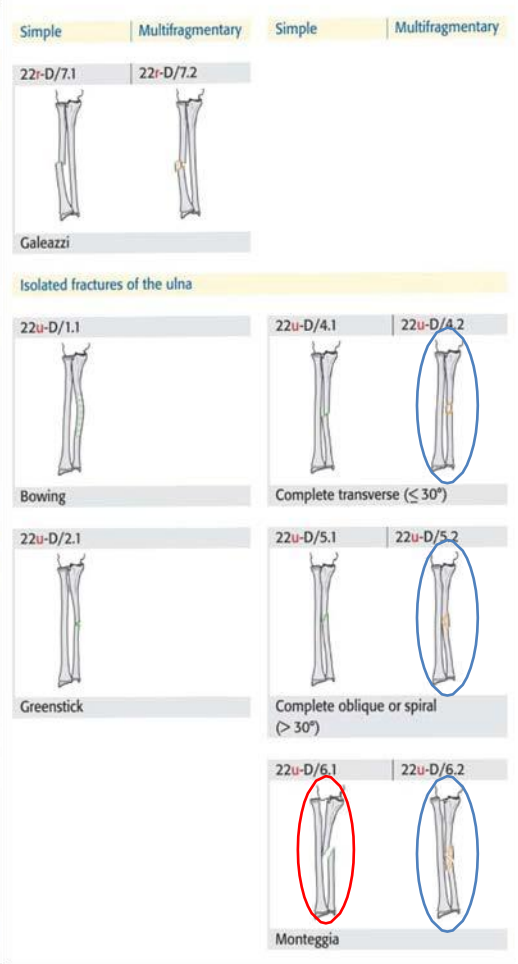


Fig: 23. **Fig: 24.**

AO-PCCF-Classification of both bones forearm and single bone forearm. The circled variants of dia-physeal forearm paediatric fractures were included in the present study.

Functional outcome

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Functional outcome was measured according to the Daruwalla's clinical grading, Price et al; criteria; and UEF index (46, 64).

[Table: 1] Daruwalla's Grade: Clinical finding.

EXCELLENT	Movements equal on both sides.
GOOD	Limitations of up to 20 degrees of rotation on injured side.
FAIR	Limitation of 20 to 40 degrees of rotation on the injured side.
POOR	Limitation of above 40 degrees of rotation on the injured side.

[Table: 2] Grading system for functional outcome according to Price et al; criteria.

Outcome	**Symptoms**	**Loss of forearm rotation**
Excellent	No complaints with strenuous activity	<15°
Good	Mild complaint with strenuous activity	15° - 30°
Fair	Mild complaint with daily activities	31° - 90°
Poor	All other results	> 90°

The gradation of Price et al; is purely based on activity accomplishment and loss of rotation.

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]

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[TABLE: 5] 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: 6] SIDE AND SITE OF FRACTURE DISTRIBUTION:

Bone involved	No:of patients'n'	Sex M/F	Side R/L	Side PT/MT/DT
Radius + Ulna	18	12M/6F	16R/2L	2PT/15MT/1DT
Radius alone	2	1M/1F	0R/2L	1PT/0MT/1DT
Ulna alone	6	5M/1F	4R/2L	1PT/4MT/1DT
Total	26	18M/8F	20R/6L	4PT/19MT/3DT

Key: PT - Proximal third forearm fracture.
MT - Middle third forearm fracture.
DT - Distal third forearm fracture.
R - Right side.
L - Left side.
M - Male.
F - Female.

[TABLE: 7] MECHANISM OF INJURY AND TYPE OF FRACTURE DISTRIBUTION:

MOI	No:of cases 'n'	% age	Nature of fracture Pattern	
			Closed	GA Type I
Fall on out stretched hand	17	65.4	17 C	0 GAI
RTA	4	15.4	2 C	2 GAI
Sports injury	3	11.5	1 C	2 GAI
Fall from height	2	7.7	0 C	2 GAI

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Total	26	100%	20 C	6 GAI

Key:
C - Closed Fracture.
GAI - Gustillo-Anderson Type I open fracture. MOI - Mode of injury.
'n' - No:of patients.

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 34: Pre-OPX-ray showing proximal third of both bones fracture left forearm. Type I open GA.

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Fig 35: Post-OP X-ray showing bony union at 6 weeks.

FUNCTIONAL OUTCOME:

Fig 36: Forearm Supination.

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Fig 37: Forearm Pronation.

CASE 2:
RADIOLOGICAL OUTCOME:

Fig 38: Pre-OPX-ray showing fracture in the junction of middle third and distal third of bothbones left forearm.

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Fig 39: Post-OP X-ray showing bony union at 6 weeks.

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

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2.5mm variant. However, in the entire study range from 1.5mm diameter TENS to 3.0 mm diameter TENS were deployed.

As per the OA-OTA classifications, Type 22-D/5.1 and

5.2 constituted 46.1% (n=12) of all our cases. The mean injury to surgery time was 2.7 days (range: 1 to 6 days) and the mean surgery to discharge time was 7.3 days (range: 5 to 10 days). Radiological union was achieved by 2 and a half months in all cases and within two months in 88.46% (n=23) of cases. The average union period in weeks was 6.2 weeks.

[TABLE: 15] OUR GOOD TO EXCELLENT CLINICAL AND FUNCTIONAL OUTCOMES WERE AS FOLLOWS:

DARUWALLA CRITERIA %age / 'n'	**Price et al; criteria 'n' %age**	**UEFI criteria 'n' / %age**
92.31 (n=24)	96.16 (n=25)	96.16 (n=25)

CONCLUSION

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. The cause of these complications is difficult to determine. All cases of compartment syndrome developed within 24 hours of initial fixation.

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

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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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Ethical approval: The study was approved by the Institutional Ethics Committee

CONFLICT OF INTEREST

The authors declare no conflict of interest

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REFERENCES

[1] FRACTURES IN CHILDREN, ROCKWOOD AND WILKINS. 6th EDITION

[2] KI Noonan, CT Price. Forearm and distal radius fractures in children. AAOS;J Am AcadOrthopSurg 1998;6-146-156

[3] Madhuri V, Gahukamble AD, Dutt V, TharyanP. Conservative interventions for diaphyseal fractures of the forearm bones in children. Cochrane Database of Systematic Reviews, Issue. Art. No.: 180.

[4] Knight and Purvis. Fractures of both bones of the forearm in adults. J Bone Joint Surg (Am); 31-A; Oct 1949; No 4: 755 – 764

[5] A Sarmiento. Forearm fractures. Early Functional Bracing

[6] – A preliminary report. Bone Joint Surg (Am); 57-A; Apr 1975; No 3:297 – 303

[7] F Sage. Medullary fixation of fractures of the forearm. J Bone Joint Surg (Am); 41-A; Dec 1959; No 8: 1489 – 1515

[8] D Anderson, T D Sisk, R E Tooms, W I Park III. Compression Plate fixation in acute diaphyseal fractures of the radius and ulna. J Bone Joint Surg (Am); 57 –A; Apr 1975; No 3: 287 – 296

[9] W P Blount, AA Schaefer, J H Johnson. Fractures of the forearm in children. JAMA; Vol 120; Sep 1942; No 2: 111– 116

[10] J C Hughston. Fractures of the forearm in children. An Instructional Course Lecture, the American Academy ofOrthopaedic Surgeons. J Bone Joint Surg(Am); 44- A; Dec 1962; No 8: 1678 – 1687

[11] E M Evans Fractures of the radius and ulna. J Bone Joint Surg; 33-B: 548 – 561

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 1, 2021, Pages. 2392 - 2410
Received 15 December 2020; Accepted 05 January 2021.

[12] E M Evans. Rotational deformity in the treatment of the fractures of both bones of the forearm. J Bone Joint Surg; 27: 373- 379

[13] DJ Fuller, C J McMullough. Malunited fractures of the forearm in children. J Bone Joint Surg ; 64 –B; 1982; No 3: 364 – 367

[14] G H Thompson, J H Wilber, R E Marcus. Internal fixation of fractures in children and adolescents. A comparative analysis. ClinOrthopRelat Res; 188; Sep 1984: 10 – 19

[15] CHILDREN'S FRACTURES. M Rang. Philadelphia. J B Lippincott Co. 1974

[16] C Creasman, D J Zaleske, M G Ehrilch. Analyzing forearm fractures in children. The more subtle signs of impending problems. ClinOrthopRelat Res; 188; Sept 1984: 40 -53

[17] D R Davis, D P Green. Forearm fractures in children. Pitfalls and complications. ClinOrthopRelat Res; 120; Oct 1976: 172 – 183

[18] R K Gandhi, P Wilson, J J Mason-Brown, W Macleod. Spontaneous correction of Deformity following fractures of the forearm in children. BJS; 1962; 50: 5 – 10

[19] S D Shoemaker, C P Comstock, S J Mubarak, D R Wenger, HG Chambers. Intramedullary Kirschner wirefixation of open or unstable forearm fractures in children. J PediatrOrthop.; Vol 19; No3; 1999: 329 – 337

[20] S Vainionpaa, O Bostman, H Patiala, P Rokkanen. Internal fixation of forearm fractures in children. ActaOrthopScand; Vol 58; 1987: 121- 123

[21] AB Nielsen, O Simonsen. Displaced forearm fractures in children treated with AO plates. Injury Int J Care Injured; Vol 15; 1984: 393 – 396

[22] S J Voto, D S Weiner, BLeighley. Use of pins and plasters in the treatment of unstable pediatric forearm fractures. J PediatrOrthop. 1990; Vol 10: 85 – 89

[23] P Lascombes, J Prevot, JN Ligier, JP Metaizeau, T Poncelet. Elastic stable intramedullary nailing in forearm shaft fractures in children: 85 cases. J PediatrOrthop. 1990;10:167-171

[24] J Patrick. A study of supination and pronation, with essential reference to the treatment of forearm fractures. J Bone Joint Surg1946;28:737-748

[25] Pediatrics Orthopedics: Core knowledge in Orthopedics. John P Dormans. 1stEdition.

[26] Textbook of fractures and dislocations, covering their pathology, diagnosis and treatment. 4th Edition, Speed Kellogg, 1942.

[27] J Pritchett. Growth and development of the distal radius and ulna. J PediatrOrthop. 1996;16(8):575-577

[28] S Lee, RO Nicoll, NS Scott. Intramedullary fixation of for pediatric unstable forearm fractures. ClinOrthopRelat Res 2002;402:245-250

[29] B Wrysch, GA Menciu, NE Green. Open reduction and internal fixation of Pediatric forearm fractures. J PediatrOrthop. 1996;16:644-650

[30] JM Flynn, JF Sarwark, PM Waters, DS Bae, LP Lenke. The operative management of pediatric fractures of the upper extremity. J Bone Joint Surg(Am)2002;84:2078-2098

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 1, 2021, Pages. 2392 - 2410
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[31] D Vittas, E Larsen, S Trop-Pedersen. Angular remodeling of mid shaft forearm fractures in children. ClinOrthopRelat Res 1991;265:261-264

[32] WL Vander Reis, NY Otsuka, P Moroz, J Mah. Intramedullary nailing versus plate fixation for unstable forearm fractures in children. J PediatrOrthop. 1998;18(1):9-13

[33] CT Price, DS Scott, ME Kurzner. Malunited forearm fractures in children. J PediatrOrthop. 1990;10:705-712

[34] J Prevot, P Lascombes, JM Guichet. Elastic stable intramedullary nailing of forearm fractures in children and adolescents. Orthop Trans.1995

[35] WP Blount. Osteoclasis for supination deformity in children.. J Bone Joint Surg (Am);1940;22:300-314

[36] HG Dietz, PP Schittenbecher, T Slongo, KE Wilkins. AO manual of fracture management. Elastic Stable Intramedullary Nailing in children.

[37] SJ Luhmann, JE Gordon, PL Shoenecker. Intramedullary fixation for unstable both bones forearm fractures in children. J PediatrOrthop. 1998;18(4):451-455

[38] M Blackburn, I Ziv, M Rang. Correction of malunited forearm factures. ClinOrthopRelat Res 1984;188:54-57

[39] PP Schmittenbecher. State of the art treatment of forearm shaft fractures. Injury Int J Care Injured, 2005;36:S-A25 – S-A34

[40] R Ortega, RT Loder, DS Louis. Open reduction and internal fixation of forearm fractures in children. J PediatrOrthop. 1996;16:651-654

[41] Y Amit, M Salai, AChechik, A Blankslein, H Horoszowski. Closed intramedullary nailing for the treatment of diaphyseal forearm fractures in adolescence – a prelimnary report. J PediatrOrthop. 1985;5:143-146

[42] AM Pankovitch. Flexible intramedullary nailing of long bone fractures. A review. Orthop Trauma. 1987;1:78-95

[43] WP Blount. Osteoclasis of upper extremity in children. Acta OrthopScand.1962;32:374

[44] Complications of intramedullary fixation of pediatric forearm fractures. J PediatrOrthop. 1998;18:14-21

[45] Flexible intramedullary nailing of displaced diaphyseal forearm fractures in children. Injury Int J Care Injured.2005;36:1221-1225

[46] D Richter, PAW Ostermann, AEkkernkamp, G Muhr, MP Hahn. Elastic intramedullary nailing: A minimally invasive concept in the treatment of unstable forearm fractures in children. J PediatrOrthop. 1998;18(4):457-461

[47] JS Daruwalla . A study of radioulnar movements following fractures of the forearm in children. ClinOrthopRelat Res 1979;139:114-120