Evaluation of the functional results of intramedullary nailing in diaphyseal both bone forearm fractures in children

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Abstract
Purpose: To evaluate the functional results of intramedullary nailing in diaphyseal both bone forearm fractures in children.

Patients and Methods: 40 patients (30 males and 10 females) with an age group of 8-14 years were included in the study. Displaced diaphyseal fractures, fractures with loss of reduction (within first week) in casting, segmental fractures, and open fractures (Gustilo & Anderson type 1 & 2) were considered for intramedullary fixation. The fractures were reduced percutaneously by manipulating the fracture fragments & were stabilised by 2-2.5 mm flexible titanium intramedullary nails. Retrograde nailing of radius was done from the dorsal entrance site. Antegraded nailing of ulna was done from the lateral cortex of the olecranon. Patients were followed at two weeks, four weeks, six weeks, eight weeks and then at monthly intervals up to 9 months. Final follow up was done at 9 months and results were assessed clinically using Daruwalla criteria with restoration of forearm rotation.

Results: In 31 (77.5%) cases, closed reduction and nailing was achieved using 2 to 2.5 mm flexible titanium nails while in 9 (22.5%) cases open reduction through limited incisions was done. In all patients fracture was united at an average of 8.1 weeks. In all patients, removal of implant was done at 6 months. Excellent results were in seen 38 (95%) patients & good results in 02 (5%) patients using Daruwalla criteria with restoration of forearm rotation. The complication reported were bursa formation in 7 (17.5%) patients, symptomatic prominent hardware in 5 (12.5%) patients, superficial radial nerve injury in 1 patient, wound related problems in 3 patients & refracture in 1 patient.

Conclusion: Elastic intramedullary nailing is a safe and reliable method for internal fixation of displaced diaphyseal unstable forearm fractures with good to excellent functional results.

Keywords: Diaphyseal forearm fractures, Intramedullary nailing, children

Introduction
Both bone diaphyseal forearm fractures are common injuries in children. Management of these injuries depends on various features including age of the child, angulation/translation of the fracture, type of the fracture and stability of the reduction. The majority of the forearm fractures can be treated with cast immobilisation because of the strong periosteum and remodelling potential [1-2]. Relative indications of surgery for these fractures in children include open injury, floating elbows, instability after reduction, and irreducibility (by closed means) [3-5].

Currently, intramedullary (IM) nails, K-wires, and plates are used for surgical treatment of pediatric forearm fractures [6-8]. Elastic stable intramedullary nailing (ESIN) has become common in the treatment of children’s long bone shaft fractures [9] and has been shown to produce excellent outcomes [10-11]. Flexible titanium nails are physis sparing because they are introduced through the metaphysis avoiding the physis.

Patients and Methods
This study was a prospective study conducted at Government Hospital for Bone and Joint Surgery, Srinagar from September 2016 to September 2018, after approval of the institutional board.
Patient Selection
The study included 40 paediatric patients: 30 males and 10 females, aged between 8-14 years. Informed consent was obtained from the parents/guardians of all the cases.

Inclusion Criteria
1. Age group: 8-14 years of either sex.
2. Displaced Diaphyseal fractures.
3. Fractures with loss of reduction (within first week) in casting.
4. Segmental fractures.
5. Open fractures (Gustilo & Anderson type 1 & 2).

Exclusion Criteria
1. Age < 8 & > 14 years.
2. Undisplaced diaphyseal fractures.
3. Open fractures, Gustilo & Anderson type 3.
4. Comminuted fractures.
5. More than one week old fractures.
6. Associated neurovascular injury.

Surgical Technique
The operation was performed under general anesthesia. Blunt ended titanium elastic nails of diameter 2.0-2.5 mm were used in all the cases. After administering general anaesthesia, elbow, arm and forearm were cleaned with antiseptic solution and painted with 10% betadine solution and draped in standard manner. Closed reduction was attempted in all patients under C-arm guidance & intramedullary nailing was done. The radius was first reduced & stabilised with intramedullary nail followed by reduction of ulna & its stabilisation with intramedullary nail.

Nailing Approaches
1. Radius: Retrograde from the dorsal (Lister’s tubercle) entrance site. A 2 – 3 cm longitudinal incision was made over the palpable dorsal Lister’s tubercle of the radius. Next the subcutaneous tissue was spread and the fascia was incised to expose the tubercle. After retracting the tendons, the awl was placed directly just proximal to the tubercle between second & third extensor tendon compartments approximately 1-2 cm proximal to the physis (physis sparing). Care was taken to avoid injury to the tendons. The awl was directed anteromedially as it is drilled to perforate the posterior cortex. While introducing the awl it was ensured that the opposite cortex was not breached. The nail was introduced using T-handle and advanced to the fracture site by gentle oscillating movements.

2. Ulna: Antegrade from the lateral cortex of the olecranon (Proximal lateral/Anconeus ulnar entry):
The skin was incised 1.5 to 2 cm longitudinally over the proximal lateral aspect of the olecranon, approximately 3 cm distal to the apophysis. The lateral cortex of the olecranon was perforated with the awl directed obliquely in a distal direction, 3 cm distal to olecranon apophysis & just anterior to the posterior border or about 4 mm lateral to the posterior crest (physis sparing). The nail was inserted using T-handle and advanced distally to the fracture site by gentle oscillating movements.
Since it is more often difficult to reduce radius, it was reduced first. Attempt to bring the fracture planes in contact indirectly by percutaneously manipulating the fracture fragments was first done under C-arm guidance & fracture stabilisation was achieved by completing the intramedullary nailing using 2-2.5 mm flexible titanium nail. After successful radial fracture reduction & stabilisation, ulna was reduced indirectly by percutaneously manipulating the fracture fragments & fracture stabilisation was achieved by completing the intramedullary nailing using 2-2.5 mm flexible titanium nail.

The fractures where closed reduction was not achievable after 2-3 closed reduction attempts or following a 10 minute rule of closed reduction maneuvers, a limited incision approximately 2-3 cms in length was given directly over the fracture sites for both radius & ulna and an open reduction was done after proper soft tissue dissection followed by fracture stabilisation by intramedullary nailing using 2-2.5 mm flexible titanium nails.

The nails were bend, cut and their ends were placed deep in the subcutaneous tissue. Before cutting, the nail was withdrawn by 1 to 2 cms, bent such that the distal end lies flush with the bone and re-impacted into the bone. The incisions were then closed with single sutures.

Post-Operative Period: A long arm posterior plaster slab was given in all the patients and the forearm was immobilised for a period of 4 weeks. Patients were followed-up at two weeks, four weeks, six weeks, eight weeks and then monthly with a final follow up at 9 months postoperatively. Removal of implant was done under local anaesthesia or under general anaesthesia after complete bony union.

Results

| Table 1: Type of Fracture |
|--------------------------|
| Fracture Type       | No of cases | Percentage |
| Closed              | 36          | 90         |
| Open Type 1         | 04          | 10         |
| Open Type 2         | 0           | 0          |

| Table 2: Fracture Location |
|-----------------------------|
| Fracture location | No. of patients | Percentage |
| Proximal 1/3rd      | 05             | 12.5       |
| Middle 1/3rd        | 20             | 50         |
| Distal 1/3rd        | 15             | 37.5       |

| Table 3: Fracture Pattern |
|---------------------------|
| Fracture Pattern | No. of patients | Percentage |
| Transverse          | 29             | 72.5       |
| Oblique             | 11             | 27.5       |
| Comminuted          | 0              | 0          |
| Segmental           | 0              | 0          |

| Table 4: Show time since injury percentage |
|-------------------------------------------|
| Time since injury | No of cases | Percentage |
| < 24 hours        | 23          | 57.5       |
| 24 - 48 hours     | 09          | 22.5       |
| 2 - 6 days        | 08          | 20         |

Surgical Time: In our study, the average surgical time was 39.7 minutes with majority of cases done within 30-40 minutes.
In majority (77.5%) of cases fracture reduction was achieved by closed means while 22.5% of the patients needed open reduction through limited incisions.

The average union time was 8.1 weeks with a range of 6-12 weeks. In all patients fracture was united. There was no delayed union or non-union in our study.

Removal of implant was done in all cases at 6 months postoperatively. In 33 (82.5%) cases, removal of implant was done under local anaesthesia and in 07 (17.5%) cases, it was done under general anaesthesia.

In 95% of patients in our study, there was no or negligible limitation of forearm rotations & in 5% of cases limitation of rotations was less than 20. In our case series of 40 patients, we had excellent results in 95% of the cases & good results in 5% of the cases. There were no fair or poor results in our study.

### Table 5: The surgical time and percentage

| Surgical time     | No. of cases | Percentage |
|-------------------|--------------|------------|
| 30-40 minutes     | 26           | 65         |
| 41-50 minutes     | 10           | 25         |
| 51-60 minutes     | 04           | 10         |

### Table 6: Final Results Using Daruwalla’s Scoring System

| Clinical definition | Grade   | No. of Cases | Percentage |
|---------------------|---------|--------------|------------|
| Movements equal on both sides | Excellent | 38          | 95%        |
| < 20° of limited rotation on injured side | Good     | 02          | 05%        |
| 20-40° of limited rotation on injured side | Fair     | 0           | 0          |
| > 40° of limited rotation on injured side | Poor     | 0           | 0          |

### Chart 1: Range of alteration of forearm rotation

**Fig 6:** A 13-year-old male with proximal third both bone complete forearm fracture. A: AP and lateral injury radiographs. B: Immediate postoperative radiographs. C: 6-month follow-up radiographs. 9-month follow-up radiograph (Implant removed). D: Pronation. E: Supination.
Discussion
Both bone forearm diaphyseal fractures are increasingly being treated by operative methods. Operative treatment was performed in 13.3% of cases in 2000–2001 and 52.7% in 2008–2009. Non-operative treatment decreased from 87% to 47% in the same time period (P=0.015) [14]. The increase in operation activity was mostly due to the increasing incidence of elastic stable intramedullary nailing: it increased from 10% in 1998–2000 to 30% in 2007–2009 (P=0.043) [14]. There is a growing trend towards flexible or titanium elastic intramedullary nailing for fixation of forearm fractures in children [11, 15, 16]. This surgery offers stable fixation without disturbance of the periosteal blood supply or removal of the hematoma, which contributes to fracture healing. This method also allows for micromotion to stimulate the callus to bridge the fracture gaps. Intramedullary nailing of forearm bone fractures in children offers an alternative form of stable fixation with few reported complications [17-19].

Most forearm shaft fractures continue to be successfully treated with closed methods. Our indications for surgical treatment of these injuries were displaced unstable diaphyseal forearm fractures, including the segmental and open fractures (Gustilo & Anderson type 1 & 2) and fractures with loss of reduction in the first week of casting. Currently, intramedullary fixation of children’s forearm fractures is preferred over plate fixation because of reduced soft tissue disruption.

In our study, the percentage of open fractures was 10%. The low percentage of open fractures in children was because the mode of injury was of moderate severity in the majority of patients including fall while playing. The study included only 30% of the cases with fall from significant height or due to RTA.

In 22.5% cases, closed reduction was not achieved after three attempts or after a ‘10 minute rule’ of closed reduction maneuvers. The cases required open reduction through a small (2-3cm) incisions directly at the fracture level. All these patients had soft tissue interposed between the fracture ends making the fracture irreducible through closed means.

In our study, the period of immobilisation was 4 weeks. The postoperative immobilisation was used as an adjunct to the osteosynthesis till callus formation & to prevent secondary displacement & refracture. Lascombes et al. [11] reported secondary displacement of the fracture in 5% of the patients when post-operative immobilisation was not used.

The union time in our study was 6-12 weeks with an average union time of 8.1 weeks. In all patients fracture was united. There was no delayed union or non-union in our study. The removal of implant was done at 6 months post-operatively. The implant was removed late to prevent risk of refracture as has been reported in the literature with early implant removal. Lascombes et al. [11] in their series of eighty-five forearm fractures treated with ESIN, the nails were removed at 4.25 months after the initial surgery. Lascombes et al. [11] in their series of eighty-five forearm fractures treated with ESIN, the nails were removed at 4.25 months after the initial surgery. Similarly, Gorter et al. [13] reported forearm refractures in patients who had elastic nails removed between two and four months after injury. Also there was low risk of infection as the implant was buried subcutaneously.

- **Fig 7:** 11-year-old male with proximal third both bone complete forearm fracture. A: AP and lateral injury radiographs. B: Immediate postoperative radiographs. C: 6-month follow-up radiographs. 9-month follow-up radiograph (Implant removed). D: Pronation. E: Supination.
Complications
Bursa formation was the most common complication seen in our study group. Bursa formation was seen in 7 (17.5%) cases. Prominent exposed nail end & hypertrophic scar formation was seen in 3 cases each. Two patients had symptomatic prominent nail irritation & one patient had superficial infection where nail end was exposed outside the skin. One patient had decreased sensations over dorsal radial nerve distribution. One patient had a refracture during the study & 2 patients had decreased forearm rotations.

| Table 7: Complications |
|------------------------|
| Bursa formation over hardware prominence | 07 | 17.5 |
| Prominent exposed nail end | 03 | 7.5 |
| Hypertrophic scar (minimally open) | 03 | 7.5 |
| Limitation of forearm Rotation | 02 | 5 |
| Infection at hardware entry site | 01 | 2.5 |
| Injury to dorsal cutaneous branch of radial nerve | 01 | 2.5 |
| Refracture | 01 | 2.5 |
| Prominent irritating nail end | 02 | 5 |

Conclusion
Elastic intramedullary nailing is a safe and reliable method for internal fixation of displaced diaphyseal unstable forearm fractures with good to excellent functional results.

Conflicts of Interest: None.

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