



IF NEEDED TO BE SURGICALLY INTERVENED UPON, IN THE PAEDIATRIC DIAPHYSEAL FRACTURES, WHICH IS THE BETTER AMONG THE AVAILABLE FIXATION DEVICES-A CASE SERIES CONSIDERATION.

Orthopaedics

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ABSTRACT

Humeral fractures, in the paediatric age group, have two peaks of incidence. It has a high incidence in babies below three years of age, and again also in children, above 10 years of age. The objective of our study, was to compare the most popular operative techniques for handling humeral diaphyseal fractures, in the paediatric age group, such as Plate Osteosynthesis (Locking Compression Plate), Elastic Stable Intramedullary Nailing System (ESIS), and the External Fixation devices (EF). This prospective study was conducted at Chettinad Hospital and Research Institute (CH&RI), Kelambakkam, from July 2017 to June 2020. A total of 15 patients were a part of this study, of which, 8 were males and 7 were females. The functional outcomes were assessed using the DASH, the Borberg and Morrey scoring system and the radiographic assessment was done using Stan's Radiographic Grading system, in all the three methods of treatment.

The Follow up period was for a minimum of twelve months. The Broberg and Morrey Score points were 88.4 (74-95) for LCP, 80.67 for ESIS (70-91) and 83.87 (80-87) for EF (p value>0.05). In the DASH score, the average was 19.2 in the LCP group, 21.17 and 21.10, respectively, in the ESIS and EF groups. Stan's Radiographic Grading showed Grade 2 to 3 fracture union status, in all the fixation modalities of our study. The prudence of the surgeon, his surgical experience, the age of the patient, the geometry of the fracture and the nature of the humeral diaphyseal fracture, all needs to be carefully weighed, analyzed and on a case-to-case basis, the decision has to be taken, regarding which fixation device is best suited for that very particular fracture. All the three modalities have been showcased to highlight their pros and cons, not with-standing the fact that, all the three modalities have fared superiorly in giving good to excellent result outcomes.

KEYWORDS

Humeral diaphyseal fracture, plate osteosynthesis, ESIS, External fixator, DASH, Borberg and Morrey scoring, Stan's radiographic score.

1. INTRODUCTION:

In paediatric long bone fractures, those involving shaft of humerus are relatively rare, amounting to less than 10% of all the humeral fractures. Humeral fractures are around 1-3% of fractures encountered, in the paediatric age group (1). Humeral fractures, in the paediatric age group, have two peaks of incidence. It has a high incidence in babies who are below three years, and also another high, in children who are above 10 years (2). Conservative management of shaft of the humerus fracture, in the paediatric age group, is the most often followed treatment modality, due to the nature of the humerus being a non-weight-bearing bone, and its ability to excellently remodel (3). The limb length discrepancy in the upper appendicular skeleton, does not pose any great functional challenge to the upper limb functionality.

In the younger children and babies the ability for the fracture callus to remodel is extremely high. In the older children however, the ability to remodel is diminished and the displacement of fracture fragment is usually more and hence surgical treatment is a preferred method of treatment (4). There are many a surgical techniques, for the surgical intervention for the diaphyseal shaft of the humerus fracture; in the older children options include K wire fixation, Plate Osteosynthesis, Elastic Stable Intra-medullary Nailing System (ESIS) and External Fixator (5). Fixation internally, after obtaining reduction surgically has shown to have improved, the outcome of surgical management, in the paediatric age groups.

The most widely used methods are Plate Osteosynthesis (Locking Compression Plate) (6), Elastic Stable Intramedullary Nailing System (ESIS), and the External Fixation devices (EF) (7). Each procedure, have their own merits and demerits depending upon their different biomechanical properties and physiological aspects (5). There are a number of clinical studies, which have helped the orthopaedic

surgeons in selecting the most appropriate management in treating humeral shaft fracture, in the paediatric age group. There is however, no evidence based study, to highlight the superiority of one system of management, over the other.

This study was performed with an objective to study, the most popular operative techniques for handling humeral shaft fractures, in the paediatric age group, such as Plate Osteosynthesis (Locking Compression Plate) (6), Elastic Stable Intramedullary Nailing System (ESIS), and the external fixation devices (EF). The study compares the clinical outcomes as assessed by DASH, Borberg and Morrey scoring, the length of stay, complication rates, Stan's Radiographic Grading and the incidence of non-union/ mal-union, in all the three methods of treatment, in the paediatric age group.

2. MATERIALS AND METHODS:

The study included all the humeral diaphyseal fractures in the paediatric age group, from July 2017 and June 2020. A total of 15 patients were a part of the present study. Of these, 8 were male and 7 were female. All the cases were followed up for a minimum period of twelve months (1 year). Thus the recruitment was for a period of 2 years and the study, spread over a period of 3 years, to ensure the minimum one year Follow-up period.

7 children had a right sided humeral shaft fracture and 8 children had a left sided humeral fracture. The inclusion criteria, included humeral shaft fractures, without articular involvement treated within 48 hours, post-injury in the paediatric age group. The study excluded injuries associated with nerve palsy, children less than three years, and those over 15 years, fractures resulting from congenital or metabolic disorders, patients with multiple limb fractures, pathologic fractures, and patients treated after 48 hours post-injury. Out of the 15 patients, 5 were managed with Elastic stable intramedullary nailing system

(ESIS), 5 with plate osteosynthesis (LCP), and the remaining 5 with external fixation devices (EF). The patients' ages ranged from 6 years to 13 years of age (mean 8.7, median 10). Table 1, depicts the above details in a compact and cohesive manner as thus graph 1.

Table 1: The summary of significant characteristics of all three groups:

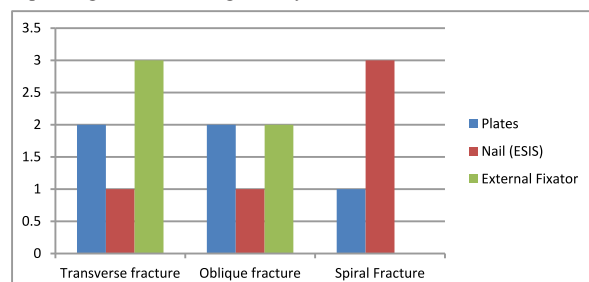
S NO	PARAMETERS	PLATE (LCP)	NAIL (ESIS)	EXTERNAL FIXATOR
1	AVERAGE AGE (in years)	8	10.2	10.4
2	SEX-M:F	3:2	2:3	3:2
3	SIDE R:L	3:2	1:4	3:2
4	TRANSVERSE FRACTURE TYPE	2	1	3
5	OBLIQUE FRACTURE TYPE	2	1	2
6	SPIRAL FRACTURE TYPE	1	3	0

Pre-operative evaluation of all patients was done, with standard views of orthopaedic radiographs, and routine haematological evaluation. In 5 patients, Brachial plexus Block with IV sedation was administered, and in 10 patient's General Anesthesia was given. One dose of Cefazolin 1g IV was used as a pre-operative antibiotic prophylaxis, after test dose. Patients allergic to beta-lactam were administered clindamycin 600 mg IV. Patient was positioned in the beach chair position in a radio-lucent operating table. Standard operative protocol was followed for each specified surgical technique.

Fracture reduction and alignment, implant position, and iatrogenic complications were determined using appropriate post-operative radiograph. The X-ray and clinical follow-up was methodologically done at the end of 15, 30, 90 and 180 days. Later on the patient was followed up once in 6 months. Functional outcome was assessed with DASH scoring system (8), Borberg and Morrey scoring protocol and radiological assessment was done with Stan's radiographic score at the elapsed time from surgery being 1 year.

Radiographic evaluations of all patients were performed with standard orthogonal projections of the humerus shaft at 30 days, 60 days, 180 days and at 12 months. Stan's radiographic grading was done by the 4 months and the data were tabulated and analyzed (9). The radiographic evaluation was done until solid radiological fracture union was noted (usually 9 months). The complication rates of the individual surgical procedures were also enumerated and compared with those mentioned in literature. Patients were followed up during the post-operative period for complications like pain, infection, discharge, restriction of movements of both elbow and shoulder joint and for any neurovascular incompetency.

Graph 1: Graphical representation of surgical modalities undertaken for the treatment of Paediatric diaphyseal humeral fractures, depending on the fracture geometry:



Post-operative protocols were followed with an arm sling support, for 3-5 days, which was then followed up by active and active-assisted ROM exercises, of both the elbows and the shoulder from POD 5 after surgery. Patient was encouraged, to use his uninjured healthy upper limb to assist in regaining ROM by, passive movement of the injured and the operated limb. Thus, no force was deployed by any therapist as it was always a case of self-assisted passive mobilization.

For the plating group, the locking compression plate was used. Antero-lateral approach, centering the fracture, was the approach used to access the fracture site. If feasible, lag screws and a neutralization plate

were used. When the extension of the cortical continuity breach was very distal, the radial nerve was safely isolated and kept out of danger. Appropriate plates of adequate lengths were used, so that, at least three screws were proximal and another three screws distal, to the fracture site. Lagging of the fracture fragments were done, if the fracture geometry demanded so.

In the nailing group, ESIS nailing was used in a retrograde fashion. For the ESIS nailing group: The surgical incision was performed on either side, just above the physal line and two ESIS nails of appropriate sizes were pushed in simultaneously.

In the External fixator group: The 5 patients, after manual reduction under image intensifier, first, the distal fragment was secured with pins ideally spaced, and in safe anatomic corridor, this was followed by insertion of the proximal pins through a set of mini-incisions of the skin, and trans-deltoid. Pins were connected to a rod each, which were then aligned to provide for good fracture reduction. The rods were connected with a cross bar, for the sake of additional stability. Sometimes, ring fixator was also used, in case of highly comminuted fractures.

The statistical data was then compiled. Continuous progressive outcomes were compared with the T-test. The categorical variables were compiled with the square of chi test. The statistical significance was attributed to when the p value was <0.05.

3. RESULTS:

The minimum follow-up was 12 months (range: 12 to 35 months, mean 18.5 months) and the final compilation and analysis of data was done, at this point in time. In all groups, removal of suture was done on POD 12. The average surgery duration (skin to skin) was 42 minutes for the LCP, 38 minutes for the ESIS nail, and 33 minutes, for the EX-FIX. Among nailing, plating, External Fixation device application, the time taken for "External Fixation" procedure was considerably less and was also statistically significant with a p value <0.05.

The hospital stay did not show any statistically significant differences among the three groups; In fact, all the patients were discharged between the 5th and the 7th post-operative day (on average 6.2). The Broberg and Morrey Score points were 88.4 (74-95) for LCP, 80.67 for ESIS (70-91) and 83.87 (80-87) for EF (p value>0.05). Regarding complications, for ESIS there was a single case of delayed union, for plating group there was a single case of superficial wound infection that was treated by immediate wound debridement, with the implant being preserved, and in the EX-FIX group there was a single case of pin tract infection, which needed a pin exchange. Regarding the DASH score, the average was 19.2 in the LCP group, 21.17 and 21.10, respectively, in the ESIS and EF groups (with no statistically significant difference).

In the EF group, the fixator was removed on an average after 6 weeks and all fractures were studied for radiological union using Stan's Radiographic Grading which showed grade 2-3 fracture union in all the subgroups. There were no cases of deep infections in all the three groups. Only the EF group had a single case of secretions at the pin tract site, which resolved with oral antibiotic therapy using amoxicillin 1 g/day for 7 days and a pin exchange.



Fig 1 – a) Pre-Op X-ray showing humeral diaphyseal fracture,

b) Post-Op X-ray after Plate Osteosynthesis for Humeral diaphyseal fracture.



Fig 2 – a) Pre-Op X-ray of Right side humeral diaphyseal fracture

b) Post-Op X-ray of Dual retrograde ESIS nailing.

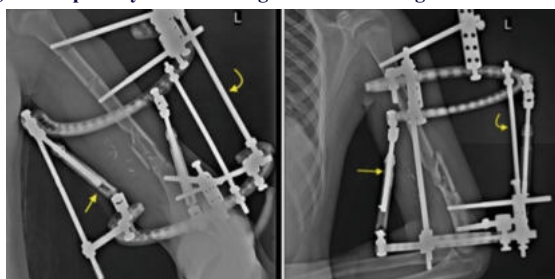


Fig 3 – Post Op X-ray of External Fixator application for a comminuted humeral diaphyseal fracture.

4. DISCUSSION:

The treatment for shaft of humerus fractures in the paediatric age group is always a controversy (10). Low energy trauma causing fracture of diaphysis of humerus in children can be managed with conservative methods (10).

Operative techniques are by far the first choice of management in open fractures, fractures with nerve impalement, in case of multiple fractures, patients with increased BMI, fracture line extending into articular surface, failed conservative management (11). Early mobilization, without any restriction of movements, is best achieved by operative techniques. There are numerous studies, that projects the disadvantages of the non-operative methods, in the management of fracture in the paediatric population with complications such as non-union, particularly in more displaced fracture patterns, loss of reduction when compared to surgical treatment (12). Since, humeral bone, is not a weight bearing bone conservative management can be opted. Humerus is a very forgiving bone, with an acceptable deformity of 30° varus, 20° procurvatum and upto 4 cm of shortening, since it is not a weight bearing bone.

Long back, it was Sarmiento et al; who commented that anatomical reduction is not always the prime concern (10). Complications of non-operative treatments are loss of range of motion in external rotation, flexion, and abduction in around 30 % of cases. It also causes decrease in the sagittal plane movement in about 10 % of children treated non-operatively (13). Surgical techniques used to treat humeral diaphyseal fractures, in the paediatric age group are Plate Osteo-synthesis, Elastic Intramedullary TENS and External Fixator application.

The advantages of plate osteo-synthesis, are its ability to restore the near normal anatomy of the fracture bone, inter-fragmentary compression of the fracture and better exposure thus protecting the radial nerve (11). There are numerous studies that emphasizes on stable elastic intra-medullary nailing in the paediatric age group it continuous to remains the preferred technique in management of the fractures of the humeral shaft (14). The disadvantage of the procedure is extensive surgical dissections, along with soft tissue damage and the radial nerve injury (11). Moreover, there will be residual scars and loss of fracture hematoma since the procedure requires opening up of at fracture site, which are considered as the disadvantages of this technique (15). The most advanced plates such as LC-DCP (limited contact DCP) which gives better results to previously used plates and may also be done using minimally invasive procedure (16). Plate osteosynthesis also results in a higher blood loss and a relatively longer surgical duration.

Stable Elastic Intramedullary Nails has been used widely in recent years since they work on principle of load-sharing properties and also have a better aesthetic result in view of their smaller incisions. They also preserve the biology of the fracture in paediatric age group. Robinson et al; commented that the Load-sharing properties of ESIN are extremely useful in paediatric population and hence are widely used in recent times (17). As per literature, ESIN had a high rate of re-surgery, due to technical mal-functions that resulted in high rate of non-union (15) (18), or else required the fracture site to be opened up and the nail re-negotiated. These problems have been largely overcome by getting reduction by a temporary external – distracter device in-situ for nail negotiation.

There are complications such as shoulder joint stiffness at the entry sector of the nail, impalement and impingement symptoms in Stable Elastic IM nail, which are described in numerous studies (18). Irreversible damage of the muscles of rotator cuff due to entry of nail through it leads to restriction of movements of the shoulder joint, which has been a topic of controversy in the past years. Rotator cuff muscles in the paediatric age group are relatively more fragile, careful insertion of nail avoiding its damage has improved the success rate of this technique (19).

Further refinement in the surgical treatment by retrograde nailing as described by Lefevre, Gordon, Garg and Kapil Mani et al, have settled this issue for good. The article by Kapil Mani even settles issues related to ulnar nerve injuries, by using a single TENS nail.

O'Donnell et al, in a group of 33 children who underwent, Elastic Stable Intramedullary nail, had complication rate of 63.6% which included 39% of sub-acromial bursitis, 15% of partial rotator cuff tear and supraspinatus tear. These complications due to nailing are greatly reduced due to introduction of transversal approach to rotator cuff tendons and their repair after ESIN (20). Newer studies show that the fracture union rates in ESIS (Elastic Stable Intramedullary nailing) in the paediatric age group is same as that of in plate osteosynthesis (20).

Incidence of non-union post fixation is markedly reduced when during surgery proper techniques of fixations are used and when fracture gaps are avoided (21). ESIS in the pediatric age group have shown to have good results in recent times due to advanced surgical methodologies and the better design of the implant. In comparison to the past used instruments(nails) the present nails are rather broad, more rigid and gives dynamic compression at the site of fracture (19) (20).

In order to achieve angular stability, ESIN has numerous multi directional fixation points both distally and proximally (22). Hardly few studies in literature have emphasized the use of EX-FIX for shaft of humeral fracture in paediatric age group. Children with multiple fractures, with lacerated wounds, open fractures, are the main indicators for the use of external fixator (23). EX-FIX is used for their ease of application, a quicker reduction, with more instant stability at the fracture site.

This contemporary technique is a minimally invasive procedure when compared to other procedures; it maintains fracture biology and avoids rotator cuff injury. EX-FIX is preferred over other methods for the above-mentioned indicators, because it provides for a better stability, which allows good healing of the fracture. Radial nerve injury upon pin insertion remains the main limitation for the use of EX-FIX in paediatric age group, which, with ultrasound tracking intra-op of the nerve, with the help of a radiologist, negates the negativity.

PEARLS:

- Eighty percent of the humeral longitudinal growth is a contribution from the proximal humeral growth plate. In the yet immature, paediatric diaphyseal fracture patients, remodelling capacity is immaculate.
- Experts swear by the non-invasive management.
- Malunion is a concern, in those paediatric diaphyseal fractures occurring close to the age of fourteen.
- Since our study excluded fracture, underage of three Battered baby syndrome, did not figure in our pathophysiology.
- Copious callus is thrown at the fracture site, but surprisingly the remodelling is completed in less than a year, if the age be within seven years.
- Operative interventions are to be considered when we are dealing with a multiple skeletally injured paediatric patient, a bad fracture,

that is open, when the elbow is a floater, when shoulder accompanying injury complicates issues, when sag and coronal alignments are a concern and rotatory malalignment is a concern in mid-humeral diaphysis.

- Expect LLD in proximal diaphyseal fractures, but functionality of the UL may not be compromised, refrain from urge to re-intervene in case of delayed union, Sarmiento bracing or Ultrasound bone stimulation comes in handy, malunion up-to thirty degrees is forgiving, but for the ROM in the externally rotated arm, expect a LLD if diaphyseal fracture is too proximal, in mid third fracture expect about 5 percent of radial nerve palsy which should recover in 16 weeks, if not plan to explore (24).

5. CONCLUSION:

Sumeet Garg et al; reported in 2009, that almost all shaft of humerus fractures can be handled by conservative means. Filippino M Senes et al; had also advocated a conservative approach in 2012. By 2013 Justus Liber et al; brought in concept of ESIS and optimized the surgical techniques. Depending on the situation clinically various methods are adoptable. Study by M.A,O'Shaughnessy et al; in 2019 brought-out a starting survey that covered a 20 year study from 1996 to 2016 and concluded that humeral shaft fractures, when managed conservatively, did well in most situations and operative stabilization was needed in the best indicated situation and had a relatively low, better union rates. However, in the age group of 11 years and above in the grossly displaced and overriding fractures with comminution, fixation is to be validly considered, as it grossly improved radiological alignment and union rates. Nerve injury fears are foolish and recoverable. We conclude that prudence of the surgeon, his experience, the age of the patient and the geometry and nature of the humeral diaphyseal fractures, all are needed to be carefully weighed, and on a case-to-case basis, the decision has to be taken.

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