Original Article

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Orthopaedics Section

Functional and Radiological Outcome of Conservatively Managed Fracture of Radius and Ulna Forearm Bone in Paediatric Population- A Longitudinal Interventional Study

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ABSTRACT

Introduction: Fractures of the shaft of both bones of forearm are one of the most common fractures in the paediatric age group. There is often a difference of opinion regarding the management of these fractures. Though, there has been an increasing inclination towards surgical correction of these injuries, conservative management is still very popular because of the advantage of good bone remodelling potential in children. Loss of reduction is a known complication of conservative method of treatment. Assessment of the cast index can serve as a tool for the prediction of failure of the conservative management.

Aim: To analyse the functional and radiological outcomes of both radius and ulna forearm bones shaft fractures.

Materials and Methods: This longitudinal interventional study was conducted in the Department of Orthopaedic Surgery, at King George's Medical University, Lucknow, Uttar Pradesh, India. The duration of the study was one year 11 months, from June 2017 to May 2019. A total of 196 (156 males and 40 females) patients were included in the study, who presented with closed diaphyseal fractures of the radius and ulna, and were managed conservatively. The patients with acceptable reductions were followed-up at three weeks, six weeks, three months and six months. The functional and radiological parameters were assessed, analysed and the cast index was estimated at each follow-up visit. Chi-square test was performed on the numerical/frequency displays of the dichotomous variables. Student's t-test with a 95% confidence interval was performed to compare the means of the two groups.

Results: The changes in angulation for Anteroposterior (AP), as well as, lateral view of both radius and ulna were significant at each follow-up ($p<0.001$), but the fracture reduction was found acceptable as per protocol. The loss of reduction was seen equally in male and female patients, only on the left-side and only in the middle third of both bone forearm fracture, but no significant association was found between sex, laterality, site and loss of reduction. The final Range Of Motion (ROM) obtained at elbow, forearm and wrist were all in the functional range at six months follow-up. There were two cases of failure, both above 10 years of age having high cast index and greater angulation in ulna in the prereduction phase.

Conclusion: Conservative treatment remains the gold standard for management of paediatric bones forearm fractures with very good functional outcome. A high cast index can be used to predict failure of the conservative management.

Keywords: Cast index, Closed reduction, Diaphyseal fractures, Non operative treatment

INTRODUCTION

Paediatric forearm bone shaft fractures are amongst the most common fractures in children [1,2] and these fractures are known to be unstable [3]. Restoration of anatomic alignment and full recovery of pronation and supination are must for successful outcome of both-bone forearm shaft fractures results [4]. Though, closed reduction and casting has been a popular and preferred treatment method, there has been an increasing trend towards surgical intervention in these fractures [5]. Thomas EM et al., in 1975 and Kay S et al., in 1986, published their studies stating that, the failure of non operative treatment of mid-shaft fractures in paediatric populations ranges between 39% to 64% [6,7]. Daruwalla JS and Carey PJ et al., published that, around 60% of children have some residual loss of motion due to malunion of the fractures [8,9]. As the age increases the ability to remodel the bone decreases, thus, the outcomes of closed reduction and casting are less favourable with increasing age [10,11]. The fact that, the distal ends of both forearm bones are the more biologically active regions contributes to the less favourable outcomes in proximal fractures [12]. It can be beneficial to identify cases that are likely to respond poorly to conservative management since, these can be treated surgically thereby, preventing complications.

Recently, there has been an increasing trend towards surgical intervention by intramedullary nail or plate [5]. The complications of surgical interventions include infection, osteomyelitis, hardware migration, stiffness, scar mark, requirement of second surgery for implant removal. The outcomes of both surgical and conservative managements are comparable in these fractures [13]. Hence, the preferred treatment for paediatric forearm fractures remains closed reduction and casting. It is generally accepted that, closer the fracture is to the distal physis, the greater is its potential for remodelling [1]. Consequently, more deformity can be accepted in the distal one third of the diaphysis versus the middle and proximal thirds [4,14]. However, the exact amount of angulation displacement and rotation that is acceptable remains controversial in the literature [5,15].

Hence, the present study was conducted to evaluate the functional and radiological outcome of paediatric diaphyseal complete both radius and ulna bone forearm fractures managed conservatively and comment upon the utility of cast index as a predictor of failure of conservative management.

MATERIALS AND METHODS

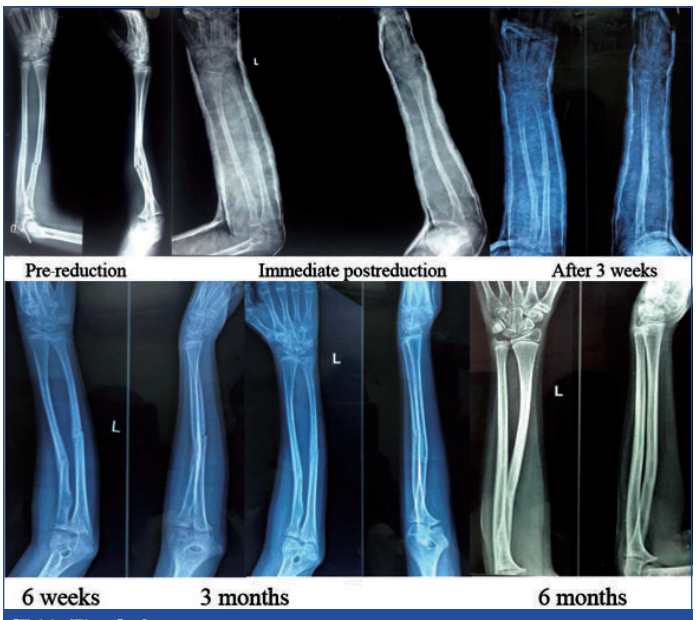
This longitudinal interventional study was conducted in the Department Of Orthopaedic Surgery, at King George's Medical University, Lucknow, Uttar Pradesh, India. The duration of the study was one year 11 months, from June 2017 to May 2019. Patients were admitted from the Outpatient Department (OPD) and informed consent was taken.

Inclusion criteria: Children aged between 4-16 years, with complete and closed diaphyseal fracture of both radius and ulna forearm bones, diagnosed radiologically and presented within one week after injury were included in the study.

Exclusion criteria: Children aged between 4-16 years with torus, greenstick fractures, compound fractures, pathological fractures, both bone forearm fractures with neurovascular deficit or compartment syndrome, Monteggia, Galeazzi fractures, fracture with intra-articular extensions and who presented after one week of injury were excluded from the study.

Study Procedure

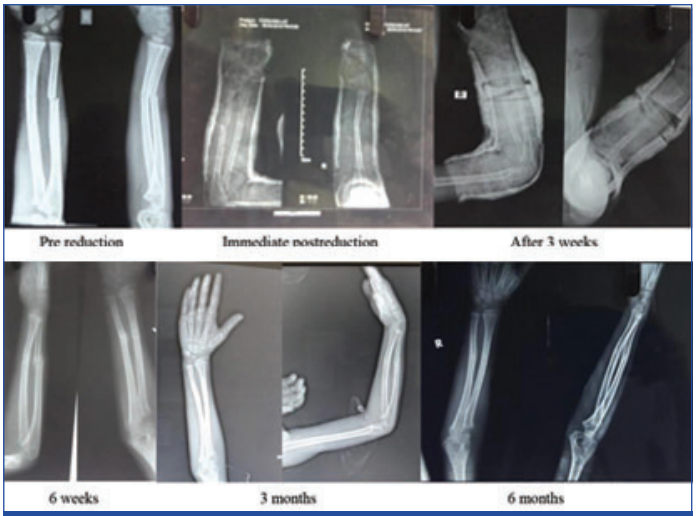
A total of 196 paediatric patients having fracture of both bone forearm diagnosed radiologically presenting at the emergency and outdoor units within the study duration, were enrolled in the study by convenience sampling. In the present study, demographic data (age, gender) were collected from all the study subjects. In all the patients, a standard closed reduction was done and above elbow Plaster Of Paris (POP) casts were applied with interosseous moulding, under general anaesthesia with a target cast index <0.8 at the level of fracture site, which was evaluated on postreduction and follow-up radiographs [16]. The cast was applied in supination for proximal one third diaphyseal fractures and in neutral position for middle and distal one third fractures. The postreduction radiographs were evaluated for acceptability of reduction, as per the following criteria based on the previous studies [Table/Fig-1,2] [17-21].



[Table/Fig-1]: Case 1.

- Angulation up to 10° for proximal third fractures, 15° for middle third and 20° for distal third fractures
- Less than 1 cm over-riding was accepted.

At 1st week postreduction, if position of fracture ends were acceptable, on both views of radiograph, as per the defined criteria, then only, patients were continued on conservative management, otherwise, the patients were labelled as 'failure of reduction'. Those with acceptable reduction were continued on conservative treatment



[Table/Fig-2]: Case 2.

and followed-up at three weeks, six weeks, three months and six months. At each follow-up, the patients were evaluated clinically and radiologically for angulation in AP and lateral radiographs, cast index (calculated by inner diameter of cast at fracture site on lateral view/inner diameter of cast at fracture site on AP view, normal=<0.8) [16] range of pronation, supination (after plaster removal), range of motion at elbow (after plaster removal). All the above parameters were noted, analysed and inferences were drawn during follow-up as per protocol. No additional physiotherapy was advised after six months except ROM exercises.

STATISTICAL ANALYSIS

The Statistical Package for Social Sciences (SPSS) (Inc., Chicago, Illinois, USA) for windows was used for the statistical analysis (26.0 version). The continuous variables were assessed by Mean±Standard Deviation (SD) or range value when essential. Chi-square analysis was performed on the numerical/frequency displays of the dichotomous variables. Student's t-test with a 95% confidence interval was performed to compare the means of the two groups. It was considered statistically significant when the p-value was <0.05 or 0.001.

RESULTS

Out of 196 subjects enrolled in the study, 156 were males and 40 were females. In present study, 101 were aged more than 10 years and 95 were less than 10 years of age, 27 patients were less than five years of age, while 68 were between five to 10 years of age. Of all the fractures in the study population the middle third diaphyseal fractures were the most common and were seen in 88 patients, followed by proximal third fractures (61 patients) and distal third diaphysis in remaining 47 patients. Slip on ground was the most common mode of trauma-seen in 147 patients followed by road traffic accidents. Other modes of trauma included fall from bicycle, fall from height, fall from stairs and being hit by a bicycle. Left-sided injury was more common, seen in 155 patients [Table/Fig-3]. A total of 182 patients showed acceptable range of angulation (AP and lateral view) of radius and ulna throughout the follow-up. Unacceptable loss of reduction was seen in 14 patients (in nine patients at 1st week and five at 3rd week). All these patients were managed by close reduction internal fixation by titanium elastic nailing. Postreduction mean angulation of radius and ulna in AP and lateral views increased significantly in follow-up till 6th week, and was followed by a slight decline. The change in angulation for both AP and lateral views of radius was significant at each follow-up, but this reduction was found acceptable as per the protocol [Table/Fig-4,5].

Parameters		n (%)
Age (in years)	<5	27 (13.8)
	5-10	68 (34.5)
	>10	101 (51.7)
Gender	Male	156 (79.3)
	Female	40 (20.7)
Site of fracture	Diaphyseal	88 (44.8)
	Proximal	61 (31.0)
	Distal	47 (24.1)
Side	Right	42 (20.7)
	Left	155 (79.3)
Mode of fracture	Slip on ground	147 (75.9)
	Road traffic accident	14 (7.14)
	Fall from bicycle	13 (6.63)
	Fall from height	12 (6.12)
	Hit by bicycle	10 (5.10)

[Table/Fig-3]: Age distribution of patients.
n: Number of patients; %: Percentage (N=196)

	AP view-radial	Comparison from postoperative		AP view-ulnar	Comparison from postoperative	
Angulation	Mean±SD	t-value	p-value	Mean±SD	t-value	p-value
Postoperative	4.79±1.63	-	-	4.62±1.74	-	-
Third week	6.61±1.73	-14.70	<0.001	6.50±1.77	-15.30	<0.001
Sixth week	7.22±0.85	-28.50	<0.001	7.07±0.87	-23.50	<0.001
Three months	7.15±0.82	-29.92	<0.001	6.96±0.81	-25.30	<0.001
Six months	6.56±0.58	-35.53	<0.001	6.44±0.58	-30.46	<0.001

[Table/Fig-4]: Assessment of angulation of radius and ulna (AP view) at fracture site.

	Lateral view-radial	Comparison from postoperative		Lateral view-ulnar	Comparison from postoperative	
Angulation	Mean±SD	t-value	p-value	Mean±SD	t-value	p-value
Postoperative	5.83±1.87	-	-	5.31±2.02	-	-
Third week	7.39±1.91	-8.86	<0.001	6.93±2.11	-9.41	<0.001
Sixth week	7.70±0.82	-12.43	<0.001	7.41±1.01	-17.38	<0.001
Three months	7.56±0.75	-14.56	<0.001	7.26±0.90	-19.51	<0.001
Six months	6.96±0.65	-20.43	<0.001	6.74±0.76	-25.1	<0.001

[Table/Fig-5]: Assessment of angulation radius and ulna (lateral view) at fracture site.
Statistical test used: Paired t-test

After cast removal, mean pronation/supination arc along with flexion/extension arc increased progressively in follow-up. There was improved angulation in both bones, in both planes as treatment progressed. The range of motion in both planes improved and became normal after cast removal thereby, giving a good functional outcome [Table/Fig-6,7]. Unacceptable loss of reduction in 14 cases (6.9%), nine at 1st week and five at 3rd week, all were more than 10 years of age. The mean cast index was 0.92 at postoperative, 0.94 at one week and 0.92 at three week and significant difference was found at each time of follow-up with p-value=0.019, 0.007 and 0.032 respectively [Table/Fig-8]. Loss of reduction was found only in patients with age >10 years. However, no significant association was found between the age and loss of reduction (p=0.367 using Chi-square test). The loss of reduction was seen equally in males and female patients, only on left-side and only in middle third of both bone forearm fracture, but no significant association was found between sex, laterality, site and loss of reduction. Failure of reduction was seen in two cases, and both cases had high mean pre reduction angulation.

	ROM	Compared with normal value (160°)		Compared from POP removal	
Follow-up	Mean±SD	t-value	p-value	t-value	p-value
At POP removal	62.0±8.59	-59.29	<0.001	-	-
Three months	110.19±7.00	-36.98	<0.001	-23.1	<0.001
Six months	116.96±5.70	-39.23	<0.001	-28.0	<0.001

[Table/Fig-6]: Pronation/supination arc at forearm.
ROM: Range of motion; POP: Plaster of paris

	ROM (elbow)	Compared with normal value (140°)		Compared from POP removal	
Follow-up	Mean±SD	t-value	p-value	t-value	p-value
At POP removal	104.81±4.90	-37.32	<0.001	-	-
Three months	117.22±4.24	-27.94	<0.001	-9.829	<0.001
Six months	119.26±3.43	-31.46	<0.001	-11.4	<0.001

[Table/Fig-7]: Flexion/extension arc at elbow joint.
ROM: Range of motion; POP: Plaster of paris

	No loss of reduction (n=182)	Loss of reduction (n=14)		
Cast index	Mean±SD	Mean±SD	t-value	p-value
Postoperative	0.80±0.07	0.92±0.08	-2.50	0.019
First week	0.84±0.05	0.94±0.07	-2.91	0.007
Third week	0.81±0.05	0.92±0.08	-2.26	0.032

[Table/Fig-8]: Association of loss of reduction with cast index.

DISCUSSION

The study included 196 subjects (156 males and 40 females). More number of males patients could be attributed to more outdoor activities. Right side involvement was seen in 41 (20.7%) patients whereas, 79.3% were left-sided. These findings in the present study were consistent with the study done by Hassan FO who conducted a prospective study and investigated the role of the dominant hand and gender in different types of forearm fractures in children and adolescents. He concluded that, non dominant side is more likely to be injured in right-handed and the dominant side in left-handed children. He also concluded that, forearm fractures occur more often in boys due to more outdoor activity. Findings in present study were similar to the study done by Hassan FO et al., [22]. The middle third diaphyseal fracture was most common and was seen in 88 (44.8%) patients, followed by proximal third and distal third in 61 (31%) and 47 (24.1%) respectively, which is consistent with the findings of the study conducted by Tarmuzi NA et al., [23]. Some recent studies like Cruz Jr AI et al., and Smith VA et al., have advocated operative treatment in cases, where satisfactory alignment is not achieved [5,13]. The decision to switch over to surgical management is difficult as the acceptability criteria of angulation are variable. Along with this, the significant remodelling potential and the improvement in functional ROM with time in cases managed conservatively, especially in the hands of experienced paediatric orthopaedic surgeons, add to the conflict of opinions among treating doctors. Franklin CC et al., stated that, successful treatment of paediatric forearm fractures should result in painless and complication-free outcomes with functional pronation/supination. It has been shown that, 15 to 20° of angulation in middle third forearm fractures can lead to major loss of forearm rotation [18,24].

In the present study, the angular deformity increased in radius and ulna in both views upto 6th week, which was statistically significant, and then there was a decrease in angulation at 3rd and 6th month of follow-up, which was also statistically significant. The mean angulation of radius at six months was 6.56° in AP view and 6.96° in lateral view whereas, in ulna it was 6.44° and 6.74° in AP

and lateral views, respectively. The present study's findings were consistent with those in the study done by Price CT et al., [18]. Price CT et al., achieved excellent results and accepted upto 15° of angulation in children less than eight years and 10° in more than eight years of age. These above findings were further supported by the studies of Hughston JC and Zionts LE et al., [11,25]. Hughston JC showed that, 10-year-old children with 30 to 40° of angulation had a good functional outcome [11]. The most common concern of the parents/caretaker was a cosmetic deformity however, the children were able to perform all the activities. A detailed counselling of the parents was done about the residual remodelling potential, the high probability of increased ROM and decrease in deformity with time and supervised physiotherapy. Daruwalla JS in his study, explained about the compensation by the shoulder in mild loss of pronation/supination [8]. In pronation loss the compensation is done by abduction and internal rotation of shoulder, whereas, adduction and external rotation is done at shoulder to compensate for the loss of supination. Therefore, even with the stringent criteria more than 85% cases have excellent functional outcome including cases with displaced fracture.

After POP removal mean pronation/supination arc at forearm showed progressive improvement at follow-up visit. The functional ROM supination and pronation is 50° each. Hence, none of the index cases had functional limitation of pronation/supination. Daruwalla JS, who reviewed 53 displaced forearm fractures in children found that, all the patients were asymptomatic and had no limitations in their activities even though 6% of them had lost more than 30° of forearm rotation [8]. This was further supported by Hughston JC described that, the patients who had an arc of 60° or less of pronation and supination, seemed to be unaware of their incapacity due to good compensation by shoulder motion [11]. At POP removal, mean flexion/extension arc at elbow joint was 104.81±4.90° degree which was found to increase progressively in follow-up. At POP removal, mean flexion/extension arc at wrist joint was 52.04±8.69°, which increased to 95.74±11.91° at three months follow-up and increased to 100.48±9.47° at six months follow-up visit. It was seen that, improvement in ROM at elbow and wrist was more between POP removal and at three months follow-up visit. Patients in the present study attained the functional ROM at both, elbow and wrist joints, and the patients were able to do all the activities of daily living with ease.

The authors observed loss of reduction in 14 cases (6.9%), nine at 1st week and five at 3rd week, all patients were more than 10 years of age. This finding was consistent with the findings of Kay S et al., [7]. It was found that, in case of loss of reduction the mean pre-reduction angulation was high for all the four types of angulation. However, the significant difference was found only for AP view ulna (p=0.038). In both the cases, the cast index was relatively high postreduction, at 1st week and 3rd week. Amongst these the mean cast index was 0.92 at immediate postreduction, 0.94 at one week and 0.92 at three week and significant difference was found at each time of follow-up with p-value=0.019, 0.007 and 0.032, respectively. Cast index should be below 0.7 to 0.8, a ratio above this range has been associated with significant increase in loss of reduction [16]. Study done by Caruso G et al., showed that, conservative management is a safe and successful treatment option in forearm fractures. Open reduction is recommended when an acceptable reduction cannot be obtained with casting [26].

Limitation(s)

Limitation of the current study was a short period of follow-up and a small sample size.

CONCLUSION(S)

Treatment of paediatric diaphyseal completes both bone forearms fractures gives very good results, thus, these fractures can be treated safely and effectively with conservative therapy. The possibility for remodelling results in great functional ROM. Loss of reduction in children under the age of 10, does not entirely depend on preoperative angulation, but in children over 10, must be assessed with caution, especially in cases where preoperative angulation is larger, because the likelihood of loss of reduction is higher in such cases. It is helpful to monitor patients with the aid of the cast index in order to forecast a poor result and adjust management as necessary. Thus, proper reduction and careful casting of fractures of both bones of forearm in paediatric age group is a very effective way of treating these injuries. However, an increased prereduction angulation at fracture site has an increased tendency to displace and thus, requires careful follow-up.

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