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ROLE OF CAST INDEX IN PREDICTING REDISPLACEMENT AFTER CLOSED REDUCTION AND CAST IMMOBILIZATION IN FOREARM FRACTURES IN AGE GROUP 5-15 YEARS.

Orthopaedics

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ABSTRACT

Background: Forearm fractures are very common in all age groups. 81% of forearm fractures happen in children above 5 years with the peak of incidence between 9-12 years in females and 12-15 years in males. In children aged >9 years, remodeling potential is low and re-displacement of fracture after cast application remains a complication (as high as 25%). Quality of casting is an important modifiable risk factor for fracture redisplacement, which can be measured by the use of cast index. The purpose of our study was to find out if cast index should be used as a standard protocol after reduction for assessment of quality of cast. **Material & Methods:** A total number of 40 patients were selected from outpatient department and trauma centre based on inclusion and exclusion criteria. These patients were treated with below elbow (B/E) or above elbow (A/E) cast application. Follow up was done radiologically using cast index at 0, 1 & 4 weeks of cast application. Out of 40 patients 2 patients were remanipulated at 1week follow up. **Results:** Out of 40 cases of paediatric forearm fracture, 30 (75%) cases were male and 10 (25%) were female. 27 (67.5%) cases belonged to 5-8 years of age. The mean age was 8.4±2.79 years in males and 6.9±2.23 years in females. The mean cast index of the whole study was 0.802±.147 (range 0.48 to 1.21). The mean cast index for proximal, middle and distal levels was 0.74, 0.85 and 0.76 respectively. **Conclusion:** Cast index gives us an analogy about the quality of cast in pediatric forearm fractures. With proper use it can also be used as a guiding stick for young orthopaedicians. Thus, regular use of cast index should be encouraged in all orthopaedic centers; especially for pediatric forearm fractures.

KEYWORDS

Paediatric forearm fractures, cast index, redisplacement, closed reduction.

INTRODUCTION

Forearm fractures are very common in all age groups. In forearm fractures, distal forearm fractures are especially very common. Distal radius fractures are the most common limb fractures in childhood[1] (20-30% of all limb fractures)[2]. 81% of forearm fractures happen in children above 5 years with the peak of incidence between 9-12 years in females and 12-15 years in males[3]. Mechanism of trauma is mostly falling on outstretched hand. Closed fractures of distal forearm in children are often treated with closed reduction and immobilization in a well-fitting plaster cast in our country and achieve satisfactory results in majority of the patients. Forearm fracture in children heals quickly and mild to moderate displacement gets corrected by itself due to remodeling[4], but in children aged above 9 years remodeling potential is low and re-displacement of fracture remains a complication (as high as 25%)[3]. Due to re-displacement wrist and hand functions are severely compromised including range of movement at wrist joint and grip power of hand. Previous studies have declared the initial displacement of the fractures to be the most important risk factor for re-displacement[3,5,6]. Other factors may be distance of fracture from the physis, angulation of the fracture, poor cast molding, edema resolution whilst in the cast and inadequate initial reduction. Quality of casting is an important modifiable risk factor for fracture redisplacement, which can be measured by use of casting indices. The first and simplest index to be described is the cast index described by Chess et al[7]. It is calculated by measuring the internal LATERAL diameter of cast (excluding Padding) and dividing it by the internal ANTERO-POSTERIOR diameter of the cast (excluding padding), Both at the level of fracture. It is measured after closed reduction and cast application in the radiograph.

Recent studies have shown that a Cast index of over 0.8 carries a significant risk of redisplacement[8]. Cast index is not being used consistently in clinical practice. Before accepting any plaster after a manipulation of forearm fractures, a rapid assessment by surgeons could be a very useful practice[9]. Given the benefits of this index and its simplicity of calculation, the question to be asked is, should it be used as a standard protocol after reduction for assessment of quality of cast and whether the applied cast requires close monitoring or revision. The hypothesis of this study is that cast index will come out to be a good index in the age group 5-16 years as far as risk of redisplacement is concerned after forearm fractures.

MATERIAL & METHODS:

Sample Size:

A total number of 57 patients were selected from outpatient department and trauma centre randomly. 10 patients were lost to follow-up due to COVID lockdown. 4 patients were excluded because of lack of complete follow up. 3 patients were excluded because of improper initial reduction and were treated with intramedullary nailing. Hence, a total of 40 patients fulfilled the criteria and were finally assessed. Out of 40 patients 2 patients were remanipulated at 1week follow up. After application of a new cast these remanipulated patients were not followed further for the study. Selection was based on some inclusion and exclusion criteria.

Inclusion Criteria:

- Mono-osseous closed forearm fracture in forearm.
- Bi-osseous closed forearm fracture in forearm.
- Age 5-16 years.
- Trauma history not more than 10 days
- Patient giving consent for examination and follow up.

Exclusion Criteria:

- Refusal to consent
- Age Less than 5 years and more than 16 years.
- Suspected Pathological fracture.
- Comminuted/compound/segmental fracture.
- Patients who did not complete follow up.
- Patients who did not have complete radiographic documentation.
- Unsatisfactory/ failed initial reduction.
- Intra-articular fractures.
- Physeal injuries

METHODS:

After the approval of the institutional ethics committee (IEC)[77/IEC-GRMC/2019], the study was carried out between October 2019 to November 2021. Written informed consent was taken from the guardian before including the child into the study.

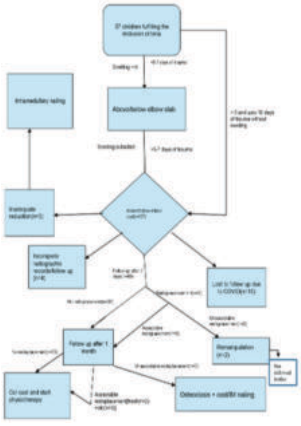

Fig.1: Flow chart depicting interventional protocol followed for this study

For reduction the children were kept NIL PER ORAL for a minimum of 6 hours as per the requirement of anesthetists. Proper history, vitals and examination of various systems was done before taking the children for reduction in OT. All the cases requiring reduction were done in the operating room under short IV sedation. Local anesthesia was not used. After induction the patients were positioned supine and the fracture was manipulated and reduced under image intensifier into acceptable anatomical reduction as per the acceptable reduction criteria already set for the study (**Table 1**)[10].

Table 1: Acceptable limits of reduction according to gender and age. (Adapted from Noonan KJ, Price CT 1998 JAAOS)

Patient Age	Angulation	Bayonet Apposition
Age 0-9 (0-8 girls, 0-10 boys)	<15◦	Up to 1 cm
Age >9 (>8 girls, >10 boys)	<10◦ proximal/mid shaft	Up to 1 cm
Age >9 (>8 girls, >10 boys)	<15◦ distal	Up to 1 cm

After acceptable reduction was achieved, the reduction was immobilized using an above elbow or below elbow cast. The reduction was checked under image intensifier. The position of the forearm was kept in mid prone position for distal 1/3rd and middle 1/3rd fractures and in supination for proximal 1/3rd fractures.

The elbow was flexed to 90 degrees in above elbow casts. An arm sling/pouch was given to all the cases after drying up of the plaster of Paris cast. All the casts were applied with plaster of Paris as the casting material and cotton wool as the padding material.

Extra padding was given at bony landmarks like wrist and elbow. Knuckles and thumb were kept free to allow finger movements and movement at metacarpo-phalangeal joints. Remolding was done to attain the contour of the limb. If acceptable reduction was not achieved as per the set criteria, intramedullary nailing was done in them to achieve the reduction.

Once the cast hardened, true antero-posterior and true lateral x-rays were taken. While taking the x-ray, a 5-rupee coin with standard diameter of 23 mm[11] was placed alongside the forearm to standardize the calculations. The x-ray machine was kept perpendicular to the forearm so that the falling rays were perpendicular to the forearm. After giving proper post casting care instructions, the patients were sent home and called for follow up and radiographic imaging and calculation after 7 days. Analgesics and calcium supplements were given to the patients.

Both the pre-reduction and immediate post reduction x-rays were photographed on a view box and this photograph was then used to make the calculations (**Fig. 2**).

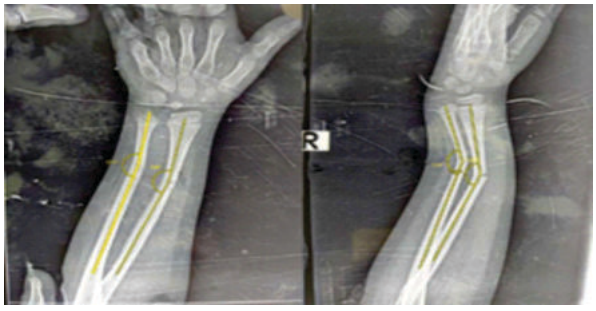

Figure 2: Measurement of angulation in AP and Lateral views pre reduction.

The calculations were done with an application available on the android store by the name 'IMAGEMETER'. Both the angles and the cast index calculation in the immediate post reduction was done using this application (**Fig. 3 & 4**).

Figure 3: Calculating the cast index just after reduction by measurements in AP and lateral view at the level of fracture.

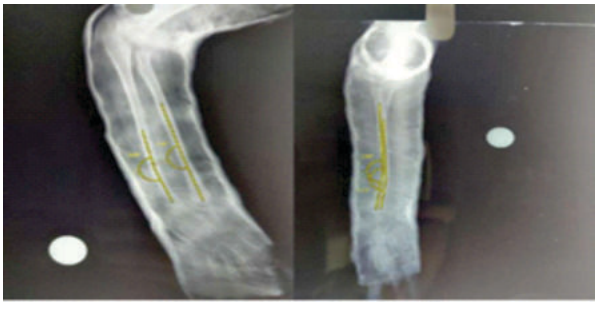

Figure 4: Calculating the angulation in AP and lateral view immediate post reduction.

For standardizing the length calculation, the diameter of 5-rupee coin was used as a standard length of 23 mm[11].

Re-displacement criteria was taken as an increase in angulation of > 10 degrees in Antero-posterior and/or Lateral views or loss of adequate contact (at least one cortex in both AP and LATERAL views) between fracture fragments. The patients were then called for follow up at the completion of 1 week of the cast (**Fig. 5**).

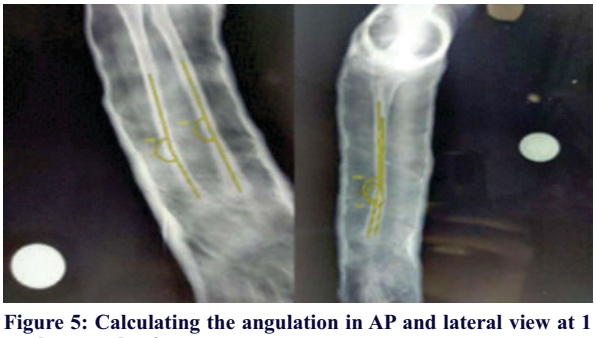

Figure 5: Calculating the angulation in AP and lateral view at 1 week post reduction.

If the re-displacement was too much to be accepted, re-manipulation was done under image intensifier.

Follow up at 1 month consisted of addressing the problems and getting a new true antero-posterior and true lateral radiographs for calculation of degree of redisplacement, if any (**Fig. 6**).

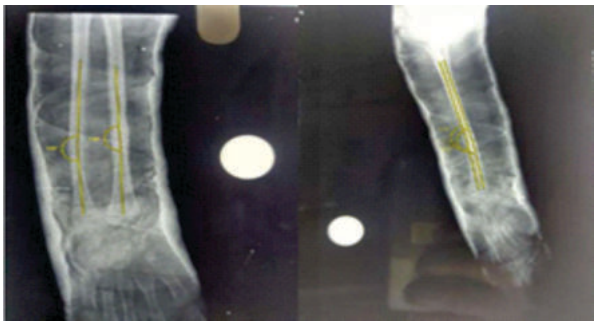

Figure 6: Calculating the angulation in AP and lateral view at 1 month post reduction.

Calculations were again done using the same software. Re-displacement criteria remained the same. In case of unacceptable redisplacement at this stage, osteoclasis or intramedullary nailing was kept as an option for correction of alignment.

Cast removal was done at 1 month and aided support to the forearm by crepe bandage was given for another 2 weeks. The patients were asked to carry out proper wrist and elbow physiotherapy meanwhile.No functional outcomes were studied. Mean cast index in non-displaced and displaced groups was calculated and compared statistically.

RESULTS

Out of 4 0 cases of paediatric forearm fracture, 30 (75%) cases were male and 10 (25%) case were female. Majority of cases were male. 27 cases (67.5%) belong to 5-8 years of age group, 7 (17.5%) belong to 9-11 years of age group and 3(7.5%) belong to 11-13 & >13 year of age group respectively. Majority of cases belong to 5-8 years of age. Out of 40 cases of paediatric forearm fracture age group <7 years contained 7 females and 11 males, age group 8-10 years contained 2 females and 14 males, and age group > 10 years contained 1 female and 5 males. The mean age was 8.4±2.79 years in males and 6.9±2.23 years in females. 17 (42.5%) cases were left side and right side was involved 23 (57.5%) cases. Out of 40 cases of paediatric forearm fracture, 18 (45%) cases were distal 1/3rd fracture, 19 (47.5%) cases were middle 1/3rd fracture and 3 (7.5%) cases were proximal 1/3rd fracture. Mechanism of trauma in most of the patients was fall during play 28 (70%) followed by RTA 7 (17.5%) followed by fall from bicycle 5 (12.5%). (**Table-2**)

Table 2: Comparison of demographic & radiological outcome among study participants (n=40)

	Non Redisplacement Group	Re Redisplacement Group	p-value
Number	34	6	
Age	8.33±2.80	6.57±1.71	0.120
Male:Female	26:8	4:2	0.810
Side (Right:Left)	20:14	3:3	0.983
Location Of Fractures			
Distal 1/3rd	14	4	0.621
Middle 1/3rd	16	3	
Proximal 1/3rd	3	0	
Type of Fractures			
Single Bone	16	3	0.787
Both Bone	17	4	
Radius	11	2	0.962
Ulna	5	1	
Radius+Ulna	17	4	
Max. angulation shift in AP	4.36±3.02	7±6.06	0.012
Max. angulation shift in Lat.	4.24±2.48	11.43±1.62	0.000
Mean Cast Index	0.779±0.124	0.910±0.208	0.034
Mean Cast index			Odds Ratio
>0.8	15	5	3
0.8	18	2	

The mean cast index of the whole study was 0.802±.147 (range 0.48 to 1.21). Ideal range for proximal 1/3rd fracture cannot be commented upon pertaining to the lesser number of cases with proximal 1/3rd fracture. Re manipulation was required in 2 (28.6%) of the total 7 redisplacement cases. In our study, for the whole forearm the value of cast index > 0. 8 had sensitivity of 71 %, specificity of 55%, odds ratio of 3, negative predictive value of 90%, positive predictive value of 25%, & accuracy of 58% for redisplacement evaluation (**Table-3,4**).

Table 3: Mean cast index and range for 95% confidence interval.

	N	Mean cast Index	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Limit	Upper limit		
Distal 1/3rd	18	0.76	0.10	0.71	0.81	0.54	0.97
Middle 1/3rd	19	0.85	0.17	0.77	0.93	0.48	1.21
Proximal 1/3rd	3	0.74	0.20	0.24	12.24	0.51	0.87
Total	40	0.80	0.15	0.76	0.85	0.48	1.21

Table 4: prediction of redisplacement for cast index >0.8.

Measure	Mean cast Index (> 0.8)
Sensitivity	71%
Specificity	55%
PPV	25%
NPV	90%
FPR	45%
FNR	29%
Accuracy	58%

The most common complication during the follow up period was itching (22.5% cases), followed by cast breakage (5% cases). No other complications were noted. Post cast cutting, the most common complication was wrist and elbow joint stiffness. P valve < 0.05 was considered statistically significant.

DISCUSSION

In our study out of the 7 cases of redisplacement, 5 cases (71.4 %) occurred within 1 week of follow up and only 2 cases (28.6%) occurred after 7 days of cast immobilization. The correlation between timing of redisplacement and redisplacement came out to be statistically significant (p=0.01). Redisplacement is more likely to occur before the formation of a soft callus which acts as a bridge to prevent further redisplacement. Only 2 (28.5%) out of the 7 cases required remanipulation and both of these cases had redisplaced within 1 week of initial reduction. This further suggests that further redisplacement gradually decreases once the cast gets older leading to formation of soft callus and finally hard callus. Haddad et al[12], found that experienced surgeons had lower rate of redisplacement. Arora et al[13] & Yang et al[14], found the correlation to be insignificant in their study. 7 patients (l7.5%) showed redisplacement. Out of these 7, 2 patients (5% of total) required remanipulation. The redisplacement rate is comparable to studies by Malviya et al[15], Alemdaroglu et al[6], Yang JJ et al[14], Mazzini et al[16].

All these studies used different parameters of redisplacement unlike ours, so comparison with them is of no significance. The 2 patients which required remanipulation had redisplacement which was unacceptable as per our reduction criteria and hence were remanipulated and a new cast was applied with proper reduction. The mean cast index of the whole study was 0.802±0.147 (range 0.48-1.21). The mean cast index in non redisplacement group was 0. 779±0.124 (range 0.48-0.98) and in redisplacement group was 0.910±0.208 (range 0.54-1.21). The mean distribution of cast index value among redisplacement group and non redisplacement group was found to be statistically significant (p= 0.034). {**Table-5**}

Table 5: Comparison of value of cast index in non redisplacement group in various.

Previous Studies	Mean Cast Index of Non Re-displacement Group
Sheikh et al19 (distal forearm)	0.77
Chess et al7 (distal forearm)	0.72
Turgut et al20 (distal radius)	0775-0.875
Basavarajanna et al21 (middle 1/3rd forearm)	0.75

Malviya et al9 (distal forearm)	0.72
Shalabh et al22 (both bone leg)	0.94-1.12
Ajmera et al18 (whole forearm)	0.852
Our study (whole forearm)	0.779

Our study including the whole forearm and including both bone as well as isolated bone fracture shows that with increasing value of cast index, the chances of redisplacement are more. All the cases with cast index more than 1, got redisplaced.

Other cast indices such as gap index15,16,17 and three point index6,17, have proven to be better than cast index in some studies. But their calculation is very cumbersome and hence reduces their use in a trauma setting. Cast index on the other hand is very easy to calculate and analyse and has the potential of becoming an effective tool for checking the quality of forearm cast normally applied in paediatric closed forearm fractures. Sarvpreet et al15 in their study proved the efficacy of using cast index in decision making even by senior consultants and registrars.

In our study the mean cast index for distal 1/3rd, middle 1/3rd and proximal 1/3rd level was 0.76±0.10, 0.85±0.16, 0.74±0.19 respectively. In the study by Ajmera et al18 this value was 0.80, 0.86 and 0.92 respectively. In the study by Sheikh et al19 mean cast index in distal ½ and proximal ½ was 0. 76 and 0.83 respectively.

The value of cast index increases as we move from distal to proximal because of increase in muscle mass and hence change in cross section of forearm from elliptical to cylindrical.

In our study the mean shift in angulation in anteroposterior view in redisplacement group was 7°±6.06. It was 4.36±3.02 in non redisplacement group. The correlation between these two groups was significant (p= 0.012). Similarly, the mean shift in angulation in lateral view in redisplacement group was 11.43°±1 .62. It was 4.24±2.48 in non redisplacement group. The correlation between these two groups was statistically significant (p= 0.000). Malviya et al[9], in their study also found out the correlation to be statistically significant.

In our study, for the whole forearm the value of cast index 0.8 as a cut off was taken and sensitivity of 71 %, specificity of 55%, odds ratio of 3, negative predictive value of 90%, positive predictive value of 25%, and accuracy of 58% suggests that cast index 0.8 for forearm fracture is a landmark to predict redisplacement. In a study by Malviya et al[9] on distal 1/3rd radius fractures, the cut off value 0.8 showed sensitivity of 48%, specificity of 88%, positive predictive value of 52.1 %, negative predictive value of 83.5%, accuracy of 78% and odds ratio of 6.8. Alemdaroglu et al[6] in their study on distal radial fractures found the cut off point of 0.8 to be 63.2% sensitive, 52.4% specific, with negative predictive of 82.5% and positive predictive value of 28.6%. Arora et al[13], in their study found the cut off of 0.81 for the whole forearm to be 69.2% sensitive, 76% specific and odds ratio of 9.

In our study the range of cast index to include 95% of cases came out to be 0.76- 0.85 for the whole forearm fracture, 0.71-0.81 for distal 1/3rd fracture and 0.77-0.93 for middle 1/3rd fracture. Ideal range for proximal 1/3rd fracture cannot be commented upon pertaining to the lesser number of cases with proximal 1/3rd fractures. This means if we keep our cast index to be between this range it is less likely to redisplace after initial reduction.

With the advancement of surgical instruments, techniques, operation theatre sterilization equipment's, anesthesia, antibiotics etc. focus of the surgeons is gradually shifting towards operating even those cases which can be conservatively treated. Because of this even the young budding surgeons pay less heed to the reduction techniques, technique of cast molding, proper application of cast and proper use of casting materials. So, gradually the quality of cast has been coming down with the fading technique of proper casting and lack of interest in budding surgeons. However, surgeries are always bound to have complications, even though them providing early mobilization. Casting in children comes with lesser complications and results on par with surgeries thus making them a better alternative compared to the surgeries. That is why, learning to apply better quality of cast is very necessary for the budding surgeons. Cast index can act as a guiding stick for such surgeons and hence its use must be encouraged on regular basis.

Limitation of study

The present study had limitations of sample size (only 40 patients) because of successive year lockdown due to COVID leading to lesser outpatient and emergency visits of patients, lesser number of proximal 1/3rd fractures, no functional outcomes were studied, no comparison between plaster of Paris and synthetic casting materials was done, fracture site obliquity as a cause of redisplacement was not studied and single hospital selection of cases.

Scope of our article

The use of cast index is not routinely done even by budding surgeons even though a number of studies have proven its simplicity and efficacy. Our study might contribute to the existing literature.

CONCLUSION

Cast index is an excellent tool to monitor the quality of cast and risk of redisplacement. Cast index gives us an analogy about the quality of cast in paediatric forearm fractures, so that a poorly applied cast can be monitored for redisplacement over the course of fracture healing. With proper use it can also be used as a guiding stick for young surgeons for a better learning curve of cast application in paediatric forearm fractures. Thus, regular use of cast index should be encouraged in all orthopaedic centres; especially for paediatric forearm fractures.

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Conflict of interest None declared.

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