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Increase in gap index over time after reduction of unstable paediatric both-bone forearm fracture does not cause displacement

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This study investigated the effects of changes in the gap index on fracture displacement during follow-up. Patients who underwent closed reduction and casting with a diagnosis of unstable paediatric both-bone forearm fractures and a cast index < 0.8 were retrospectively evaluated. Patients were divided into Groups 1 and 2 based on their gap index (<0.15 and >0.15, respectively). Anteroposterior and lateral displacements of the radius and ulna and the gap index of the cast were measured on the X-ray after the first reduction and on the last X-ray before plaster removal. The mean patient age (n = 94, 74 boys and 20 girls; 51 in Group 1 and 43 in Group 2) was 7.09 ± 2.66 years. Fracture union times (plaster removal) were 38.8 ± 7.1 days. The mean cast index was 0.76 ± 0.05 (0.59–0.8). Both groups had similar distributions in terms of age, sex, fracture side, anatomic location and plaster removal time (p > 0.05). No significant differences were observed in either group in any radial or ulnar angulation values at any time point or the difference between the first and last values (all p > 0.05). Moreover, the gap index difference between the first and last measurements was significantly different in both groups (p = 0.002). If the cast index remains <0.8, despite the increase in the gap index in both groups, the amount of fracture displacement was small and acceptable.

Keywords: Conservative treatment, gap index, loss of reduction, unstable paediatric both-bone forearm fractures.

INTRODUCTION

Both-bone forearm fractures are the third most common fractures in the paediatric population[1]. Completely displaced fractures are unstable, and conservative treatment of unstable fractures can have considerable reduction loss[2,3].

Many casting indices are used to predict reduction loss, the most common being the cast index, three-point index and gap index[4,5]. These indexes are routinely and successfully applied during plaster application. The risk of displacement is indicated when the upper limits of these indices are exceeded[6,7]. Among them, the cast index has the highest predictive value. The gap index, on the other hand, has a dynamic process due to decreasing fracture edema and loosening of the plaster over time[8].

Although a gap index cut-off value of <0.15 is recommended[8] to prevent displacement, no study has evaluated whether changing the gap index during follow-up increases fracture displacement risk. Changing the gap index over time and revealing its effect on reduction will contribute to treatment algorithms during follow-up. Severe displacement may require repeating and remoulding the plaster or repeating fracture reduction. However, if the displacement is less severe, clinicians may not apply a tight plaster and may eliminate concerns of fracture displacement that may be caused by the increased gap index over time.

In this study, we investigated whether an increase in the gap index during follow-up visits among paediatric patients with unstable both-bone forearm fractures affects reduction loss.

PATIENTS AND METHODS

In this retrospective study, we included patients diagnosed as having paediatric both-bone forearm fracture between June 2020 and October 2021. Local ethics committee approval was obtained for the study (KAEK/2021.09.195).

Patients who were admitted to the emergency room with a diagnosis of paediatric (≤12 years old), unstable (fully displaced and noncontact),[9] both-bone forearm midshaft, distal and proximal shaft fractures, and followed up with closed reduction and plaster cast were included in the study. There was no lower age limit due to the follow-up of the displacement amount.

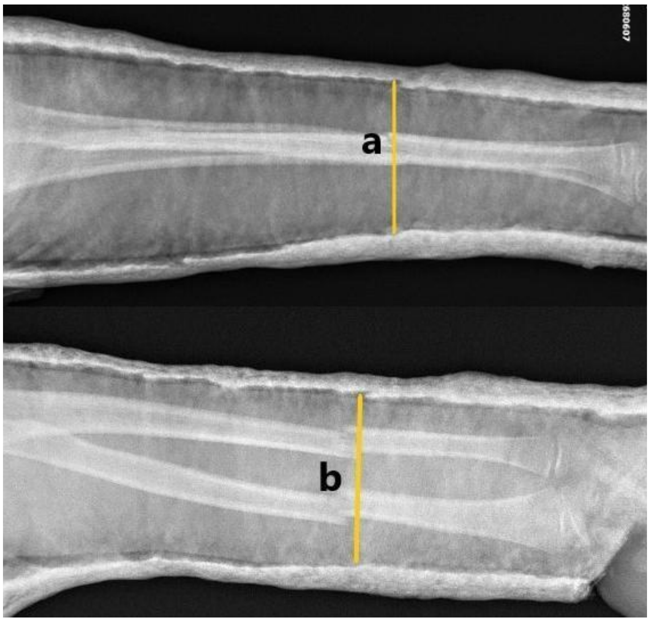

Figure 1. — Cast index measurement (CI=a/b).

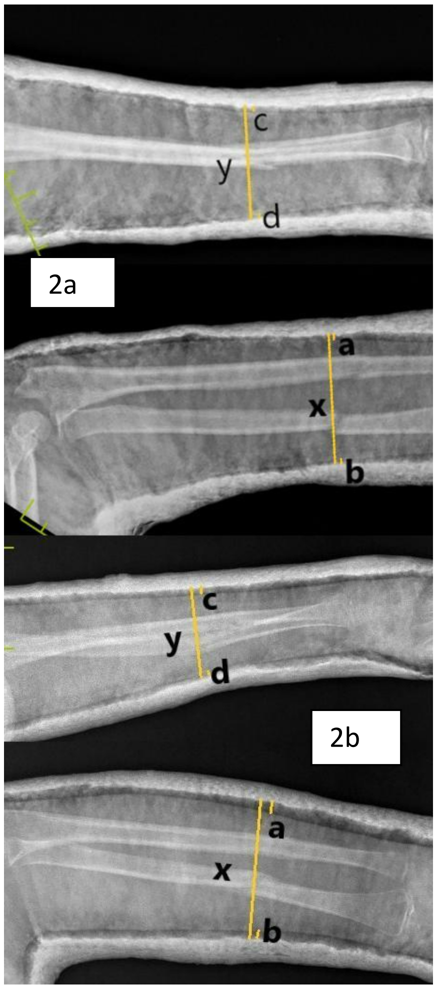

Figure 2a and 2b. — Gap index measurement (GI= [c+d/y] + [a+b/x]). 2a.: Gap index measurement in the first cast after reduction in an example case; 2b.: Gap measurement of the same sample case before plaster removal.

We excluded patients with a cast index value > 0.8, fractures that are unstable but surgically treated, fractures in a stable pattern (greenstick, torus, non-displaced or partially displaced), other fractures or dislocations in the same extremity, open fractures and pathological fractures (syndromic patient) and previous fracture history.

Patients were divided into two groups based on their gap index: Group 1, gap index < 0.15 and Group 2, gap index > 0.15. Based on the results of the power analysis, the sample size was determined to be at least 41 patients per group.

The cast index[8] is based on moulding the cast in the anteroposterior (AP) position and shaping the forearm into its normal oval shape. Values below the cut-off have been demonstrated to prevent reduction loss.[4,5] The cast index was calculated by dividing the inner diameter of the cast on the lateral view by the inner diameter of the cast on the AP view (Figure 1). The cut-off was 0.8.

Gap index[8]: It is the amount of distance between the skin and the plaster in the X-ray taken after the reduction. Maintaining the gap index below the cut-off values can prevent reduction loss[4,5]. This value is calculated as follows: (Radial fracture site gap + Ulnar fracture site gap/Inner diameter of cast in AP plane) + (Dorsal site gap + Volar fracture site gap/Inner diameter of cast in lateral plane) (Figure 2a and b). The cut-off was 0.15.

The plaster application technique in the emergency room is consistent among all orthopaedic doctors. After traction on the forearm and volar and dorsal angulation, long arm casting was applied with the elbow maintained at 90°, and the forearm was maintained in the neutral position with the thumb pointing up. The cast was frozen by hand pressing the fracture line in an oval shape to maintain the cast index in the most ideal (<0.8) position (Figure 3). A control graph was taken. If proper alignment was not achieved, surgical treatment was considered.

No consensus has been reached on the criteria for conservative follow-up of paediatric both-bone forearm fractures[10]. Based on our clinical experience, radioulnar angulations < 20° and fractures with ≥50% contact and ≤30° rotations on AP and lateral radiographs were considered suitable for conservative follow-up. To determine the amount of rotation, the relationship between tuberositas radii and radius styloid on AP X-ray and between olecranon type and ulna styloid on lateral X-ray were considered as references[11]. Minimal angulation excesses for some patients who are younger

Figure 3. — Oval maneuver to provide cast index.

and have a high chance of remodelling have also been interpreted conservatively by some surgeons.

Patients called for circulation control 1 day later; control radiographs were taken 1 week later and then every 2 weeks. After callus bridge development was observed in both planes, the plaster was removed.

Demographic data were obtained using the patients' electronic medical records. All radiological measurements were made by the principal investigator. The following radiological parameters were measured: first X-ray after closed reduction and casting ("first" measurements), last X-ray before plaster removal ("last" measurements); cast index, first gap index, last gap index, gap index difference (the value on the last X-ray – the value on the first X-ray), first and last radial and ulnar angulations on AP and lateral views, radial AP/lateral angulation differences (the value on the last X-ray – the value on the first X-ray), ulnar AP/lateral angulation difference (the value on the last X-ray – the value on the first X-ray) (Figures 1, 2 and 4).

SPSS v26 (IBM, Chicago, IL, USA) was used for the statistical analysis. Explanatory statistics (mean ± standard deviation, median, frequency, ratio and range) and data distribution were evaluated using the Shapiro–Wilk test. Student's t-test was used to compare the data distributed between the two groups. $p < 0.05$ was considered statistically significant.

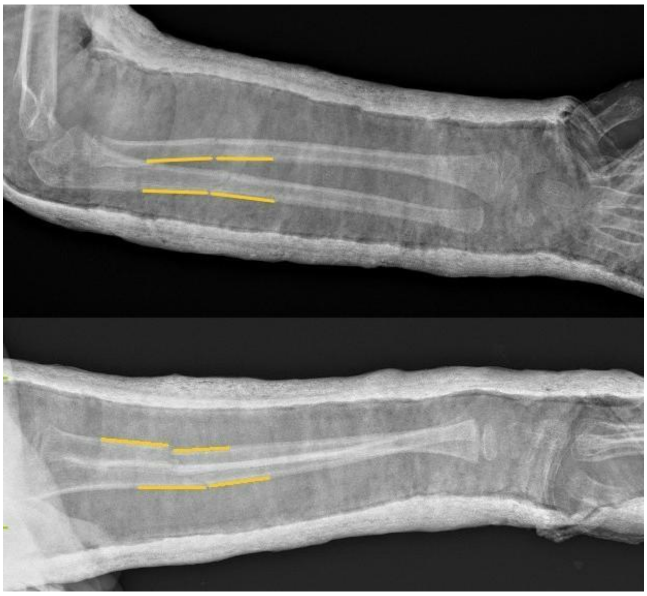

Figure 4. — AP and lateral angulation measurements of the radius and ulna.

RESULTS

We included 94 patients (74 boys and 20 girls) in this study. Their mean age was 7.09 ± 2.66 years (range: 3-12 years). Fracture union times (plaster removal) were 38.8 ± 7.1 (24-67) days. The mean cast index was 0.76 ± 0.05 (0.59-0.8). Groups 1 and 2 included 51 and 43 patients, respectively.

Both groups were comparable in terms of age, sex, fracture side (right/left), fracture anatomic location (midshaft/distal shaft/proksimal shaft) and plaster removal time (all $p > 0.05$) (Table 1). No significant differences were observed in either group in any radial or ulnar angulation values at any time point or

Table 1. — Demographic data

	Group 1 n: 51	**Group 2 n:43**	**p-value**
Age	7,52 ± 2,38* (3-12)**	6,58 ± 2,89 (3-12)	0,160
Gender	Male: 43 (85%) Female: 8 (15%)	Male: 31 (72%) Female: 12 (28%)	0,090
Fracture Side	Right: 23 Left: 28	Right: 22 Left: 21	0,562
Anatomic location	Midshaft: 41 Proksimal shaft: 4 Distal shaft: 6	Midshaft: 35 Proksimal shaft: 2 Distal shaft: 6	0.551
Plaster removal time (day)	39,4 ± 5,95 (28-60)	38,1 ± 8,4 (24-67)	0,399

* Mean±Standard deviation (SD), ** Min-Max.

the difference between the first and last values (all $p > 0.05$) (Table 2). We observed that the gap index difference obtained when the first Gap index values were subtracted from the final Gap index values were significantly different in both groups. ($p < 0.05$; $p = 0.002$). We observed that patients with a gap index less than 0.15 (Group 1) had a greater increase in the gap index during follow-up than patients with a gap index greater than 0.15 (Group 2) (Table 2).

All fractures healed uneventfully, and plaster cast-related complications were reported. During the follow-up, no reduction loss was noted that would require surgical intervention.

Table 2. — First and last angulation amounts and analysis between groups

	Group 1 n: 51	Group 2 n:43	p-value
Cast index	0,76 ± 0,04* (0,68-0,8)**	0,76 ± 0,04 (0,59-0,8)	0,418
First Gap index	0,095 ± 0,028 (0,034-0,145)	0,178 ± 0,036 (0,15-0,269)	-
First radius Ap angulation (degree)	1,86 ± 3,21 (0-10)	2,86 ± 3,97 (0-15)	0,190
First radius lateral angulation (degree)	5,72 ± 6,5 (0-21)	5,9 ± 6,17 (0-20)	0,890
First ulna Ap angulation (degree)	0,23 ± 1,17 (0-6)	1,25 ± 3,56 (0-15)	0,078
First ulna lateral angulation (degree)	2,35 ± 4,28 (0-20)	1,86 ± 2,46 (0-7)	0,488
Last Gap index	0,150 ± 0,043 (0,075-0,235)	0,211 ± 0,046 (0,158-0,319)	-
Last radius Ap angulation (degree)	3,16 ± 4,12 (0-12,5)	3,61 ± 4,64 (0-10)	0,624
Last radius lateral angulation (degree)	8,23 ± 7,17 (0-23)	8,25 ± 7,64 (0-24)	0,989
Last ulna Ap angulation (degree)	3,56 ± 3,72 (0-11)	4,70 ± 4,36 (0-15)	0,182
Last ulna lateral angulation (degree)	4,39 ± 5,035 (0-20)	3,58 ± 4,06 (0-13)	0,390
Gap index difference (last-first)	0,055 ± 0,037 (0,003-0,144)	0,033 ± 0,030 (0-0,088)	**0,002***
Radius Ap angulation difference (last-first)	1,30 ± 2,84 (0-10)	0,75 ± 2,27 (0-11)	0,302
Radius lateral angulation difference (last-first)	2,50 ± 3,05 (0-9)	2,34 ± 2,73 (0-8)	0,788
Ulna Ap angulation difference (last-first)	3,33 ± 3,45 (0-7)	3,45 ± 3,79 (0-11)	0,873
Ulna lateral angulation difference (last-first)	2,03 ± 3,73 (0-12)	1,72 ± 3,73 (0-13)	0,681

* Mean±Standard deviation (SD), ** Min-Max.

DISCUSSION

In this study, we observed that the change in the gap index over time in paediatric both-bone forearm fractures did not cause fracture angulation.

Both-bone paediatric forearm fractures are frequently referred to emergency services. Most of these fractures are torus or greenstick fractures and heal uneventfully with conservative methods[12,13]. In displaced fractures where the contact is completely broken, reduction is difficult due to the complete disruption of the periosteum and the penetration of the periosteum, interosseous membrane or muscle tissue into the fracture line. Even if the reduction is fully achieved, the fracture tends to be displaced due to the completely disrupted periosteum and muscle tissue[14].

The most well-known and defined index to predict and thus prevent fracture displacement is the cast index. The second known index is the gap index, and its predictive value remains controversial[4,15]. The acute fracture site has edema and hematoma; as they clear up with time, the gap index in the first plaster cast inevitably increases during follow-up visits. Although there was an increase in gap index herald fracture displacement, our data indicated that this was not necessarily the case. We even found that an initial gap index of even >0.15 did not cause worrying displacements.

The use of a single layer of cotton or over-moulding and tightening of the plaster seems to be a preferable technique among surgeons to reduce the gap index; however, serious complications can ensue due to compartment syndrome and plaster burns[16]. Notably, our results revealed that a high gap index does not cause displacement loss, implying that loose cotton plastering can be used. Maintaining a cast index below 0.8 has been discussed extensively in the literature, with sufficient evidence to indicate that this can prevent displacement loss. Taking these findings and ours together, considering only the cast index and ignoring the gap index may be an acceptable approach.

Another important index is the three-point index, which measures the gap amount using a different method. Although some studies have touted it as a displacement predictive method, its superiority over the cast index remains unclear[4,15]. Our findings suggest that the gap index does not predict displacement; we argue that the effect of the gap amount increasing over time in the three-point index method is small. However, verification of this argument requires a repeat analysis of the data of previous studies. We recommend that other authors who deal with this subject include the three-point index in their work.

Many researchers have stated that the quality of the initial reduction of the fracture is a more important parameter than the plaster indexes and that first fracture displacement is the most important factor in displacement loss[17-18]. Unsurprisingly, the loss of displacement is low due to the intact periosteum, interosseous membrane and muscle tissue in torus fractures, greenstick fractures or partially displaced fractures; studies on unstable fractures are scarce in the literature. Most previous studies have claimed that displacement loss is mostly observed in unstable fractures, yet they have persistently included stable fractures in their study. In contrast, we chose to include only unstable fractures. Fractures with insufficient contact (<50%) and angulations above 20°, whereas those not meeting these criteria (e.g. full contact) were managed conservatively; union was achieved uneventfully in every case. We think that we achieved this success by performing our oval casting manoeuvre, which standardises the cast index (allowing it to be <0.8), and by performing surgery in cases with a high probability of displacement.

Our results thus revealed that the change in the gap index alone over time should not be a cause of alarm for clinicians. Because this change in the gap index does not cause significant changes in radial and ulnar angulation, early plaster changes seem to be unnecessary, according to the available evidence. We believe that plaster intervention, wrapping the plaster very tightly using a few layers of cast cotton, is not required for gap index changes during follow-up, as long as the cast index is maintained below 0.8.

Limitations of the study

First, this was a single-centre study, which reduced the generalisability of the results. Second, the sample size may be small. Future studies should include a larger sample size because of the differences in the localisation of the fracture in the forearm and both bones and the differences in the paediatric age group (different bone remodelling characteristics of each age group). Because it is a paediatric age group, its effect on clinical outcomes could also be important for clinicians. Third, the absence of different casting methods, indices and a control group weakens our study. Randomisation and double-blinding or triple-blinding techniques are required to increase the level of evidence. Future multicentre, prospective, randomised, blinded studies with a control group are warranted to both validate and extend our findings.

CONCLUSION

Gap index increases in plasters with a gap index > 0.15 were more limited than those in plasters with a gap index < 0.15. Despite the increase in the gap index in both groups, the amount of fracture displacement was small and acceptable. Thus, despite an increase in the gap index, if the cast index remains <0.8, the first reduction can be maintained for a long time without resorting to unnecessary plaster interventions.

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