Gap index: a good predictor of failure of plaster cast in distal third radius fractures

Ajay Malviya, Dionysis Tsintzas, Kamal Mahawar, Christopher E. Bache and Philip R. Glithero

The aim of this study was to assess the usefulness of the cast index and an indigenously developed gap index as measures of poor moulding of plaster. Twenty cases of re-manipulation of distal third radius fractures in children excluding growth plate injuries were compared with a control of 80 patients. A significant difference ($<0.001$) was observed in the cast index and the gap index of both the groups. The gap index was more sensitive than the cast index in predicting failure. At a level of cast index of more than 0.8 the relative risk of failure is 6.8 as compared with 35 when the sum of the gap index is more than 0.15. The gap index is a better predictor of failure than the cast index.

A quick assessment of these indices is a good practice before accepting any plaster following a manipulation of distal radial fractures. J Pediatr Orthop B 16:48–52 © 2007 Lippincott Williams & Wilkins.

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Introduction

Distal radius fractures in children are well recognized for re-displacement after manipulation. Variable rates of re-displacement [1–5] have been reported ranging from 7 to 39%. Several studies have looked into the causes of this loss of position. Factors include a non-anatomical reduction [6,7], the position of the forearm after manipulation [8–10], the inclusion of the elbow in the plaster [11], the pre-manipulation displacement [3,6,12] and the seniority of the surgeon [1].

Poor moulding of the plaster and excessive padding is a recognized cause of a loose fitting plaster leading to re-displacement. The cast index [11] has been previously described as a radiological measure of moulding of the plaster. We propose another radiological index, the gap index, as a tool to identify a poorly applied plaster. The gap index is a measure of poor moulding and excessive padding applied before plaster application.

The aim of our study was to assess the ability of the cast and the gap index to predict a failure of plaster for distal third radius fractures, excluding growth plate injuries, in children. Our hypothesis was that these objective measures of poor moulding might reflect the final outcome of plaster treatment.

Materials and methods

Between January 2002 and September 2004, 267 distal third radius fractures were treated in our unit either by manipulation under anaesthesia alone or with supplemental K-wire fixation. Among those who had manipulation alone, 20 patients had a loss of position that required a re-manipulation under anaesthesia. We compared this group with a cohort of 80 consecutive similar fractures treated by manipulation under anaesthesia and plaster application over a period from April 2003 to July 2004.

Only patients with fractures in the distal third radius in the diaphyseal or metaphyseal region were included while epiphyseal injuries were excluded. All patients had a displacement that was warranted to be significant enough to need manipulation in the morning trauma meeting.

All had an above-elbow plaster of paris cast with elbow at $90^{\circ}$ flexion following manipulation. Wool was used for padding.

Failure of treatment was considered if the axial angulation of the fracture was more than $10^{\circ}$ during follow-up even if re-manipulation was not an endpoint. This value was selected because of previous reports suggesting that an angulation of more than $10^{\circ}$ may not remodel satisfactorily in patients above 6 years of age [13]. Five patients out of the cohort of 80 had an axial angulation of more than $10^{\circ}$ during follow-up and were included in the failure group. We therefore had a total of 25 patients in the failure group and 75 in the control group.
Both the indices were measured in the intraoperative X-rays at the fracture site by two independent observers (A.M. and D.T.). Only true anteroposterior and true lateral views were considered. The cast index was estimated by measuring the inside diameter of the plaster in the lateral view as a ratio to the diameter in the anteroposterior view at the fracture site (Fig. 1).

The gap index is a measure of the space between the plaster and the skin measured as a ratio to the inside diameter of the plaster (Fig. 2). On the radiographs, it is represented as the radiolucent space between the plaster and the less dense but easily identifiable outline of the skin. It was measured at the fracture site in both the anteroposterior and the lateral views. The sum of the two indices was calculated.

Sensitivity, specificity, positive and negative predictive values, accuracy and odds ratio of the cast index and the sum of gap index were determined as predictors of failure.

Interobserver variation of the gap index was determined from 10 randomly selected sets of radiographs measured by two of the authors (A.M. and K.M.). Intraobserver variability (A.M.) was determined using the same radiographs measured initially and after 6 weeks. Analysis was carried out using the Pearson correlation coefficient [14]. Scores between 0.61 and 0.80 represented good correlation and those greater than 0.81 represent excellent correlation.

Results
The results of the two groups are summarized in Table 1. The mean age of the failure group was 8.2 years, which was similar \( (P = 0.22) \) to the control group at 9 years.

Male to female ratio was slightly higher in the failure group than in the control group.

The adequacy of reduction after manipulation in both the groups was estimated by the postreduction translation and angulation of the radius in lateral and anteroposterior views. No significant difference was noted between the two groups.

All the patients had an above-elbow plaster following manipulation and in none of these was the plaster split following manipulation.

The mean cast index of the failure group was 0.80, which significantly differs \( (P < 0.001) \) from the control group at 0.72 (Table 2). The gap index was higher \( (P < 0.001) \) in the failure group than in the control group both in the anteroposterior and in the lateral views.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Comparison of the demographics and adequacy of reduction of the two groups</th>
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<tbody>
<tr>
<td>Number</td>
<td>Failure group</td>
</tr>
<tr>
<td>Age</td>
<td>25</td>
</tr>
<tr>
<td>Male : female</td>
<td>8.2 : 9</td>
</tr>
<tr>
<td>Side (right : left)</td>
<td>10:15</td>
</tr>
<tr>
<td>Postreduction anteroposterior translation</td>
<td>1.67%</td>
</tr>
<tr>
<td>Postreduction lateral translation</td>
<td>1.84%</td>
</tr>
<tr>
<td>Postreduction anteroposterior angulation</td>
<td>0.43°</td>
</tr>
<tr>
<td>Postreduction lateral angulation</td>
<td>0.47°</td>
</tr>
<tr>
<td>Shift in anteroposterior angulation</td>
<td>10.5°</td>
</tr>
<tr>
<td>Shift in lateral angulation</td>
<td>17.6°</td>
</tr>
</tbody>
</table>
The distribution of the cast index and the gap index on a scatter plot is shown in Figs 3 and 4, respectively. The scatter plots suggest that there is a clearer distinction between the two groups when considering the gap index in contrast to the more even distribution of the cast index. This seems to be corroborated by the higher values for the gap index than for the cast index in predicting failure.

The sensitivity, specificity, positive and negative predictive values, the accuracy and the odds ratio of the two tests to predict failure of treatment are depicted in Table 3. The index used for estimating these values was set at mean plus one standard deviation of the control group. Therefore, the value of the cast index was set at 0.8 and the sum of the gap index at 0.15.

Interobserver and intraobserver variability was excellent in all measurements (Table 4).

**Discussion**

Treatment of distal radial fractures has always been controversial because of the high failure rate of closed treatment. Closed reduction of paediatric forearm fractures followed by long arm plaster has been reported to be the accepted standard and the technique of pins and plaster should be considered a reliable alternative for the unstable injuries when acceptable alignment after manipulation cannot be achieved or maintained [15–18]. Some suggest that percutaneous wire fixation is a safe, convenient, effective and reliable means to maintain alignment [18,19] and, considering the high re-displacement rate, recommend that all isolated distal radius fractures in children requiring manipulations should have percutaneous wire fixation [12,20]. Our unit reserves stabilization by K-wires for only those fractures that remain unstable after a manipulation. This study only includes patients who were treated by closed reduction under anaesthesia followed by plaster application.

A below-elbow plaster has previously been reported to be adequate in the treatment of distal paediatric forearm fractures followed by long arm plaster has been reported to be the accepted standard and the technique of pins and plaster should be considered a reliable alternative for the unstable injuries when acceptable alignment after manipulation cannot be achieved or maintained [15–18]. Some suggest that percutaneous wire fixation is a safe, convenient, effective and reliable means to maintain alignment [18,19] and, considering the high re-displacement rate, recommend that all isolated distal radius fractures in children requiring manipulations should have percutaneous wire fixation [12,20]. Our unit reserves stabilization by K-wires for only those fractures that remain unstable after a manipulation. This study only includes patients who were treated by closed reduction under anaesthesia followed by plaster application.

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### Table 2 Comparison of the cast and gap index

<table>
<thead>
<tr>
<th></th>
<th>Failure group mean (SD)</th>
<th>Control mean (SD)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast index</td>
<td>0.80 (0.1)</td>
<td>0.72 (0.08)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Gap index (anteroposterior)</td>
<td>0.12 (0.04)</td>
<td>0.06 (0.03)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Gap index (lateral)</td>
<td>0.11 (0.04)</td>
<td>0.04 (0.02)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Gap index (sum)</td>
<td>0.23 (0.08)</td>
<td>0.10 (0.05)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

### Table 3 Prediction of failure

<table>
<thead>
<tr>
<th></th>
<th>Cast index (&gt;0.8)</th>
<th>Gap index (&gt;0.15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>48%</td>
<td>88%</td>
</tr>
<tr>
<td>Specificity</td>
<td>88%</td>
<td>82.7%</td>
</tr>
<tr>
<td>Positive predictive value</td>
<td>52.1%</td>
<td>62.9%</td>
</tr>
<tr>
<td>Negative predictive value</td>
<td>83.5%</td>
<td>95.3%</td>
</tr>
<tr>
<td>Accuracy</td>
<td>78%</td>
<td>84%</td>
</tr>
<tr>
<td>Odds ratio</td>
<td>6.8</td>
<td>34.9</td>
</tr>
</tbody>
</table>

### Table 4 Reproducibility of measurements

<table>
<thead>
<tr>
<th></th>
<th>Gap index</th>
</tr>
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<tbody>
<tr>
<td>Intraobserver difference (Pearson correlation)</td>
<td>0.93</td>
</tr>
<tr>
<td>Interobserver difference (Pearson correlation)</td>
<td>0.87</td>
</tr>
</tbody>
</table>
fractures if attention is paid to the proper moulding of the cast [11]. All the patients in our study, however, were treated by an above-elbow plaster.

Forearm position during cast immobilization was initially thought to be a significant factor in preventing re-displacement [9,10], but studies have shown that it is probably not related to the final outcome [21]. We, therefore, did not include this parameter in this study.

Fractures with complete initial displacement and those involving both the radius and ulna have been identified as risk factors for re-displacement [12] and therefore require more careful follow-up [6]. Mani et al. [3] reported that translation of the radius of more than half the diameter of the bone was associated with a risk of failure of 60%, compared with 8% for fractures with less translation.

Haddad and Williams [7] felt that the most favourable factor was achieving a perfect anatomical alignment on the immediate postreduction radiographs. This would in turn depend on the seniority and experience of the surgeon. Indeed, it has been reported that the re-manipulation rate depends on the grade of surgeon and the time of manipulation [1].

Regular radiological review is recommended to monitor loss of reduction and Younger et al. [22] recommend a re-manipulation if the axis deviation is more than 5° in younger patients or more than 3° in patients close to or after growth plate closure. Green et al. [6] reported that a residual angulation after manipulation under anaesthetic of less than 10° was not associated with an increased rate of re-angulation.

The remodelling potential may decrease with age. Vorlat and De Boeck [13], in a long-term follow-up of forearm fractures in children, found that above the age of 6 years angulations more than 10° would not remodel. Fuller and McCullough [23], on the other hand, believe that malunion of the distal third of the radius and the ulna will remodel satisfactorily providing the child is less than 14 years of age.

In our study, the adequacy of reduction was assessed by immediate postreduction translation and angulation of the radius and was found to be similar in the failure and the control group.

Both the groups were similar in terms of age, sex distribution, side and the extent of plaster. Right forearm fractures in boys have previously been identified at greater risk for re-displacement [22]. In our study, while the fractures had a male preponderance, this was not found to be a significant factor to predict failure of plaster.

Poorly applied plaster is a well recognized cause of failure of treatment and both the cast and the gap index measure this.

We have found that a high cast index and a high gap index were associated with a higher failure rate in closed treatment of distal radial fracture.

Anthropometric studies have shown that the cast index [11] is normally around 0.7 in the distal paediatric forearm. In our study, the mean cast index of the control group was found to be 0.72. The cast index is an indicator of how well the cast has been moulded to the normal contours of the forearm. While a poorly moulded plaster may be a cause of a high cast index, in young normally chubby children there is very little control over this otherwise useful tool.

The gap index has been developed as a direct measure of poor moulding and excessive padding application, which is quite commonly seen. A high gap index immediately following manipulation has been found to be associated with a higher displacement rate.

The gap index will obviously increase once the swelling following the fracture subsides. This can of course be noted during follow-up and an impending displacement identified. Our study, however, did not look into this.

The cast index measures only the moulding of the plaster and in some cases we do not have any control over this index especially when the anatomy of the forearm does not allow one to measure this. In such cases, a better option would be to try to control the gap index with, of course, the best possible cast index.

The gap index and the cast index may be used as screening tests to predict failure of plaster. An ideal screening test should have a high sensitivity and a high negative predictive value. According to our study, the gap index (sum > 0.15) has a high sensitivity (88%) and a high negative predictive value (95.3%), therefore making it a useful screening test. The cast index (> 0.8) has a lower sensitivity (48%) and negative predictive value (83.5%). The accuracy of the gap index (84%) in predicting failure is again higher than the accuracy of the cast index (78%). The relative risk (odds ratio) of failure of plaster was much higher (34.9) for the gap index than (6.8) for the cast index. Therefore, if the gap index is more than 0.15, the plaster cast is almost five times more likely to fail than when the cast index is more than 0.8.

The gap index, with its higher accuracy, is therefore a more useful indicator of failure than the cast index. The easy way to assess the gap index is to not accept a value
that is more than and equal to 1/13 in both the views, thereby giving a sum of more than 0.15.

This study has obvious limitations of any retrospective analysis and the next step in validation is a prospective collection of data that is being set up in our unit. Padding index has been discussed in a recently published paper [24]. Although the authors have used a different methodology to measure this, it confirms our belief that there is a direct relationship between the degree of padding and failure rate.

We have found measuring these indices immediately after manipulation is a worthwhile exercise. A quick assessment, especially by the less experienced surgeons, is a good practice before accepting any plaster following a manipulation of distal radial fractures. It has the potential of not only saving the patient a second anaesthesia but also complications of a more extensive second procedure and of course hospital resources.

References