The reliability and variation of measurements of the os calcis angles in children

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Fractures of the os calcis are rare in children, accounting for about 0.005% of all paediatric fractures. However, there is often a delay in diagnosis, with the rates of missed diagnosis varying from 27% to 43% in children under the age of ten years. The ability to detect and treat these rare injuries appropriately would be aided by a reliable method for evaluating radiographs.

Various angles have traditionally been used when analysing lateral views of the os calcis to detect and quantify intra-articular displacement. Bohler’s angle and Gissane’s angle are commonly measured and used in the management of adult fractures. It is recognised that, as the os calcis grows its morphology changes, and this will have an impact on the angles measured. Because of this variation in ossification with age, some authors have stated that the absolute measurement of Bohler’s angle is meaningless in children. Despite such concerns, Bohler’s angle is commonly used in studies of the paediatric calcaneal fracture, but the reliability of measurement of Bohler’s or Gissane’s angle in children is not known. This study aimed to assess the reliability of measurements of these two common angles in children, and to analyse their variation with age.

The databases of the Picture Archiving and Communication Systems of two hospitals were searched and all children who had a lateral radiograph of the ankle during their attendance at the emergency department were identified. In 227 radiographs, Bohler’s and Gissane’s angles were measured on two separate occasions and by two separate authors to allow calculation of inter- and intra-observer variation. Intraclass correlation coefficients were used to assess the reliability of the measurements.

For Bohler’s angle the overall inter-observer reliability, the intraclass correlation coefficient was 0.90 and the intra-observer reliability 0.95, giving excellent agreement. This reliability was maintained across the age groups. For Gissane’s angle, inter- and intra-observer reliability was only fair or poor across most age groups.

Further analysis of the Bohler’s angle showed a significant variation in the mean angle with age. Contrary to published opinion, the angle is not uniformly lower than that of adults but varies with age, peaking towards the end of the first decade before attaining adult values. The age-related radiologic changes presented here may help in the interpretation of injuries to the hindfoot in children.

Patients and Methods

Radiologic data from the Picture Archiving and Communication System (PACS) at two London teaching hospitals were searched from their inception (January 2006 and November 2006) until May 2007. All patients under 16 years of age who had a lateral radiograph of their ankle on attending the Accident and Emergency department were identified. The age and gender of the children was recorded.

The first author (SAC) examined all the radiographs and excluded any that were oblique or of poor quality. Images demonstrating a fracture of the os calcis were also excluded. All authors received written instructions on measuring Bohler’s and Gissane’s angles based on the earliest published description of their use. All images were viewed on the Phillips EasyVision viewer (Philips Healthcare, Guildford, United Kingdom) and measurements made using the Philips EasyViewer software tools.

The images were anonymised by removing identifying data, and presented in a random order. All were then examined by an author, and Bohler’s and Gissane’s angles measured. They were then re-examined after at least 24 hours by the same author to obtain intra-observer comparisons. All images were
Bland-Altman plots were created to investigate agreement (0.40 to 0.59), good (0.60 to 0.74) or excellent (> 0.75). These were interpreted as poor (< 0.40), fair (0.40 to 0.74) or excellent (> 0.75). Bland-Altman plots were created to investigate agreement between observers. One of the two measures from each observer was randomly chosen, and the difference between observers and the mean of their measurements calculated.

Bohler's angle was measured three or four times in each of the 227 patients in the process of collecting the data, giving a total of 908 measures. Some patients did not have a fourth measure because not all authors analysed all the images twice. Data were assumed to be ‘missing completely at random’, i.e., their disease did not depend on observed or unobserved measures. An analysis that ignores ‘missingness’ is valid. Data were cross-classified (a specific type of multi-level structure defined by the lack of natural ‘nesting’ of patient with doctor, or vice versa). Patients were not analysed as 908 separate individuals, but equally the second, third and fourth measures were not ignored. A linear mixed model was estimated by Gibbs sampling in MLwiN 2.02 software (Centre for Multi-level Modelling, University of Bristol, United Kingdom), and graphics were produced in Stata 10 (StataCorp LP, College Station, Texas). Reference intervals were computed by adding the mean of their measurements calculated.

The gender distribution was 56:44 male:female. The mean age of the patients was 9.41 years (1.0 to 15.8). Of the 227 patients, 22 were aged one to three years, 57 were aged four to seven years, 92 were aged eight to 11 years and 56 were aged 12 to 15 years.

Intra-observer variation in the measurement of Bohler’s angle demonstrated disagreement of < 2.5° in 82.4% of cases (187 patients). This level of agreement was at its lowest in the 0 to three-year age group (68.2% < 2.5° disagreement (15 of 22)) and at its highest in the four- to seven-year age group (87.7% < 2.5° disagreement (50 of 57)). No measurements disagreed by more than 6.1°. Inter-observer variation in the measurement of Bohler’s angle demonstrated a higher level of disagreement: 59.9% of cases demonstrated disagreement < 2.5° (136 patients). This was lowest in the eight- to 11-year age group (51.1% (46 of 90)) and highest in the four- to seven-year age group (70.2% (40 of 57)). No measurements disagreed by more than 8.0°.

There was a much greater level of disagreement in the measurement of Gissane’s angle. Only 31.7% of observations by the same clinician (72 patients) and 21.1% of those by different clinicians (48 patients) were within 2.5°. This was lowest in the 0 to three-year age group (22.7% intra-observer (5 of 22) and 9.1% inter-observer (2 of 22)). Intra-observer disagreement > 10° was seen in 18.9% of cases (43 patients), highest in the eight to 11-year age group (51.1% (46 of 90)) and lowest in the 12- to 15-year age group (12.1% (seven of 58)). Of measurements by the same observer, 2.6% differed by > 20° (six patients). Inter-observer disagreement was even greater, with 29.5% (67 patients) of all measurements disagreeing by > 10° and 5.3% (12 patients) by > 20°. This disagreement was highest in the 0 to three-year age group, with 40.1% (9 of 22) disagreeing by 10° to 20° and 18.2% (4 of 22) by > 20°.

Intraclass correlation coefficients were calculated to investigate the intra- and inter-observer reliability of measuring Bohler’s and Gissane’s angles (Table 1). We found excellent intra- and inter-observer reliability of measuring Bohler’s angle throughout all age groups. Measuring Gissane’s angle demonstrated poor to fair intra- and inter-observer reliability throughout the age groups with the exception of intra-observer reliability in the 12- to 15-year age group which was good. There was a trend of improving reliability as age increased.

### Table 1. Intraclass correlation coefficients (95% confidence interval) of intra- and inter-observer reliability for measurement of Bohler’s and Gissane’s angles

<table>
<thead>
<tr>
<th>Years</th>
<th>All ages (n = 227)</th>
<th>0 to 3 (n = 22)</th>
<th>4 to 7 (n = 57)</th>
<th>8 to 11 (n = 92)</th>
<th>12 to 15 (n = 56)</th>
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</thead>
<tbody>
<tr>
<td><strong>Bohler’s</strong></td>
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<td>Intra-observer</td>
<td>0.947 (0.893 to 0.958)</td>
<td>0.920 (0.844 to 0.960)</td>
<td>0.926 (0.886 to 0.952)</td>
<td>0.933 (0.906 to 0.953)</td>
<td>0.938 (0.848 to 0.962)</td>
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<tr>
<td>Inter-observer</td>
<td>0.903 (0.879 to 0.922)</td>
<td>0.892 (0.793 to 0.945)</td>
<td>0.854 (0.779 to 0.905)</td>
<td>0.885 (0.839 to 0.918)</td>
<td>0.878 (0.803 to 0.925)</td>
</tr>
<tr>
<td><strong>Gissane’s</strong></td>
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<tr>
<td>Intra-observer</td>
<td>0.566 (0.483 to 0.639)</td>
<td>0.194 (0.155 to 0.5)</td>
<td>0.373 (0.133 to 0.571)</td>
<td>0.562 (0.428 to 0.672)</td>
<td>0.744 (0.624 to 0.829)</td>
</tr>
<tr>
<td>Inter-observer</td>
<td>0.450 (0.354 to 0.537)</td>
<td>0.036 (0 to 0.371)</td>
<td>0.450 (0.223 to 0.631)</td>
<td>0.484 (0.336 to 0.608)</td>
<td>0.452 (0.255 to 0.613)</td>
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Results

We identified 356 patients as having had a lateral radiograph of the ankle taken as part of their hospital attendance between the beginning use of the PACS databases and May 2007; 128 films were excluded as being of poor quality and one because of the presence of a fracture of the os calcis. This left radiographs from 227 patients which were used in this study. The gender distribution was 56:44 male:female. The
Bland-Altman plots were generated to demonstrate the appropriateness of using a single measure of agreement for the angles measured (Fig. 1). Neither the intercept nor the slope of the regression models was significant (p = 0.52 and p = 0.61, respectively, for Figure 1). The mean difference was therefore assumed to be zero. Regressing the absolute residuals from this model also showed no relationship with the mean. This implies that neither the mean nor the SD of the two observers changes depending on the size of the angle being measured, and so one measure of intraclass correlation coefficient is adequate.

Given the inability to measure Gissane’s angle reliably, these data were not further analysed, but we felt that the reliability of the measurements of Bohler’s angle warranted further analysis. We had observed that the Bohler’s angle tended to vary with age, and therefore analysed our data to see whether any pattern could be demonstrated.

Using the documented methods, we estimated the parameters of a model describing the relationship between Bohler’s angle and age, and provided the associated 50% and 95% reference intervals (Fig. 2). The reference intervals presented in Figure 2 are based on a fractional polynomial of degree 3,\(^{16}\) with random doctor and patient effects as well as residual variance.

The relationship between the Bohler’s angle and age was formulated separately for each gender. No significant difference was seen between the curves produced for male and females (p = 0.12), although the reference intervals were wider, in keeping with the reduced sample sizes.

**Discussion**

Fractures of the os calcis are rare in children.\(^1\) As in adults, the most common cause is a fall from a height, although fractures from direct trauma to the heel account for a higher proportion of fractures than in adults.\(^2\) The traditional view of these paediatric fractures is that they tend to do well if managed conservatively,\(^7\) but recently attention has turned to the operative management of such injuries.\(^1,9,10\)

In the literature on adult fractures of the os calcis, Bohler’s angle and, to a lesser degree, Gissane’s angle, are frequently quoted. As the morphology of the os calcis varies with age in children, some authors have raised concerns about the reliability of Bohler’s angle in children.\(^2,6\) Despite such concerns, it is commonly used in studies of these fractures in children. It has been used as a measure of the severity of articular displacement,\(^7\) as an indication for operative management\(^10\) and as an outcome measure for the management of these fractures, both operatively\(^8,10\) and conservatively.\(^7\)

This study has demonstrated that the measurement of Bohler’s angle is reliable and reproducible in children of all ages. We therefore feel its continuing use in children is valid. However, we have failed to demonstrate any reliability of Gissane’s angle. The large inter- and intra-observer variation in its measurement makes reliable conclusions drawn from observed changes in the angle meaningless. We consider it to be of no value in the study or management of fractures of the os calcis in children.

It is recognise that as the os calcis grows its morphology changes, and that this will have an impact on the angles measured. Measurements of 11 angles excluding Bohler’s or Gissane’s in 74 children’s feet showed distinct variations of each angle with age, which was attributed to maturation of the foot.\(^17\) The angles measured included the talocalcaneal, talus-first metatarsal, calcaneus-fifth metatarsal angles on anteroposterior radiographs and the talocalcaneal, tibiocalcaneal, tibiotalar, talus-first metatarsal and talohorizonal on lateral radiographs. It has been stated that in children Bohler’s angle tends to be smaller than in
adults. This has been ascribed to the late ossification of the posterior lip of the posterior facet and the tuberosity as the child enters the second decade, resulting in a flatter angle than in adults, which may mimic a fracture.

We have shown that Bohler’s angle in children is not uniformly lower than in adults, which are often quoted as between 20° and 40°. Although the angles in the very young are indeed lower than in the adult, they rapidly increase with age. By the age of seven years the estimated mean angle in our series was 42°, with a 95% confidence interval of 31° to 53°. The angle tends to decline towards adult values as the child enters adolescence.

An explanation for this variation can be suggested by examining the series of radiographs used in this study. In the very young child, the ossification centre of the calcaneum is devoid of most features and thus the angle is low (Fig. 3a). With increasing age, the posterior facet begins to appear, giving an increase in the angle (Fig. 3b). As the child approaches the age of six to eight years, the development of the posterior facet is out of proportion to that of the calcaneal tuberosity, giving an angle greater than that seen in the adult foot (Fig. 3c). Finally, as the patient reaches skeletal maturity, the tuberosity develops and the morphology approaches that of the adult os calcis.

Lateral radiographs demonstrating the morphology of the paediatric os calcis at (a) 1.2 years, (b) 3.2 years, (c) 7.6 years and (d) 11.7 years.
(Fig. 3d). This observed development is in agreement with that described by Schindler, Mason and Allington. 19

There are several limitations to our study, particularly the analysis of the variation of Bohler’s angle with age. Our population sample represents all patients attending two busy central London Accident & Emergency departments. The catchment populations for these hospitals are racially diverse, as is typical of large metropolitan centres. In adults, it has been shown that the normal range for Bohler’s angle varies between racial groups. 20,21 We would therefore expect to see some variation in the angle in children of different ethnic groups, but we did not have access to this information.

We observed no statistically significant difference in the age variation of Bohler’s angle between genders. This agrees with the work of Vanderwilde et al., 17 who measured 11 angles in normal paediatric feet and noted no difference between the genders. However, this may reflect our sample size, and a larger study might demonstrate a difference.

In this study we have shown that the measurement of Bohler’s angle is valid in children but that of Gissane’s angle is not. The demonstrated variation in Bohler’s angle with age should be borne in mind when using this angle as an indicator for treatment of calcaneal fractures in children.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References