Distal tibial physeal fractures are the second most common growth plate injury and the most common cause of growth arrest and deformity. This study assesses the accuracy of pre-operative planning for placement of the screws in these fractures using either standard radiographs or CT scans.

We studied 62 consecutive physeal fractures over a period of four years. An outline of a single cut of the CT scan was used for each patient. An ideal position for the screw was determined as being perpendicular to and at the midpoint of the fracture. The difference in entry point and direction of the screw between the ideal and the observers’ assessments were compared using the paired Student’s t-test. There was a statistically significant improvement \((p < 0.0001)\) in the accuracy of the point of insertion and the direction of the screw on the pre-operative plan when CT scans were used rather than plain radiographs.

We would, therefore, recommend that CT scans are routinely used in the pre-operative assessment and treatment of distal tibial physeal fractures.

Distal tibial physeal fractures are the second most common growth plate injury accounting for between 11% and 33% of this type of injury.\(^1\) They are most common in boys aged between ten and 15 years and are the most common cause of growth arrest and deformity.\(^1,4\)

The type of fracture is determined by the pattern of ossification of the growth plate. The distal tibial physis begins to close in a characteristically asymmetric pattern about 18 months before the cessation of tibial growth. Fusion begins in the midportion seen as a tibial ‘hump’ on the anteroposterior (AP) radiograph. As fusion proceeds, the medial part of the plate closes, then it progresses posteriorly and finally, the anterolateral part of the plate fuses.\(^2,5-8\) The fused part of the epiphyseal plate becomes an area of relative strength. The irregular fusion pattern and the resulting areas of relative strength and weakness are responsible for the unusual transitional fracture patterns, specifically, juvenile Tillaux and triplane fractures. Epiphyseal closure normally occurs by the age of 12 to 14 years in girls and 15 to 18 years in boys.

Operative treatment is indicated more often in ankle fractures than in other lower limb injuries because of the high rate of complications. These are usually due to failure of reduction and include stiffness of the ankle, joint incongruity, osteoarthritis and growth arrest.\(^1,2,6,9\)

Partial arrest is more common than complete arrest and can lead to angular deformity, shortening or a combination of the two.\(^10\)

Open reduction is indicated in grossly displaced intra- or extra-articular fractures, open fractures or where there has been a failure to obtain and/or maintain reduction. Opinions vary as to the accuracy of reduction which is required from precise anatomical reduction to displacement of less than 2 mm.\(^1,2,7,9,11-14\)

The purpose of our study was to determine if there was any difference in the accuracy of the entry-point and direction of screws when using standard radiographs compared with CT scans.

**Patients and Methods**

Over a four-year period we assessed 62 consecutive patients with distal tibial physeal fractures. We made three outlines on tracing paper of a single cut of the CT scan for each patient; two of these did not have the fracture marked (Fig. 1). Four surgeons (two consultants and two middle-grade trainees) were asked to mark on one of the unmarked outlines a pre-operative plan for the best position of screw placement using plain radiographs only. One week later they were asked to repeat this on a fresh outline using the CT scan only. This was done for all fractures by each observer.
Two other authors (LC, AM), not those who had used the unmarked outlines, used the third outline with the fracture traced on it as well as both CT and plain radiographs to plan the optimum position of the screw. This position was drawn perpendicular to the centre of the fracture line (Fig. 2). In this position it should exert the most compression creating stability and aiding bony union and cartilage healing. This was repeated for each patient. In all the fracture patterns seen, the ideal position of the screw was surgically possible using a standard approach, without compromising important soft tissues.

We laid each of the observer’s drawings precisely over the ideal position and measured the distance between the entry-points and the difference in angle of the direction of the screw (Fig. 3).

The results were statistically analysed using the paired Student’s t-test and the Bland and Altman test.

Results

There were 62 patients with a mean age of 13.4 years (8 to 16). The mean ages were 13.4 years for the 29 patients with a Salter Harris type-II fracture, 12.9 years for the 21 with a type-III fracture, 14 years for the four with a type-IV fracture and 14.4 years for the eight with a triplanar fracture.

There were statistically significant differences between the use of plain radiographs and CT scans to determine both the entry-points and the direction of the screws. Using plain radiographs, the mean difference between the observers’ entry-point and the ideal position was 12 mm (0 to 20). Using CT scans this was reduced to a mean of 2 mm (0 to 19.5). The mean difference between the observers’ direction of the screw and the ideal position was 31˚ (0 to 87) using plain radiographs. This was reduced to 6.5˚ (0 to 42) using CT scans. Both of these figures were significant (p < 0.0001).

Figure 4 illustrates the mean differences between the observed and ideal entry-points for each of the four observers using both plain radiographs and CT scans. Figure 5 shows the mean difference between the observed and ideal direction of the screws for each observer.

The statistical tests were repeated for each observer and each type of fracture. Despite the small number of some types of fractures, all results reached significance (p < 0.0001). The Bland and Altman test, comparing the entry points of the screw determined by two observers using CT scans gave narrow 95% confidence intervals suggesting good interobserver correlation. Comparing the record by each observer of the entry point and direction of the screw on radiography and CT scan showed very poor correlation, indicating a large difference in the accuracy of the two methods.

Figure 6 shows a plain radiograph of a Salter Harris type-III fracture. Figure 7 shows a slice of the corresponding CT scan and Figure 8 shows the post-operative radio-
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Graphs. Figure 9 shows post-operative radiographs of a fracture which was fixed without careful pre-operative planning using a CT scan and Figure 10 shows the corresponding CT scans. The plain radiograph shows an incomplete reduction, which is more apparent on the CT scan which also demonstrates screws within the fracture site.

Discussion

Aitken suggested that crushing the epiphysis at the time of injury was responsible for growth disturbance and that this disturbance was not determined by treatment. Many studies have shown, however, that treatment has a major effect on complication rates. Salter and Harris showed in experimental rabbits that the fracture gap in the physis fills with bone so that the metaphysis fuses to the epiphysis. They, therefore, recommended that physeal fractures should be anatomically reduced so as to eliminate the gap in which the bony bridge forms.

Cooperman et al stated that all fractures with more than 2 mm of displacement should be reduced with the initial attempt being closed. Ertl et al showed in a study of 25 triplane fractures that more than 2 mm displacement...
was associated with a high rate of complications. No patient whose fracture was reduced to less than 2 mm displacement had a functional or symptomatic grade less than good using a modified Weber protocol. Papariz et al.\textsuperscript{12} found that all patients with a residual displacement of more than 2 mm had degenerative changes at six to nine years. Kling et al.\textsuperscript{1} and Kling\textsuperscript{2} found that only two of 24 patients with growth arrest following a Salter Harris type-III or type-IV fracture had had an adequate initial reduction. In his prospective study of 35 children with distal tibial fractures, three patients with residual displacement of more than 2 mm developed premature growth arrest. They recommended anatomical reduction and noted that there were no post-operative complications after internal fixation.
Spiegel et al. divided distal tibial epiphyseal fractures into three risk groups depending on their Salter Harris type and displacement. Low-risk fractures were considered to be type-I or type-III/IV with less than 2 mm displacement, which carried a 6.6% risk of complications. Salter Harris-type II fractures were unpredictable as the rate of complications was independent of the displacement and the risk was 16.7%. High-risk fractures were Salter Harris type-III/IV with more than 2 mm displacement and comminuted fractures, which carried a 32% risk of complications. They concluded that distal tibial fractures should be anatomically reduced.

In order to reduce and fix fractures accurately, the exact fracture pattern should be known. Horn et al. studied the accuracy of plain radiographs and CT scans in determining the displacement of Tillaux fractures in cadaver specimens. They found that CT scans were far more accurate than plain radiographs in differentiating between displacement of more or less than 2 mm. Several authors have recommended that CT scans be carried out to elucidate the fracture pattern and displacement in more complex distal tibial physeal fractures. Lag screws should be inserted through the centre of the fracture and perpendicular to its plane in order to exert the most compression. This also aids articular cartilage regeneration and healing.

We conclude that identification of the entry point and direction by the screw is significantly more accurate using CT scans compared with plain radiographs. We, therefore, recommend that CT scanning is used routinely in conjunction with plain radiographs for the pre-operative planning of fixation of distal tibial physeal fractures.

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References