Fracture after distraction osteogenesis

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We reviewed 173 patients undergoing distraction osteogenesis to determine the incidence, location and timing of fractures occurring as a complication of the procedure.

There were 17 fractures in 180 lengthened segments giving an overall rate of fracture of 9.4%.

Unexpectedly, the pattern and location of the fractures were very variable; six were within the regenerate itself, six at the junction between the regenerate and the original bone and five at distant sites in the limb. Of those occurring in the regenerate, five were noted to be associated with compression and partial collapse of the regenerate. In three patients collapse and deformity developed gradually in the distracted segment over the six months after removal of the frame.

The method of treatment of these fractures should be chosen to take into account multiple factors, which are additional and often different from those to be considered during management of acute traumatic injuries. Internal fixation appears to be most appropriate for displaced fractures, although in small children, or in those in whom there has been, or is, infection of the screw tracks, a new period of treatment using external fixation may be needed. Fixation by intramedullary nailing was associated with a risk of infection, even if screw tracks were assessed as healthy at the time of insertion of the nail. Internal fixation with the use of plates is safe for displaced, unstable fractures in children.

The introduction of methods of limb lengthening, which encourage effective formation of bone within the distracted segment, has reduced the incidence of fracture after lengthening. Unfortunately, however, this complication still occurs and often leads to the need for further surgical intervention which lengthens the time of treatment.

Our aim was to determine the incidence and pattern of fracture after distraction osteogenesis. The results of the treatment of the fractures are presented and predisposing factors identified.

Patients and Methods

We reviewed the results of 180 procedures on 173 patients in whom distraction osteogenesis had been carried out. We used unilateral systems (Dynabraces; Smith & Nephew, Cambridge, UK), limb lengtheners and limb reconstruction rails (Intravent; Orthofix, Maidenhead, UK), Red Monotube with multi and single pin clamps (Howmedica, Staines, UK) and circular external skeletal fixation frames (Ilizarov; Smith & Nephew). There was a minimum period of six months between the time of removal of the frame and review. We analysed all records, radiographs and ultrasound examinations, made at two-weekly intervals. All the fractures were examined, according to time of occurrence, site and pattern of bone failure. Table I gives details of the aetiology of shortening of the limb in those patients in whom a fracture occurred.

Results

There were 17 fractures in 15 patients (two patients each had two fractures) after 180 procedures. The site of fracture varied widely; they also varied in time, in relation to the removal of the frame and in their overall pattern.

Time of fracture. Acute fractures occurred within six weeks of removal of the frame in nine instances, but in three patients an insidious late fracture occurred with deformity noticed several months after the frame had been removed (Fig. 1). One patient had a second fracture 12 days after removal of the frame through the screw holes of a plate which had been applied for treatment of a previous fracture which occurred two days after removal of the frame (Fig. 2a). Four patients had a fracture with the frame...
still in situ. In one of these, it occurred through the screw tracks of the external fixator (Fig. 2b), in two the ipsilateral tibia fractured while the femur was being lengthened, and in one the fracture was in the contralateral femur when the patient was walking with a frame applied to the tibia.

**Site of fracture.** The regenerate itself fractured in six patients. A further six fractures occurred at the junction between the original bone and the regenerate. In the remaining five patients the fracture occurred as a result of minimal violence at levels separate from the distracted segment. In two of these, they were through screw tracks (Fig. 2b). A fracture was also seen through the upper tibial growth plate in one femoral lengthening (Fig. 3). In the 17 instances of fracture only two of the regenerates showed a narrowed portion producing a waist in the new bone of smaller diameter than the original bone (Fig. 4a). The fracture through one of these segments occurred within the waist and in one, surprisingly, not at the waist, but at the junction of the regenerate and the original bone (Fig. 4b).

**Pattern of fracture.** Two radiological patterns of bone failure were observed. In one there was partial collapse of the regenerate, which resulted in angulation. This happened

**Table I.** The pattern of the 17 secondary fractures which occurred in 15 patients after distraction osteogenesis

<table>
<thead>
<tr>
<th>Fracture</th>
<th>Maturity (number of fractures)</th>
<th>Aetiology (number)</th>
<th>Bone (number)</th>
<th>Length of regenerate (cm)</th>
<th>Method of stabilisation*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within regenerate with collapse</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute</td>
<td>Adult (2)</td>
<td>Trauma (1)</td>
<td>Tibia (1)</td>
<td>5</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>Osteomyelitis (1)</td>
<td></td>
<td>Femur (1)</td>
<td>6</td>
<td>C</td>
</tr>
<tr>
<td>Gradual</td>
<td>Adult (2)</td>
<td>Congenital (2)</td>
<td>Tibia (2)</td>
<td>5,4</td>
<td>N (2)</td>
</tr>
<tr>
<td></td>
<td>Congenital (1)</td>
<td></td>
<td>Tibia (1)</td>
<td>4</td>
<td>C (1)</td>
</tr>
<tr>
<td>Within regenerate without collapse</td>
<td>Child (1)</td>
<td>Congenital (1)</td>
<td>Femur (1)</td>
<td>6</td>
<td>P</td>
</tr>
<tr>
<td>Junctional</td>
<td>Child (6)</td>
<td>Trauma (1)</td>
<td>Tibia (1)</td>
<td>6,5</td>
<td>P (2)</td>
</tr>
<tr>
<td></td>
<td>Osteomyelitis (1)</td>
<td></td>
<td>Femur (6)</td>
<td></td>
<td>Ex (3)</td>
</tr>
<tr>
<td></td>
<td>Congenital (4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Through screw track</td>
<td>Child (2)</td>
<td>Congenital (2)</td>
<td>Femur (2)</td>
<td>6</td>
<td>P</td>
</tr>
<tr>
<td>Distant site</td>
<td>Child (3)</td>
<td>Trauma (1)</td>
<td>Tibia (1)</td>
<td>6,3,1</td>
<td>Ex</td>
</tr>
<tr>
<td></td>
<td>Metabolic (1)</td>
<td></td>
<td>Femur (2)</td>
<td></td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>Congenital (1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* N, intramedullary nail; Ex, external fixation; P, plate; C, cast
both acutely (Fig. 5) and gradually (Fig. 1). In the remaining fractures, no loss of length of the regenerate itself was observed; complete non-committed fractures were sustained in the region of the regenerate (Fig. 6).

Factors predisposing to fracture. The mean range of knee movement in the six patients whose fractures occurred through the junction of the regenerate and original bone was 28°. In the remaining patients with a fracture it was 85° at the time when this occurred.

In the overall series of 180 lengthenings, ‘cysts’ developed in 12, in five of which bone grafting of the distracted segment had been performed before the frame was removed. They healed well. In two patients the ‘cysts’ were small (less than 5 mm in diameter) and peripheral. They were left untreated and healed spontaneously without complication. In four patients the ‘cysts’ were aspirated, lengthening was stopped for a week and then recommenced at a slower rate. In one of these patients the ‘cyst’ did not reappear. In the other three patients, however, the ‘cysts’ recurred although smaller in size; two of these segments healed, and one fractured. In one patient, treated early in the series, large ‘cysts’ were left untreated and were seen to persist even after the consolidation period. The bone subsequently fractured. The persistence of large ‘cysts’ appears to be a predisposing factor to fracture.

In our series, fractures occurred in patients of all ages and with both small and large lengths of regenerate. There appeared to be no direct relationship between the risk of fracture and age or length of the segment (Table I).

Classification of fracture. On the basis of the site, pattern and timing of the fracture we have developed a classification as shown in Table II and Figure 7.

Treatment. A variety of methods of treatment was used to allow for a number of individual factors, including skeletal maturity, stability of the fracture and its suitability for surgical fixation or treatment in a cast (Table I). Account was also taken of the risk of developing infection from sepsis at the screw hole, the severity of stiffness of the knee and the tolerance of the patient for a further protracted period of treatment. The quality of the regenerate was also assessed to see whether bone grafting was needed.

All fractures eventually healed soundly, without loss of the length gained, and without the development of permanent deformity associated with the fracture, with the single exception of the patient who developed acute collapse and was treated in a cast. This patient required a subsequent corrective osteotomy.

Complications. In adult patients, with displaced type-I fractures and apparently satisfactory screw tracks, the limb was realigned and an intramedullary nail inserted. Deep
infection, which was confirmed bacteriologically, developed in all three patients in whom this method was used. In each instance, the screw tracks were well healed at the time of insertion of the nail. The interval of time left between removal of the frame and intramedullary nail fixation was between three and 25 weeks and infection still occurred. On the radiographs there was no sign of local infection although a widened screw track was visible. All infections settled completely after debridement. The nail was removed after bone healing and the infection
had not recurred at the time of follow-up at least two years later.

One refracture in the femur occurred after the use of a plate and screws. The plate bridged the distracted segment, but there was refracture at the level of the most distal screw (Fig. 2a).

Discussion

Fracture after distraction osteogenesis is a serious complication which leads to a considerable increase in morbidity. Our study and that of Bernard et al.\(^\text{10}\) have both shown that fractures do occur, despite attempts to minimise the problem. Fractures in the region of the regenerate occurred early after removal of the frame in 5% of our patients which is comparable with the incidence described by DeBastiani et al.\(^\text{2}\) If all fractures are considered, the rate rises to 9.4%. This is similar to that reported by Stanitski et al.\(^\text{11}\) who included all bony problems.

The controllable factors which enhance effective bone formation have already been described.\(^\text{12-16}\) They include a low-energy osteotomy, a delay before distraction is commenced and a slow rate of distraction carried out in small daily increments. Bone does not, however, always form effectively and variable patterns of bone formation have been described on radiographs by Hamanishi et al.\(^\text{17}\) If the bone formed is not adequate as assessed by ultrasound,\(^\text{18,19}\) radiography,\(^\text{17,20,21}\) or by measurement of stiffness, the dynamics of distraction can be changed. Unfortunately, such manoeuvres, which include the use of the accordion technique, are not always effective, resulting in an insufficient quality or quantity of bone. In our group of patients the formation of cysts was associated with a poor final regenerate and a bone graft was often required. In the two instances when this protocol was not employed there was collapse of the regenerate when the frame was removed.

Aldegheri, Renzi-Brivio and Agostini\(^\text{22}\) stressed the importance of loading the distracted segment for several weeks before removal of the frame. Similarly, Ilizarov\(^\text{14}\) recommended loading the distracted segment in order to accelerate bone consolidation. The results from a large number of patients have shown low rates of fracture. In our study weight-bearing was encouraged. Unilateral fixators were also dynamised to allow axial slide. When circular frames were used distraction was reversed by making a few turns of the screws when the regenerate had sufficient maturity to resist collapse.

Despite the use of these measures to enhance osteogenesis and the careful assessment of healing at the time of removal of the frame,\(^\text{5}\) fractures have occurred. Various patterns were seen and classified according to a system shown in Table II and Figure 7.

Approximately one-third of all fractures occurred at the

<table>
<thead>
<tr>
<th>Type</th>
<th>Classification of the fracture</th>
<th>Number of fractures</th>
<th>Prevention</th>
<th>Treatment of fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Within the regenerate:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Collapse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Acute</td>
<td>2</td>
<td>Bone graft large cysts before frame removal</td>
<td>Operative stabilisation ± bone graft</td>
</tr>
<tr>
<td></td>
<td>Gradual</td>
<td>3</td>
<td>Accelerate maturation by dynamisation/compression of frame</td>
<td>Osteotomy and operative stabilisation</td>
</tr>
<tr>
<td></td>
<td>No collapse</td>
<td>1</td>
<td>Strengthen bone by dynamisation/compression ± bone graft ± brace</td>
<td>Stabilisation: operative for displaced and non-operative for undisplaced</td>
</tr>
<tr>
<td>II</td>
<td>Junctional</td>
<td>6</td>
<td>Physiotherapy to maintain range of movement of knee</td>
<td>Stabilisation ± quadricepsplasty</td>
</tr>
<tr>
<td>III</td>
<td>Through screw track</td>
<td>2</td>
<td>If possible use wires or narrower external fixation screws</td>
<td>Operative stabilisation</td>
</tr>
<tr>
<td>IV</td>
<td>Distant site</td>
<td>3</td>
<td>Increase weight-bearing to reduce osteoporosis</td>
<td>Operative stabilisation for displaced and non-operative for undisplaced</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>17</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 7

The patterns of fracture as defined in Table II.
external fixation was an essential component of leg lengthening. Despite precautions to ensure that the tracks were well healed, infection was seen in three patients. Radiographs showed wide screw tracks at the time of nailing in each instance, and it is probable that there was low-grade infection and some necrotic bone lying within these. Tracks should be formally curetted at the time of removal of the frame in adults considered to be at risk of sustaining a subsequent fracture. Nailing is probably still the treatment of choice for such fractures, although special precautions are required. In a recent study, Antich-Adrover et al.\textsuperscript{27} recommended that there should be an interval of at least ten days between removal of the frame and intramedullary nailing, and that antibiotics need to be given at the time of the nailing; they recorded a low incidence of infection after secondary nailing.

In children, open reduction and plate fixation gave reliable results. The plate should extend well beyond the distracted segment and the screws must avoid the previous tracks of external fixation; insertion through or adjacent to such a site risks subsequent fracture.

In a child in whom rapid healing of the fracture is expected, or in those with infected screw tracks, repeated use of an external fixation frame should be considered. Most patients, however, are reluctant to undergo a further period of treatment with the frame and onlay plate fixation is the first choice for fracture after leg lengthening.

Patients with fracture who have had a protracted period of treatment, and in whom there is grossly restricted knee flexion at the time of open reduction, require quadricepsplasty. In each case in which this has been performed with the use of postoperative continuous passive motion, the range of knee movement obtained at operation was maintained.

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References


