BIFOCAL SURGERY FOR DEFORMITY AND BONE LOSS AFTER LOWER-LIMB FRACTURES

COMPARISON OF BONE-TRANSPORT AND COMPRESSION-DISTRACTION METHODS

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We report the results in the first 16 patients treated in Sheffield using bifocal techniques for diaphyseal bone loss and deformity secondary to trauma. Eight patients had bone-transport and eight had compression-distraction methods.

At a mean follow-up of 24 months all 16 had excellent or good results with union of the fracture, correction of deformity and normal or near normal leg length. There were no major complications. Mean treatment times were 16 months for bone transport and 9.8 months for compression-distraction. Bone transport was more complicated requiring an average of 2.2 additional operations compared with only one for compression-distraction. Femoral cases had shorter treatment indices than tibial cases but had less favourable outcomes.

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Leg shortening with bone loss, deformity or nonunion after fracture provides a considerable challenge. Correction of deformity by nailing or external fixation may leave residual shortening, and secondary skeletal defects have required treatment with massive autogenous cancellous bone grafts (Christian, Bosse and Robb 1989) or vascularised bone grafts (Weiland, Moore and Daniel 1983; Weiland, Moore and Hotchkiss 1983). If bone loss has been secondary to infection, sequestration of the graft may be a problem, and the Papineau type of open grafting has been used (Papineau et al 1979).

These methods may not allow realignment or restoration of limb length, and may be associated with significant donor-site morbidity. We have used the Papineau technique for partial defects, but when infection involves the whole diaphysis or there is a large bone defect, we prefer the newer technique of callus distraction. This allows mobilisation of joints and correction of leg-length discrepancy (Ribbans, Stubbs and Saleh 1992; Saleh 1992a).

In the 1950s and 1960s Ilizarov developed the use of external fixation, compression of the defect and limb lengthening through spontaneous callus formation. He called this bifocal distraction-compression osteosynthesis (Ilizarov and Ledyaev 1992). The bone segments are fixed proximally by external fixation, and a corticotomy (bone division sparing the medulla) is performed in the metaphysis furthest from the defect.

After a delay of five to seven days, this is gradually distracted. Bone is thus lengthened by callus distraction, and the defect is gradually closed at the same rate by movement of the segment of bone between the corticotomy and the defect to meet the opposite end rather like a lift in a lift shaft. After the defect has been closed, distraction may be continued to correct any residual length discrepancy. This method, called bone transport, is used for larger defects; smaller defects can be closed at the time of surgery and compressed. Length is then gradually restored in the metaphysis; this is termed compression-distraction.

These techniques have significant advantages. The surgery is confined to the affected segment, and technetium uptake studies have shown that the metaphyseal osteotomy more than doubles the blood supply to the bone (Sveshnikov et al 1984), which has important implications for the
healing of a nonunion of the tibia. This has been shown clinically. Corticotomy improved the union rate in atrophic nonunion (Paley et al 1989). It has also been shown that the bone formed by callus distraction will remodel to a quality similar to that of normal bone (Saleh et al 1993).

We have used three types of bifocal surgery for deformity and bone defects associated with shortening. Large defects have been treated by bone transport and smaller diaphyseal defects by compression-distraction (Fig. 1a). Metaphyseal deformities and some diaphyseal hypertrophic nonunions have been treated by bifocal lengthening (Saleh and Hamer 1993) (Fig. 1b).

We now report the results in the first 16 patients treated by bifocal surgery and compare bone transport with immediate compression-distraction closure of the defect.

PATIENTS AND METHODS

We reviewed 16 consecutive men with bone loss and deformity at an average follow-up of 24 months (8 to 66) after completion of treatment. Their mean age was 31.3 years (19 to 52) and there were five femoral and 11 tibial fractures. Twelve patients had nonunion, six had active infection, three had an open fracture with initial bone loss, and one had malunion with shortening. The mean shortening was 4.8 cm (1 to 7) and the mean bone defect was 3.7 cm (1 to 7).

The three acute cases with bone loss were all in the femur, presenting at from one to 16 weeks after injury (mean 7.6). All had had only one previous operation. The other 13 patients had had salvage procedures on average 39 months after injury (7 months to 10 years) and had had an average of 3.8 previous operations (2 to 10). Further details are given in Table 1.

All patients had a metaphyseal osteotomy placed under tension to produce lengthening (Saleh 1992b). Diaphyseal deformity was treated by either a closing wedge or an opening osteotomy and compression (Fig. 2). Bone defects from trauma or resection of abnormal or infected bone were treated by initial compression when less than 3 cm in the tibia and less than 5 cm in the femur. Larger defects were treated by bone transport (Fig. 3). Eight patients had compression-distraction and eight had bone transport.

Fixation was by a unilateral or a circular fixator. The Limb Reconstruction System (Orthofix, Bussolengo, Verona, Italy) was used in ten patients and a circular frame (Sequoia, ATS, Paris) in six. A unilateral frame was used unless the defect was close to a joint, the bone was osteoporotic or gradual correction of angulation was necessary. Intraoperative alignment was ensured by fluoroscopy with an alignment grid (Saleh, Harriman and Edwards 1991).

In most of the salvage procedures amputation was the only other reliable option. It is difficult therefore to assess the results by conventional function scores. We recorded whether our treatment had achieved the goals of union, equalisation of leg length, correction of deformity and eradication of infection. We categorised the results as follows:

1) excellent, all goals achieved and no major complication,
2) good, with most goals achieved and no major complication,
3) fair, with some goals achieved and no major complication, and
4) poor, with failure to achieve goals, or any major complication.

We defined a major complication as one which persisted after the end of treatment.

RESULTS

At a mean follow-up of 24 months (8 to 66) after the removal of fixation 12 patients had excellent bony results. The four good results were in femoral cases in which leg-length equality was not achieved. Case 3 had screw loosening in osteoporotic bone which precluded further lengthening. In case 2, the patient was over two metres tall.

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Fig. 1a

Diagrams to show management of bone loss (a) and shortening with deformity (b).
Case 1. Compression-distraction of an infected, nonunited tibia. Preoperative radiographs show sclerosis proximally from previously infected pin sites which contraindicated proximal metaphyseal osteotomy (a,b). After distal osteotomy and square osteotomy of the nonunion site and compression (c), after distal lengthening (d) and the end result (e,f).

and the frame did not provide enough stability for full lengthening. In case 12, lengthening was deliberately stopped short of equalisation to avoid knee stiffness; the fracture involved the femoral condyles and required simultaneous internal fixation (Fig. 3). After removal of the frame, knee movement returned and the patient has since had a further lengthening. In case 7, discomfort led to cessation of lengthening at 2 cm from equality. Premature removal of the frame for sound reasons led to a fracture; this was treated with a new fixator and good alignment and function were obtained but a length discrepancy of 3 cm remained.

Bone transport had an average time to union of 16 months (11 to 24); compression-distraction had an average time to union of 9.8 months (5 to 12). This difference is largely because the defect is closed gradually in bone transport, delaying the start of healing at the nonunion (docking) site. The second factor is that the bone-transport group underwent more lengthening (mean 6.5 cm compared with a mean of 4.7 cm for compression-distraction). The times to consolidation per cm gain in length (treatment index) were similar at 2.4 months for bone transport and 2.65 months for compression-distraction. After bone transport the limiting factor was usually union at the fracture site, but after compression-distraction it was consolidation at the lengthening site.

Seven patients needed additional bone grafting at the nonunion site to promote consolidation, five after bone transport and two after compression-distraction. Two patients required bone grafting at the lengthening site, one after compression-distraction and one after bone transport.

Minor complications were common. Pin-site infections usually resolved satisfactorily with antibiotic treatment, but in two cases poor bone quality led to intractable pin-site infection with loosening of the frames, one unilateral and one circular. In both cases this occurred near to the time of consolidation; plaster protection after frame removal achieved union. Loosening of the wires of one ring led to frame instability requiring further pin fixation. Frame adjustment was necessary in five patients.

There were two fractures during treatment, one above an Orthofix screw and one through lengthening calus. The latter required further external fixation; both united satisfactorily without adversely affecting the result. In one bone transport the docking site eventually healed after frame removal and further frame application with bone grafting.

Infection was eradicated in the six infected cases. The bone-transport patients required a mean of 2.2 additional operations compared with one for patients having compression distraction. Five patients required no additional procedures, four after compression-distraction and only one after bone transport. The circular frames took longer to apply, but we found no other difference between the results for circular compared with unilateral fixators.

**DISCUSSION**

Bifocal diaphyseal correction produced excellent results in 12 patients and good results in the other four, all femoral. Thirteen patients had had failure of previous conventional treatment. Treatment times were long, and in some cases may have been prolonged by our inexperience. Careful selection of patients is therefore necessary.

These results represent our early experience. More recently, the techniques have been refined and the outcome is now more reliable. Bone transport is more complicated than compression-distraction, with longer treatment times and more need for secondary operations. Because the defect is closed gradually there is a delay before bony contact and compression. On occasions the transported
segment of bone may deviate as it passes through soft tissues; this may lead to translation at the docking site. We did not experience blocking of the transported segment by dense scar tissue, but in case 14 there was a bony block which required a further operation to place an olive-ended wire to deviate, temporarily, the transported bone medially.

Bone grafting will be necessary if the contact area at the docking site is small. Bone grafting at this site was needed in five of the eight bone-transport procedures. Occasionally, the leading edge of the transported segment is relatively avascular (Green et al 1992). This also can delay union unless the sclerotic end is trimmed. We have used this technique in later cases, but not in any of the present series.

In contrast to conventional limb lengthening and compression-distraction the screws or wires move with the bone during transport, cutting their way through the soft tissues and requiring soft-tissue releases under local anaesthesia. On occasions a long necrotic skin track may form behind a wire or screw, but this usually heals progressively and spontaneously. In one recent case both wires and screws were used; we saw no difference in the size or depth of the resultant necrotic tracks.

Compression-distraction is much simpler. Since the defect is closed at operation there should be no problems of translation. Good bony apposition is obtained at once and healing can start. Bone transport needed longer to union and consolidation although the treatment index was similar in the two groups. The limiting factors were union at the docking site after transport and consolidation of the lengthening site after compression-distraction. The mean gain in length was 3.7 cm in the compression-distraction group and 6.5 cm in the bone-transport group. There was a trend for the femur to consolidate faster than the tibia (treatment indices of 2.1 months per cm for the femur, and 2.85 months per cm for the tibia).

The four patients whose treatment was prolonged to over 15 months all had delayed consolidation at the docking site. Three of them had not been bone grafted, two had no resection of the bone ends. Three were the earliest cases in this series, while the fourth had problems with docking and translation of the transported segment.

Ilizarov originally described the procedure without bone graft or resection as reported by some authors (Morandi, Zembo and Ciotti 1989; Paley et al 1989; Dagher and Roukoz 1991). Others have recommended bone resection to achieve a satisfactory docking configuration (Cattaneo, Catagni and Johnson 1992; Green et al 1992). Green et al also reported that bone grafting was necessary on occasion; their biopsies showed the empty lacunae of avascular bone at the forward end of the transported segment. Bone grafting is not always necessary, but we feel that it is indicated when the contact area is small. We favour percutaneous harvesting of bone from the iliac crest (Saleh 1991); this gives less morbidity than conventional open operations (Kreibich et al 1994).

Many authors have reported the high complication and secondary operation rates after bone transport (Paley et al 1989; Cattaneo et al 1992; Green et al 1992; Marsh, Prokuski and Biermann 1994). Although we needed to perform further operations, the rate was consistent with the complexity of the procedure; minor complications did occur, but none was serious or persisted after the end of treatment.

The choice between compression-distraction and bone transport has not been widely discussed. We used compression-distraction for defects of less than 3 cm in the tibia and less than 5 cm in the femur, with bone transport reserved for larger deficits. Our recommendation includes a significant safety margin, and it remains to be seen whether the acute closure of larger defects (Giebel 1991) is safe enough to allow bone transport to be performed less often.

Bone transport takes time: a gap of 6 cm being closed at 1 mm per day adds 60 days to the treatment time. It may be possible to shorten treatment times by using bifocal transport for the longer defects; this may be doubly important since it is our impression that complications increase when treatment times exceed 15 to 18 months. Treatment times may also be reduced by an initial shortening of part of the defect followed by a shorter transport (Catagni, personal communication, 1992) or by longer immediate shortenings (Giebel 1991). These procedures have the advantage of producing shared stability between the bone ends and the fixator earlier; this offloads the fixator and reduces the likelihood of fixation failure. Another strategy recommended by some authors (Raschke et al 1992) is bone transport over a nail. This allows the fixation frame to be removed before consolidation is complete.

The choice of fixator is a matter of personal preference, but most authors have used only circular frames (Morandi et al 1989; Paley et al 1989; Cattaneo et al 1992) or unilateral fixators (Marsh et al 1994). We have used both and find the Orthofix unilateral fixator simple with excellent rigidity. We prefer it to circular frames as it is less cumbersome, quicker to apply and better tolerated by the patient. We used a circular frame when the fracture was near a joint, the bone was very osteoporotic, or a gradual correction of angulation was needed. Previous microvascular free flaps may make it unsafe to use transfraction wires in the transported segment because of the risk of pedicle transection.

Our early experience with bone transport and compression-distraction has shown that the techniques produce union and, in most cases, restoration of leg length, with few complications. They have the advantages of restricting major surgery to the affected segment, and of addressing both alignment and length with a single treatment.

The technique is complicated, and requires careful monitoring with good patient compliance and co-operation. Patients must have full understanding and mental prepara-
tion, and such surgery should be performed only in centres with experience of callus distraction (Saleh 1992b; Saleh and Scott 1992). The aim should be to complete treatment within 18 months.

Compression-distraction is simpler than bone transport and should be used whenever it is possible to close the defect directly.

When bone transport is necessary we believe that necrotic or infected bone ends should be resected and fashioned to facilitate docking, and the frame should be parallel in both planes to prevent translation. Bone grafting of the docking site, when necessary, should be performed early.

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REFERENCES


