Original article

Reconstruction of femoral bone loss with a monoplane external fixator and bone transport

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ABSTRACT

Background: Treatment of femoral bone loss is difficult. Ilizarov described the bone lengthening technique using a circular external fixator, but this technique is uncomfortable on the femur because of the circular fixator. We have therefore opted for use of a monoplane external fixator to treat femoral bone loss with bone lengthening. The objectives of this study were to determine whether (1) bone union can be obtained with a monoplane external fixator; (2) infections can be treated; (3) the lower limb axes and alignment can be controlled; and (4) patient satisfaction is high.

Hypothesis: A monoplane external fixator provides a high rate of bone union during bone transport with no risk of deformity over the long term.

Material and methods: Between 2007 and 2012 seven patients were treated with bone transport using a monoplane external fixator for femoral bone loss measuring a mean 8.1 cm (range, 6–10 cm). All were infected (osteomyelitis) or contaminated following Gustilo type IIIb fractures. The mean time from initial injury to the beginning of bone loss management was 3.9 months (range, 1.5–8 months) for six of them and 108 months for one patient.

Results: At the mean follow-up of 4.7 years (range, 2–7 years), all of the patients showed union after a mean 11.1 months (range, 8–18 months), i.e., 41.2 days/cm of transport, and all infections were resolved. Only one patient had unequal leg length measuring 2 cm and another showed 3° varus. Five patients were satisfied despite disappointing functional results. All could fully extend the knee but the mean flexion was 50° (range, 20–90°).

Discussion: This series confirms that use of the monoplane external fixation with descending bone transport to treat infected femoral bone loss is efficient and provides bone union, treatment of the infection, and control of bone axes and lengths. This technique does not allow recuperation of complete knee flexion.

Level of evidence: IV, retrospective study.

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1. Introduction

Several bone loss reconstruction procedures exist for the long bones that use à la carte bone auto- or allografts, vascularized bone lengthening, the induced membrane technique [1], or bone mobilization initially described by Ilizarov and Ledyaev [2] and conceptualized by Cattaneo et al. [3]. Few studies have been reported on the treatment of femoral diaphyseal bone loss with bone transport. This method requires particular management of the soft tissues because of using a circular external fixator that is uncomfortable for the patient and its cumbersomeness. We therefore chose to use a monoplane external fixator for bone transport. The monoplane fixator nonetheless exposes the patient to potential problems (assembly instability, pin infection) and has rarely been assessed in the literature for femoral bone transport. We have found three studies [4–6] reporting only 39 cases with time to treatment longer than six months and with a majority of the bone transport using the ascending technique.

The objectives of this study were to determine whether:

- bone union can be obtained by bone transport using the descending technique with a monoplane fixation;
- associated bone infections can be treated;
- there are axis deformities and residual length discrepancies;
- patient satisfaction is obtained.
We hypothesized that a monoplane external fixator would provide a high rate of bone union during bone transport with the descending technique with no risk of long-term deformity.

2. Material and methods

2.1. Patients

This was a retrospective, single-center study on seven patients operated on between 2007 and 2012. Diaphyseal bone loss of the femur was a mean 8.1 cm (range, 6–10 cm). There were five men and two women with a mean age of 30 years (range, 15–53 years). The etiology included five traffic accidents (four involving two-wheeled vehicles) and two ballistic injuries (isolated with no other traumatic lesion). Five of the cases involved multiple fractures, three of whom sustained multiple injuries. All the fractures were diaphyseal (five of the middle third and two of the lower third) and Gustilo stage IIIb [7]. Five of these patients were treated secondarily in our center. The mean time from the initial injury to bone loss treatment was 3.9 months (range, 1.5–8 months) for six patients and 108 months for one patient who came from abroad. According to the classification described by Catagni et al. [8], there were three B1 (bone loss only), one B2 (shortening and nonunion), and three B3 (shortening and bone loss) (Fig. 1).

2.2. Surgical technique

The patients were installed on a traction table, with the first phase consisting in débridement and cleaning of the bone loss area with bacteriological, mycological, and anatomopathological sampling. After identifying the femoral osteotomy area with the image intensifier, the two proximal and middle pin groups were inserted, then the last group of pins was inserted on the distal extremity of the femur. All of these pins had to be located in the frontal plane and be parallel. We used 50 pins covered with hydroxyapatite and six without.

Through the surgical approach, we performed a femoral corpectomy, between 2 and 4 cm under the lesser trochanter using the post-stance technique with a 3.2-mm-diameter drill, as described by De Bastiani et al. [9].

All patients received an external monoplane fixator (Limb Reconstruction System, Orthofix, Verona, Italy) designed to allow bone transport. The Ilizarov technique was used postoperatively. After five days of waiting, we progressively began bone transport at a rate of 1 mm per day. The first adjustments were made by the surgeons and the procedure was then taught to the patients. Touch-down weightbearing was authorized the 4th week and weightbearing with load was encouraged based on the pain and comfort experienced by the patient, with systemic use of two crutches. When bone union seemed acquired, we undertook progressive weaning off the external fixation by unlocking the compression system and then removing the compression unit. In all cases, the pins were removed one month later.

Once the bone transport in contact with the distal segment had been obtained, a bone autograft was performed after 6 months if there was no progression of fusion on X-rays at the docking site.

2.3. Assessment method

Bimonthly x-rays or intermediate long-leg standing films were taken to prevent malunion. At the end of treatment, a long-leg standing film was taken for each of the patients to assess possible leg length discrepancy or malunion.

3. Results

The minimum follow-up was two years (range, 2–7 years) after removal of the external fixator. The cases are detailed in Table 1. Three of the patients achieved bone union at 8–18 months (median, 10 months), a mean speed of 41.2 days/cm of transport. Six patients underwent at least two surgeries. Only one patient had a single surgery (patient no. 7) for a ballistic injury, who, after damage control for scarring, immediately underwent bone transport that resulted in bone union in 8 months with complete union at the 12th month (Figs. 2 and 3). At the last follow-up, no infectious problems were noted. The patients had undergone a mean 4.4 (range, 1–9) surgeries on their femur before we undertook treatment.

Bone loss was always diaphyseal and six of the seven cases (one case of Gustilo IIIb contamination but with negative samples) were infections proven on samples taken during bone resection at the bone loss site. Bacteria, treatment, and its duration were discussed.
in a multidisciplinary meeting in our reference center for complex osteoarticular infections (Table 2).

Four of the seven patients received exclusively pins covered with hydroxyapatite. Six patients out of seven presented signs of local infection of the external fixator pins treated with daily treatments (15 pins with hydroxyapatite, four pins without hydroxyapatite) or with removal of the infected pins (two pins without hydroxyapatite) without replacing the latter pins and without antibiotic treatment. Bone transport lasted 12–20 weeks (median, 12 weeks) for mean external fixator wear lasting 9–25 weeks (median, 17 weeks).

To obtain bone union, we needed one to five (median, three) interventions per patient. Four patients required modifications of the external fixator to control the bone axis. In two patients we performed two bone autografts at the transport site using an ipsilateral tibial rod (65 mm × 15 mm) and a vascularized fibula (160 mm) because there was no fusion progression on X-rays at 6 months and the patient was experiencing pain. Unfortunately, one patient experienced a fracture at the donar tibial site treated nonoperatively (Fig. 4). In three patients, an autograft from the iliac crest was required on the docking site.

We observed only three limb length discrepancies (1.5 cm, 2 cm, and 4 cm). These three patients used compensation (two heel pieces and a platform shoe).

A single patient presented a frontal deformity, 3° genu varum compared to the contralateral knee, but this was well tolerated.

The joint range of motion was systematically reduced. All patients could extend the knee completely but the mean flexion was only 50° (range, 20–90°). Two patients out of seven were dissatisfied with their functional result (Table 3).

4. Discussion

This study confirms that use of the monoplane fixator allows bone transport to treat femoral bone loss with a high level of fusion.

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Table 1
Mechanism, location, and origin of bone loss.

<table>
<thead>
<tr>
<th>Case</th>
<th>Age</th>
<th>Gender</th>
<th>Side</th>
<th>Bone loss size</th>
<th>Diaphyseal location</th>
<th>Mechanism</th>
<th>Grade</th>
<th>Initial management</th>
<th>Time to bone loss treatment (months)</th>
<th>Infection at bone loss site</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>F</td>
<td>Left</td>
<td>1/3 m</td>
<td>TR 2w</td>
<td>III B</td>
<td>Ext fix</td>
<td></td>
<td>2</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>M</td>
<td>Left</td>
<td>1/3 m</td>
<td>TR 2w</td>
<td>III B</td>
<td>IMN</td>
<td></td>
<td>7</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>25</td>
<td>F</td>
<td>Right</td>
<td>1/3 m</td>
<td>TR 2w</td>
<td>III B</td>
<td>Ext fix</td>
<td></td>
<td>3</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>29</td>
<td>M</td>
<td>Left</td>
<td>1/3 m</td>
<td>TR LWV</td>
<td>III B</td>
<td>IMN</td>
<td></td>
<td>108</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>19</td>
<td>M</td>
<td>Right</td>
<td>1/3 d</td>
<td>TR 2w</td>
<td>III B</td>
<td>IMN</td>
<td></td>
<td>8</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>49</td>
<td>M</td>
<td>Right</td>
<td>1/3 d</td>
<td>Ballistic</td>
<td>III B</td>
<td>Ext fix</td>
<td></td>
<td>2</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td>55</td>
<td>M</td>
<td>Right</td>
<td>1/3 m</td>
<td>Ballistic</td>
<td>III B</td>
<td>Ext fix</td>
<td></td>
<td>1.5</td>
<td>No</td>
</tr>
</tbody>
</table>

1/3 m: middle third; 1/3 d: distal third; TR: traffic accident; 2w: 2-wheeled vehicle; LWV: lightweight vehicle; IMN: intramedullary nailing

Table 2
Type of bacteria identified and treatment.

<table>
<thead>
<tr>
<th>Case</th>
<th>Infection</th>
<th>Bacterium</th>
<th>Antibiotic therapy</th>
<th>Antibiotic therapy duration (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>Pseudomonas aeruginosa/Klebsiella pneumoniae</td>
<td>Ceftazidime/ciprofloxacin</td>
<td>6</td>
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<tr>
<td>2</td>
<td>Yes</td>
<td>Clostridium butyricum</td>
<td>Amoxicillin/metronidazole</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Yes</td>
<td>Staphylococcus aureus, methicillin-sensitive</td>
<td>Rifampicin/levofloxacin</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>Staphylococcus epidermidis</td>
<td>Fusidic acid/clindacin</td>
<td>12</td>
</tr>
<tr>
<td>5</td>
<td>Yes</td>
<td>Staphylococcus aureus, methicillin-sensitive</td>
<td>Rifampicin/levofloxacin</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>Yes</td>
<td>Staphylococcus epidermidis</td>
<td>Fusidic acid/meropenem</td>
<td>12</td>
</tr>
<tr>
<td>7</td>
<td>No</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

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Fig. 3. Final results of case no. 7.

Fig. 4. Case no. 2. Catagni B2, bone loss 10 cm, bone autograft on corticotomy site with tibial bone block complicated by fracture at ipsilateral tibial sample site (orthopaedic treatment). A. Preparatory status. B. During treatment. C. At bone union after complementary tibial graft and union of tibial fracture.
without exposing the patient to misalignment over the long term. Before undertaking this treatment, it is indispensable to warn the patient on three important notions: first of all that he or she will become the main actor in bone transport, then that this is a long salvage surgery, and finally, that the mobility of the knee will be limited. It is therefore indispensable to bring up amputation in case the surgery fails.

The present study presents several limitations. The first is its retrospective design, but it is difficult to envisage a prospective study on this type of case with the limited numbers of subjects, each having a very specific clinical history. The second is the limited number of cases because the progress in traffic safety has considerably reduced the number of victims suffering from multiple injuries. In addition, given the diversity in the patients’ initial treatments, we could not conclude on the unfavorable initial management in terms of bone transport success.

The choice of bone transport with the descending technique for bone loss in a septic or contaminated milieu is open to debate. The use of osteosynthesis material (plate or intramedullary nailing) did not seem adapted and much less so an allograft. Moreover, it seemed complicated to intervene surgically in contused areas for which healing was sometimes long to obtain. Although the initial Ilizarov technique [2] required circular external fixators, we found it difficult to propose them for the thigh because of the care that was particularly difficult for the patient and the care delivery team [10–13]. However, femoral bone transport with a circular fixator has been widely reported, with approximately 300 cases to date [10,11,14–29].

The discomfort of the circular fixator led us to a monoplane external fixator, although only three studies had reported on it [4–6], which, grouped with our seven cases provides a total of 39 femoral bone transport patients using the monoplane fixator (Table 4). In the present series, which included more rapid management of bone loss, we obtained bone union in all patients. The time to bone union was similar whether the treatment included monoplane or circular external fixation, with a mean around 40 days/cm.

Optimal initial treatment is indispensable to preserve acceptable knee function. Joint stiffness sets in within the first 8–12 weeks following injury, whereas the median time to treatment is three months.

Krishnan et al. [11] reported that 90% of patients have flexion less than 30° at the end of bone loss treatment, and therefore these two problems, stiffness and bone loss, must be distinguished.

We performed a total of five complementary bone autografts on five patients. The poor bone quality stemming from the multiple surgeries and infection can work against bone union at both the osteotomy site and the docking site.

It remains difficult to demonstrate the superiority of the circular fixator compared to the monoplane external fixator and vice-versa. Iacobellis et al. [24], who used both techniques, reported the advantages and disadvantages of each method: circular fixators, notably those of the last generation (with six struts), can be used to treat larger deformities while transporting the bone but at the price of substantial bulk. On the other hand, the monoplane external fixator, easier to use and less cumbersome, seems to be indicated when the alignment is controlled. Similarly, it is more easily manipulated and explained to patients.

5. Conclusion

Treatment of femoral bone loss in a septic milieu is a long and difficult challenge. The monoplane external fixator for bone transport with the descending technique can be used to treat this type of bone loss when the leg axis is controlled and the patient is fully informed. This type of fixator in femoral bone loss treatment is an effective alternative to circular external fixators whose placement and use can sometimes disconcert both the patient and the surgeon.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.
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**References**


