Acute invaginating docking for infected non-unions of the humerus

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INTRODUCTION

Non-unions are a direct result of the initial injury and mechanical instability, often compounded by bone loss, osteomyelitis, multiple surgical procedures, disuse osteoporosis, soft tissue atrophy, and decreased arterial blood flow.1,2 Non-unions with infection limit the use of microvascular hook-ups, allografts, autografts, and devascularised cortical struts.3,4

Living tissue when subjected to slow steady traction becomes metabolically activated in both the biosynthetic and proliferative pathways, depending on vascularity and functional use. The Ilizarov technique enables simultaneous treatment for non-union, infection, shortening, deformity, and osteoporosis-to-be.5

In severe infected non-unions, radical debridement of the septic bone and soft tissue6,7 often results in a large defect, which can be treated by shortening or transport of bone segments.2 A shortening of up to 5 cm in the upper limb can be tolerated without notable cosmetic or functional disability. We
assessed the efficacy of acute invaginating docking with shortening and Ilizarov fixation for infected non-unions of the humerus. This modality enables simultaneous treatment of infected non-union, axial alignment, vascularity, stability, and function.8

**MATERIALS AND METHODS**

From June 2001 to January 2007, 8 men and 3 women aged 17 to 59 (mean, 38) years with infected non-unions of the humerus who underwent acute invaginating docking with shortening and Ilizarov fixation were prospectively studied. Informed consent was obtained from each patient. Bone ends were classified according to Schwartzman et al.9 Non-unions with one end that was rhomboidal, pencil-like, trapezoidal, or torsion wedge were included (Fig. 1). Torsion wedge at both ends was excluded to avoid excessive bone resection.
Unhealthy soft tissue was debrided aggressively. An invaginating segment of 1 cm was sculpted and fitted as a cortical peg into the medullary hole of the receiving segment (Fig. 2). The peg margins should show small punctuate haemorrhages; the base of the peg should be >1/3 of the diameter of the receiving end. A pre-assembled Ilizarov frame was affixed and compression applied at the docking site (Figs. 3 and 4). In diaphyseal non-unions, 2 rings each proximal and distal to the site were configured. In metaphyseal non-unions, 2 rings in the longer segment and one in the shorter one were configured.

Postoperatively, any angulation was corrected by differential compression and distraction using the Ilizarov apparatus. Patients were followed up every 4 weeks. Range-of-motion exercises were allowed on day 1. At 8 weeks the threaded rods were removed and the non-union site tested. Movement and pain were correlated with radiographs. Bone union was defined as radiological ‘melting’ of the invaginating peg. The frame was removed on an outpatient basis after bone union was confirmed by stress testing and radiological examination.

Final bone assessment was undertaken 6 weeks after frame removal. An excellent result was defined as bone union, no infection, deformity of <7°, and leg length discrepancy of <2.5 cm; a good result was defined as union with any 2 of the other 3 criteria; a fair result was defined as union with one of the other 3 criteria; and a poor result was defined as non-union or refracture or union in the absence of any of the other 3 criteria.

The functional result was considered excellent when the patient was active with no notable stiffness of adjacent joints (motion loss of >15°), soft tissue sympathetic dystrophy, or pain that affects activities of daily living or sleep; good when the patient was active with one or 2 of the other criteria; fair when the patient was active with 3 of the other criteria; and poor when the patient was inactive.

RESULTS

Patient characteristics and outcomes are shown in the Table. The causes of injury included traffic accident (n=5), firearm injury (n=4), and fall from a height (n=2). Five injured the right side and 6 the left. Four injured the metaphysis and 7 the diaphysis; 2 were type I, 4 type II, and 5 type III. Infection was draining in 8 and quiescent in 3; 5 were staphylococcal, 3 mixed, one klebsiella, and 2 pseudomonas. The mean number of previous surgeries was 2.7. The mean interval from injury to the present procedure was 5.8 months. The mean shortening was 2.9 cm (owing to additional debridement). The mean time to external fixation...
Table

Patient characteristics and outcomes

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Sex/age (years)</th>
<th>Injury</th>
<th>Cause</th>
<th>Type</th>
<th>Site</th>
<th>Infection</th>
<th>No. of previous surgery</th>
<th>Interval from injury to present surgery (months)</th>
<th>Defect size (cm)</th>
<th>Shortening (cm)</th>
<th>Time to union (weeks)</th>
<th>Complications</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M/45</td>
<td>Traffic</td>
<td>Traffic</td>
<td>I</td>
<td>Left diaphysis</td>
<td>Staphylococcus</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>12</td>
<td>Dysthesia, pin tract infection</td>
<td>Good</td>
</tr>
<tr>
<td>2</td>
<td>M/27</td>
<td>Traffic</td>
<td>Traffic</td>
<td>II</td>
<td>Left diaphysis</td>
<td>Mixed</td>
<td>3</td>
<td>12</td>
<td>2</td>
<td>3</td>
<td>8</td>
<td>Pin tract infection</td>
<td>Good</td>
</tr>
<tr>
<td>3</td>
<td>F/17</td>
<td>Traffic</td>
<td>Traffic</td>
<td>I</td>
<td>Left diaphysis</td>
<td>Mixed</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>12</td>
<td>Pain</td>
<td>Good</td>
</tr>
<tr>
<td>4</td>
<td>M/46</td>
<td>Firearm injury</td>
<td>Firearm injury</td>
<td>I</td>
<td>Left metaphysis</td>
<td>Pseudomonas</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>16</td>
<td>Pin tract infection, pain</td>
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</tr>
<tr>
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<td>Staphylococcus</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>16</td>
<td>Metal allergy</td>
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<tr>
<td>6</td>
<td>M/45</td>
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<td>Firearm injury</td>
<td>III</td>
<td>Right diaphysis</td>
<td>Staphylococcus</td>
<td>3</td>
<td>3</td>
<td>2.5</td>
<td>3</td>
<td>12</td>
<td>Pain, pin tract infection</td>
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<tr>
<td>7</td>
<td>F/23</td>
<td>Fall</td>
<td>Fall</td>
<td>II</td>
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<td>2</td>
<td>8</td>
<td>2</td>
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<td>8</td>
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<td>2</td>
<td>3</td>
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<td>Pin tract infection, dysthesia, pin loosening</td>
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<tr>
<td>9</td>
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<td>Fall</td>
<td>Fall</td>
<td>III</td>
<td>Left metaphysis</td>
<td>Staphylococcus</td>
<td>3</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>12</td>
<td>Pin tract infection</td>
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<tr>
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<td>1</td>
<td>2</td>
<td>-</td>
<td>1</td>
<td>28</td>
<td>Pain, ring sequestrum</td>
<td>Fair</td>
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<tr>
<td>11</td>
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<td>Firearm injury</td>
<td>II</td>
<td>Right metaphysis</td>
<td>Pseudomonas</td>
<td>4</td>
<td>11</td>
<td>2</td>
<td>2</td>
<td>8</td>
<td>Pin, pin tract infection</td>
<td>Good</td>
</tr>
</tbody>
</table>

Fixator removal was 14.9 (range, 8–28) weeks. The final bone result was excellent in 1, good in 8, and fair in 2. The functional result was excellent in 7 and good in 4.

DISCUSSION

Treatment modalities for humeral fractures include casting, bracing, external fixation, compression plating, and intramedullary nailing. Persistently infected non-unions of long bones are a therapeutic challenge, especially when associated with deformity, bone loss with leg length discrepancy, and soft tissue damage.5,13 Treatments often combine radical debridement of the septic bone and soft tissue with stable fixation,6 involving cancellous bone grafting, vascularised free tissue transfer, and electrical stimulation.12 Bone grafts should be kept moist. A large extent of graft loss makes bone grafting unsuitable for larger defects.13 Fatigue fracture, non-union, and donor-site morbidity complicate the use of composite osteomyocutaneous free tissue transfer in the reconstruction of bone defects.14 The use of long vascular pedicles for anastomosis outside the infective zone often fails.14 Electricity (in the form of direct current) is contraindicated in the presence of draining osteomyelitis and may result in immobilisation.15

Conventionally, infected draining non-unions are treated with conversion to non-draining non-unions and bone grafting.16 The Ilizarov technique should be the primary treatment for non-unions of the humerus, because it can restore function, decrease pain, and improve quality of life.17 Debridement defects can be treated by bone transport or acute shortening. A shortening of up to 5 cm in the upper limb can be tolerated without notable cosmetic or functional disability.8 Transport of a bone segment often causes non-union at the docking site, deviation from the proposed path, and refracture after frame removal.18,19 The time in the external fixator is prolonged as healing does not begin until docking.8 Bone grafting is often required at the docking site and may cause donor-site (iliac crest) infection.20

Acute invaginating docking under vision enables compression and does not rely on transformational osteogenesis. To achieve adequate bone contact and stability, the shape of the bone ends must be appropriately selected for sculpting the contact surfaces.9 Transverse cuts in the docking surfaces maximise the contact surfaces, but may result in
loss of some vascularised bone. These vascularised fragments can be preserved and uncovered by removing small bits of bone from the designated invaginating fragment. Fragments are irregularly shaped and can be used as cortical invaginating pegs. In our study, the benefits of acute invaginating docking included: (1) stability at the docking site, which was tested intra-operatively to enable alignment correction postoperatively, without fear of loss of contact; (2) no bone grafting required, owing to the increased contact area and focused compression; (3) no docking site refracture; (4) avoidance of transarticular extension of the fixator in metaphyseal fractures, owing to the stabilising effect of the peg that resulted in less fixator weight and absence of angulation at the docking site.

REFERENCES