Endoprosthetic reconstruction of the distal tibia and ankle joint after resection of primary bone tumours


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Before the advent of limb salvage surgery in the 1970s, the primary treatment for most bone tumours of the upper and lower limbs was amputation.1 However, with steady improvements in neo-adjuvant and adjuvant treatments, the development of new operative techniques, better patient selection, improved prosthetic designs, and the availability of modern methods of imaging, limb salvage surgery is now possible without adversely affecting the survival of the patient.

Primary bone sarcomas of the distal tibia and fibula are very rare; the commonest forms are chondrosarcoma and osteosarcoma.2 The best method of reconstructing the lower limb after resection of the distal tibia remains open to debate. Options include the use of autografts, allografts and modular or custom-made endoprostheses.3-10

The aim of this single-centre retrospective study was to assess the results of treating distal tibial bone tumours by en bloc excision and reconstruction with a custom-made endoprosthetic distal tibia and ankle replacement. We describe the functional and oncological outcomes of this procedure and compare them to published data.

Patients and Methods

Between 1981 and 2007, six patients with a primary bone sarcoma of the distal tibia underwent excision of the tumour and reconstruction with a custom-made endoprosthetic distal tibia and ankle replacement. There were four males and two females, with a mean age of 43.5 years (15 to 75) at the time of operation. There were two cases of osteosarcoma, two of Ewing’s sarcoma, one adamantinoma and one malignant fibrous histiocytoma (Table I). We retrospectively reviewed all clinical data from the patients’ medical records, radiological studies, and clinic reviews. Functional scores were obtained by telephone interview and patient-completed questionnaires.

All patients had been referred to our regional sarcoma service and managed by a multidisciplinary team. Staging investigations including plain radiographs, bone scans, CT and MRI were performed pre-operatively. The diagnosis was confirmed by needle and/or open biopsy in all cases. Neo-adjuvant and adjuvant chemo- and radiotherapy were tailored to the individual patient by our medical oncologists. Patients with extensive soft-tissue disease or involvement of the neurovascular bundle or fibula were not considered for endoprosthetic replacement.

We assessed functional outcome using the system adopted by the Musculoskeletal Tumour Society for the functional evaluation of reconstructive procedures after skeletal
Table 1. Details of the six patients included in this study

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (yrs)</th>
<th>Gender</th>
<th>Diagnosis</th>
<th>Year of surgery</th>
<th>Follow-up (yrs)</th>
<th>Patient survival (yrs)</th>
<th>Implant survival (yrs)</th>
<th>MSTS* (%)</th>
<th>TESS† (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>42</td>
<td>F</td>
<td>Ewing’s sarcoma</td>
<td>1981</td>
<td>27</td>
<td>Living at 275</td>
<td>275</td>
<td>73</td>
<td>71</td>
</tr>
<tr>
<td>2</td>
<td>56</td>
<td>F</td>
<td>Adamantinoma</td>
<td>1992</td>
<td>16</td>
<td>Living at 16.50</td>
<td>Tibial component 16.5</td>
<td>60</td>
<td>65</td>
</tr>
<tr>
<td>3</td>
<td>75</td>
<td>M</td>
<td>Osteosarcoma</td>
<td>2002</td>
<td>6</td>
<td>Living at 6.75</td>
<td>BKA‡: 2.6</td>
<td>60</td>
<td>57</td>
</tr>
<tr>
<td>4</td>
<td>19</td>
<td>M</td>
<td>Osteosarcoma</td>
<td>2003</td>
<td>5</td>
<td>Living at 5.5</td>
<td>5.5</td>
<td>67</td>
<td>71</td>
</tr>
<tr>
<td>5</td>
<td>54</td>
<td>M</td>
<td>Malignant fibrous histiocytoma</td>
<td>2005</td>
<td>3</td>
<td>Living at 3.4</td>
<td>BKA: one month</td>
<td>53</td>
<td>57</td>
</tr>
<tr>
<td>6</td>
<td>15</td>
<td>M</td>
<td>Ewing’s sarcoma</td>
<td>2007</td>
<td>1</td>
<td>Living at 1.6</td>
<td>1.6</td>
<td>80</td>
<td>79</td>
</tr>
</tbody>
</table>

* MSTS, musculoskeletal tumour society
† TESS, Toronto extremity salvage score
‡ BKA, below-knee amputation

Both scores are calculated as a percentage of the maximum possible score. Thus, a higher percentage indicates a better functional outcome.

The prosthesis. The prosthesis is custom made (Stanmore Implants Worldwide, Centre for Biomedical Engineering, London, United Kingdom) and manufactured using computer-assisted design and manufacturing (CAD-CAM) technology. It has a constrained design to reproduce the stability normally provided by the capsule of the ankle and its ligaments. These usually have to be sacrificed when resecting the tumour. The prosthesis consists of two components, tibial and talar, and has an ultra-high molecular weight polyethylene (UHMWPE) bearing surface on the tibial component. The latter is made of titanium alloy (TA1) with a grooved intramedullary stem for cemented fixation in the proximal tibia. Since 1993, the design has been modified to include a hydroxyapatite (HA) collar to encourage bone ingrowth. Distally, the tibial component has a nitrided surface to prevent surface wear with subcutaneous accumulation of wear debris. The talar component, which is made of a cobalt-chromium-molybdenum alloy (ASTM F75), is anchored in the talus by one or two flanges (Fig. 1).

Operative technique. The operation is performed through a standard anterior approach, dividing the extensor retinaculum and avoiding the cutaneous branches of the superficial peroneal nerve. The incision is deepened through the plane between extensor hallucis longus and extensor digitorum longus. The neurovascular bundle of the deep peroneal nerve and anterior tibial artery are identified, traced distally, and mobilised to expose the capsule of the ankle joint. The distal tibia and any surrounding tissues that need to be sacrificed to enable complete resection of the tumour are mobilised and the tibia is transected at the previously determined level and removed. Before transecting the tibia, a mark is made above the plane of transection to establish the correct rotational orientation of the prosthesis. The talus is prepared by creating a trough in the bone to match the inferior part of the talar component (Fig. 1) using a dental burr.
surface, which surrounds the trough is then denuded. Following this the talar component is cemented in situ. The proximal part of the tibia is reamed and prepared, after which the prosthesis is cemented in place. The reduction is then tested for stability. Special attention is paid during closure to ensure that the prosthesis is well covered by a soft-tissue envelope. Antibiotics are given on induction and for three days post-operatively. Initially, a plaster of Paris back slab is applied. This is replaced after 72 hours with a complete plaster cast which is retained for six weeks. Thereafter, progressive weight-bearing is allowed and is accompanied by intensive physiotherapy. Patients are followed up at regular intervals for clinical and radiological assessment (Figs 2 and 3).

**Results**

After a mean follow-up of 9.6 years (1 to 27) no patient had died and there were no cases of local recurrence or metastasis.

Two developed significant complications which led to failure of the endoprosthetic replacement and a below-knee amputation. In one a persistent superficial infection caused early breakdown of the overlying skin, which exposed the prosthesis. In the other, a deep infection developed after 31 months. After below-knee amputation, both patients remained free of disease.

The mean implant survival was 94 months (1 to 330). One patient required a revision of the talar component for aseptic loosening 13 months after the initial operation. She subsequently underwent subtalar arthrodesis and ostectomy of the os calcis for a persistently valgus position of the foot. She now walks well and remains free of disease.

One patient who was skeletally immature at the time of surgery has a 3.5 cm leg-length discrepancy when fully grown. This complication can now be avoided by careful monitoring of leg lengths and a contralateral epiphysiodesis if appropriate, or by using a non-invasive growing prosthesis.15-21

The mean functional outcome scores for the four patients with a surviving endoprosthesis were musculoskeletal tumour society 70% (60% to 80%), TESS 71% (65% to 79%), compared to the former 57.5% (53% to 60%) and the latter 57% for the patients who needed below-knee amputation and a prosthesis. The four patients with the endoprosthesis were able to put on and take off their socks and shoes, ascend and descend stairs, and walk for relatively long distances, up to three miles. Only one required a stick outdoors. They also found it much easier to shower and to get in and out of the bath than the two amputees, who found this difficult and needed to use a seat while showering. All four patients with an endoprosthesis were free of pain.

**Discussion**

The most important factor in the successful treatment of a primary tumour of bone is to achieve an adequate margin of resection. Adjuvant therapies may be needed. Reconstruction of the resulting defect in the distal tibia has been attempted using autografts,3-6 allografts,7 and endoprostheses.8-10
A published series of six patients with malignant tumours of the distal tibia managed by tibial resection arthrodesis, using an autogenous fibular graft and an Ilizarov external fixator, had a mean post-operative musculoskeletal tumour society score of 70%.3 Two of the six patients developed complications, one a local recurrence, the other an infection, and the latter needed an above-knee amputation. In a similar study,5 13 patients were treated with an autologous pedicled vascularised fibular graft and ankle arthrodesis. This group had a mean musculoskeletal tumour society score of 80%. A further study described 14 patients treated by limb salvage surgery using allograft.7 The resulting Casadei functional scores, a very similar scoring system to the tumour society scores, were mostly ‘poor’ and ‘fair’. Infection or other wound problems occurred in eight patients (57%), and four (29%) needed amputation.

It is generally accepted that biological limb reconstruction using autograft and allograft after tumour excision is more time-consuming than endoprosthetic replacement because of the need for a prolonged period of immobilisation, and is associated with a significant risk of nonunion, fracture and infection.22,23

There have been a small number of reports on the use of endoprostheses to reconstruct the lower limb after resection of tumours in the distal tibia.8-10 These are summarised in Table II and compared with our results.

The increasing use of total ankle replacement (TAR) is reflected by a growing number of published reports. It is increasingly offered as an alternative to ankle fusion both in inflammatory or degenerative disease of the ankle joint and in trauma. Most studies describe a satisfactory functional outcome and survival of the prosthesis.24-27 In the case of tumours of the distal tibia, however, the literature is limited. The rarity of this condition has not resulted in any large case series which allows us to analyse the effectiveness of this intervention vs amputation.

Limb salvage at the level of the distal tibia is complicated by the complex biomechanics, and the difficulty of obtaining adequate soft-tissue cover.28 Infection has been shown to be the most frequent cause of failure of proximal tibial endoprosthetic replacements,29 and our results indicate that this is also a common complication in the distal tibia (Table II).

Some authors have shown that increasing age has no detrimental effect on the functional outcome of this operation for non-neoplastic conditions.26 Whether or not this is true for patients with malignant disease is unknown. Other studies, however, have shown that the survival of the prosthesis is worse in younger patients and in those who have had a greater proportion of the tibia resected.30 Mechanical failure can also be the result of polyethylene wear. In our study, we had only one case of mechanical failure. This was aseptic loosening of the talar component and occurred after 13 months. The component was replaced together with the UHMWPE insert, and the patient remains free of disease 15 years later, with a musculoskeletal tumour society score 60%, and TESS 65%.

Our results show that patients who have a bone tumour of the distal tibia treated by wide resection and reconstruction with a distal tibial replacement do well, provided they do not develop a post-operative infection. All four patients who retained their endoprosthesis remain disease and pain free, with a good functional outcome. The other two patients, who had post-operative infection required below-knee amputation, which is the treatment they would have had were it not for the development of endoprosthetic limb-salvage surgery. Attempting to salvage their limbs did not change their final oncological outcome or survival (Table I).

Custom-made endoprosthetic reconstruction of the ankle following resection of a bone tumour is a viable treatment in carefully selected patients. Pre-operative counselling is essential, and should cover the associated risks, morbidity and the possibility of subsequent amputation. However, we believe that the complication rates are acceptable if amputation is the alternative.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References

Table II. Comparison of published outcomes following endoprosthetic replacement of the distal tibia and ankle joint for bone tumours

<table>
<thead>
<tr>
<th>Study</th>
<th>Number of patients</th>
<th>Follow-up (yrs)</th>
<th>Prosthesis</th>
<th>Local recurrence</th>
<th>Metastases</th>
<th>Significant infection/wound problems</th>
<th>Amputation</th>
<th>Functional outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lee et al8</td>
<td>6</td>
<td>5.3</td>
<td>Custom-made</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>ISOLS: 80%</td>
</tr>
<tr>
<td>Natarajan et al9</td>
<td>6</td>
<td>3.4</td>
<td>Custom-made</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>MSTS: 80%</td>
</tr>
<tr>
<td>Abudu et al10</td>
<td>4</td>
<td>4.6</td>
<td>Custom-made</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>MSTS: 64%</td>
</tr>
<tr>
<td>Present study</td>
<td>6</td>
<td>9.6</td>
<td>Custom-made</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>MSTS: 70%; TESS: 71%</td>
</tr>
</tbody>
</table>

* ISOLS, International society on limb salvage; MSTS, musculoskeletal tumour society; TESS, Toronto extremity salvage score


