The purpose of this paper is to describe a biologic reconstruction strategy for defects after resection of malignant tibia tumors. Limb-sparing surgery was used for 4 patients with malignant tibia tumors. All patients were male, with an average age of 39.5 years (range: 34–46 years). Mean length of the resected tibia segment was 135 mm (range: 120–150 mm). The defects were primarily reconstructed with bone cement and locked plate until completion of the medical treatment of the tumor. The bone transport was made through locked plate, and the docking site was grafted at the final stage. Mean follow-up period was 49.75 months (range: 71–22 months). Mean distraction index was 1148 mm/days (range: 1130–1175 mm/days), and mean external fixation time was 167 days (range: 152–187 days). According to Paley, functional results were excellent in 2 cases and good in the other 2 cases. Radiological results were excellent in all cases. Two major and 2 minor complications were observed. In this method, stable internal fixation and active usage of extremities are provided until biological reconstruction, and possible wound problems can be completely eliminated during the duration of medical treatment of the tumor.

**Keywords:** Biological reconstruction; malignant tibia tumor.

Despite improvements in limb-sparing surgical treatment modalities, isolation of the surgical site with proper wound closure, making a stable reconstruction of the extremity, and providing a satisfactory functional extremity remain concerns of orthopedic surgeons involved in musculoskeletal oncology. Whichever method is preferred, the priority of the treatment should be resection of the tumor, providing satisfactory soft tissue coverage and achieving a stable fixation which allows the patient use it functionally. Stability and functional usage of the extremity until the definitive treatment of the defect could provide a huge advantage in patients, such as avoidance of disuse atrophy and possible wound problems during the long period of chemoradiotherapy. For definitive biological reconstruction, bone transport using external fixators is a common and very successful method. Though resection of the tumor and reconstruction of the extremity are different protocols, there should be a synergism between these procedures. Protecting the integrity of the skin is necessary for the prevention of wound problems that may occur during prolonged chemoradiotherapy. Permitting full weight-bearing usage of the extremity throughout the treatment period is necessary to ensure the highest level of emotional well-being and success of the final reconstruction procedure.

While the conventional bone transport method has a high success rate for extremity reconstruction, there are frequent and severe complications that are associ-
ated with it, including pin-tract infections, soft tissue contracture, fibrosis, and refracture.[7,8] In order to minimize the external fixation period, intramedullary nails are commonly used along with external fixators. Using this combination of devices decreases the rates of complications and refractures.[9] However, most malignant tumors which lead to massive bone defects are located in the b junctions of long bones in the extremities. Technically, these lead to an instability of intramedullary nails used in these procedures, and malignant cells may disperse through the medullary canal throughout the extremities.[10–12] In this study, we present a novel biological reconstruction of bone defects arising after resection of tibial sarcomas using locked plates, bone cement, and external fixators. With this technique, patients are encouraged to use their extremities functionally in every stage of the treatment.

**Case reports**

Between 2006 and 2011, 4 patients with malignant tumors of the tibia and fibula (malignant fibrous histiocytoma, osteosarcoma, synovial sarcoma, and Ewing’s sarcoma) were treated at our institution. The primary tumor was located in the proximal tibial metaphysis in 1 case, in mid-diaphysis in 1 case, in the distal tibia in 1 case, and in the distal fibula in the remaining case. The tibiotalar joint had to be resected in 2 cases and the distal third of the fibula in 1. All patients were male, with an average age of 39.5 years (range: 34–46 years). Of the 4 patients, mean length of the resected tibial segment was 135 mm (range: 120–150 mm); 150 mm of fibula was resected in 1 patient. Before surgical intervention, 3 patients were treated with chemotherapy and 1 with radiotherapy, and all received chemotherapy after resection. Mean period between the initial diagnosis and the resection was 112.25 days (range: 67–147 days), and mean period between the bone transport and the biological reconstruction after resection was 191.75 days (range: 127–361 days) (Table 1).

All patients were treated in 3 stages. In the first stage, the tumor was resected, the existing defect was reconstructed with bone cement, and the defective bone and cement combination was fixed by locked plates. The second stage of treatment was initiated after a second course of medical treatment, with the white blood cell count returning to normal levels. In this stage, the cement was removed, and bone transport was performed by external fixator. In the last stage, the transported fragment was fixed with the existing locked plate, and the docking site grafting was performed.

Longitudinal incisions were used in accordance with

<table>
<thead>
<tr>
<th>No</th>
<th>Gender</th>
<th>Age (year)</th>
<th>Side</th>
<th>Primary localization of tumor</th>
<th>Histological evaluation</th>
<th>Preop. medical treatment</th>
<th>Postop. medical treatment</th>
<th>Biopsy + 1st stage surgery</th>
<th>2nd stage surgery</th>
<th>duration (day)</th>
<th>Distraction period</th>
<th>Distraction index (day/mm)</th>
<th>External fixation</th>
<th>External fixation index (day/mm)</th>
<th>Follow up time (month)</th>
<th>Functional results (Paley)</th>
<th>Radiological results (Paley)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Male</td>
<td>36</td>
<td>L</td>
<td>Proximal tibia metaphysis</td>
<td>Malignant fibrous histiocytoma</td>
<td>Chemotherapy</td>
<td>Chemotherapy</td>
<td>125</td>
<td>110</td>
<td>160</td>
<td>140</td>
<td>1.29</td>
<td>1.42</td>
<td>152</td>
<td>71</td>
<td>Good</td>
<td>Excellent</td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>42</td>
<td>L</td>
<td>Distal tibia metaphysis</td>
<td>Osteosarcoma</td>
<td>Chemotherapy</td>
<td>Radiation Therapy</td>
<td>110</td>
<td>138</td>
<td>160</td>
<td>140</td>
<td>1.14</td>
<td>1.42</td>
<td>173</td>
<td>49</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>3</td>
<td>Male</td>
<td>46</td>
<td>R</td>
<td>Distal fibula metaphysis</td>
<td>Synovial sarcoma</td>
<td>Chemotherapy</td>
<td>Radiation Therapy</td>
<td>67</td>
<td>127</td>
<td>130</td>
<td>150</td>
<td>1.17</td>
<td>1.27</td>
<td>147</td>
<td>156</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>4</td>
<td>Male</td>
<td>34</td>
<td>R</td>
<td>Middle tibia diaphysis</td>
<td>Ewing’s sarcoma</td>
<td>Chemotherapy</td>
<td>Chemotherapy</td>
<td>147</td>
<td>361</td>
<td>150</td>
<td>150</td>
<td>1.15</td>
<td>1.27</td>
<td>172</td>
<td>57</td>
<td>Good</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

| Mean | 40   | 36.25 | 191.75 | 135 | 1.175 | 1.266 | 152 | 167 | 155 | 1.285 | 1.305 | 1.327 | 1.285 | Excellent | Excellent |

Solid and white lines were drawn at the end of the treatmental stage.
the localization and size of the mass (Figures 1a–c). Locking plates were inserted through a separate lateral incision in 3 cases (Figures 1d, e) and a medial incision in 1. In 2 cases, distal femoral lateral anatomic plates were used (d, f, g) in this case.

Fig. 1. The tumor (a–c) was resected in the first stage. Longitudinal incisions were used (d, e) in accordance with the localization of the mass. Site of the defect was temporarily reconstructed by bone cement. The cement was shaped as the original bone (f, g). Locking plates were inserted through a separate lateral incision (e). Distal femoral lateral anatomic plates was used (d, f, g) in this case.

Fig. 2. In the second session, an external fixator bridging the defect was applied to the extremity. The device was made up of 3 parts, 2 of which were used to fix the proximal and distal segments, whilst a mobile third part was used to fix the segment to be transported (a). In this case, the foot was fixed with the fixator. A lengthening osteotomy was performed in the longer fragment (b). Lengthening was continued until the defect was eliminated. The fixator was removed, the transported fragment was fixed with the existing plate, and the docking site was grafted from the iliac crest in the final stage (c, d).
were used, and in the other 2 cases, proximal tibial lateral anatomic plates were preferred. In 2 cases, the fixation was between 2 tibial fragments, while it was between the tibia and talus in the other 2 cases (Figures 1f, g).

The cement at the site of the defect replicated the shape of the original bone (Figures 1d, f, g), and teicoplanin was added to the mixture. The plate was affixed to the cement by 2–4 screws (Figures 1d, f). If necessary, anatomical layers were closed with an aspirative drain. For easier wound closure, the diameter of the extremity was decreased as needed (Figure 1e), and rotational flaps were used. As soon as wound healing was achieved, all patients were allowed full weight-bearing with protective orthoses. Medical treatment of the tumor was continued after wound healing (Table 1). In the second stage, the cement was removed through the previous incision scar, and the wound was reclosed according to the anatomical layers. A hybrid external fixator bridging the defect was applied to the extremity. The device was made up of 3 parts, 2 of which were used to fix the proximal and distal segments, while a mobile third part was used to fix the segment to be transported. A lengthening osteotomy was performed in the longer fragment (Figures 2a, b). In 2 cases, the foot was fixed with the fixator, and the knee was fixed in another. Lengthening at a rate of 1 mm/day was initiated after a latent period of 7–15 days. Lengthening was continued until the defect was eliminated. The fixator was removed, the transported fragment was fixed

Table 2. Complications and their treatment.

<table>
<thead>
<tr>
<th>Patient no</th>
<th>Complications</th>
<th>Minor</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Foot equinus, which required percutaneous achiloplasty.</td>
<td>–</td>
<td>Percutaneous achiloplasty.</td>
</tr>
<tr>
<td>2</td>
<td>Exposition of the plate after docking side grafting.</td>
<td>–</td>
<td>Remove the plate and fixation by circular external fixator.</td>
</tr>
<tr>
<td>3</td>
<td>–</td>
<td>Grade I pin tract infection</td>
<td>Local pin-site care and oral antibiotic.</td>
</tr>
<tr>
<td>4</td>
<td>–</td>
<td>Grade II pin tract infection</td>
<td>Local pin-site care and oral antibiotic.</td>
</tr>
</tbody>
</table>

During the treatment, major and minor complications (according to Paley Classification) were observed.
with the existing plate, and the docking site was grafted from the iliac crest in the final stage (Figures 2c, d). All patients were allowed full weight-bearing immediately after wound healing with orthoses until solid osseous healing.

Follow-up was conducted by clinical evaluation and laboratory tests, including C-reactive protein, sedimentation, and white blood cell count. Functional and radiologic evaluations were made according to Paley.[8] Patients were encouraged to perform muscle strengthening exercises. In order to prevent joint contractures, night splints were used during bone transport. Daily pin-site care was performed for the external fixator, and oral antibiotics were used when necessary. After wound healing, all patients were allowed to bathe. They were supported with a daily administration of 0.25 mg alfacalcidol and 1 g calcium until end of the consolidation phase.

Solid osseous union was achieved in all cases. Functional results were good in 2 patients and excellent in the other 2, and radiological results were excellent in all patients according to Paley. Mean follow-up period after the treatment was 49.75 months (range: 22–71 months). Mean distraction index was 1148 mm/day (range: 1130–1175 mm/day), mean external fixation time was 167 days (range: 152–187 days), and external fixator index was 1237 mm/day (range: 1200–1266 mm/day). During the course of treatment, 2 major and 2 minor complications were observed. Minor complications were grade I and II pin-tract infections, treated with local pin-site care and oral antibiotics. One of the major complications observed was the exposition of the plate after grafting of the docking site. For this patient, the plate had to be removed, and further fixation was provided by a circular external fixator (Figures 3a–f). The other major complication was foot equinus, which required percutaneous achiloplasty (Tables 1, 2).

Discussion

Resection of a malignant tumor within an extremity leads to significantly large soft tissue and bone defects. It usually requires an extended period to achieve a tumor-free extremity, to preserve the functional status, and to achieve satisfactory reconstruction.[13,14] Many reconstructive procedures have been described in the literature. In most cases, arthroplasty or biological reconstruction methods are preferred. Though there are advantages and disadvantages of both procedures, the common aim is to provide a stable and functional extremity with no limb length discrepancy.[15–18] Compliance of the patient is a necessity for optimal results, while maintaining the patient’s psychosocial status. Even if these can be achieved, reconstruction of the extremity is still a major concern for orthopedic surgeons treating musculoskeletal tumors.[5]

In cases where the ankle joint must be removed, arthroplasty has many complications such as infection, talar collapse, and dysfunction.[19,20] Arthrodesis using intramedullary nails and allografts has a high rate of nonunion and allograft fracture.[21] Microsurgical techniques such as vascularized fibula transfer and free tissue transfer can be performed in few institutions. Experience regarding these techniques is very limited, and the results are inconsistent.[22–24] In addition to radiotherapy or chemotherapy, patients are at risk for wound problems and infection, which have a negative effect on vascular autograft and allograft healing rates. In our treatment, the risk is lower compared to the other treatment protocols mentioned above. After resection, the defect was treated with a combination of cement and locking plate, which is a relatively simple application, permitting good compliance with follow-up.

The Masqualet technique described in the literature is similar to the first phase of our technique.[25] However, the Masqualet technique is primarily intended for the treatment of traumatic defects.[26] Studies on the treatment of large defects due to malignant tumors are lacking in the literature. In our patients, the defects were too large to be treated with graft chips. Furthermore, also necessary for an effective long-term treatment of tumor radiotherapy and chemotherapy, it can be significant burden on the integration of the applied bone graft and host bone.[27]

In the literature, there are many reports about classical bone transport methods, and in many of these cases, further surgical intervention is required due to serious complications.[28–30] As the external fixation period increases, complications are observed with greater frequency and seriousness.[31] In recent years, external fixators have been used in combination with intramedullary nails to decrease the external fixation period. [9] However, our patients were not good candidates for intramedullary nailing due to the risk of dispersing malignant cells throughout the body, as well as the risk of insufficient fixation of small metaphyseal fragments.

Our patients had an increased tendency to infection because of medical treatment of the tumor.[32] It is of great importance to be able to continue medical treatment and prevent infection. The method we describe has the advantage of acute wound closure after resection, thus isolating the resection site from the exterior. The cement implanted is an important factor in preventing infections, as it includes teicoplanin. As a result, deep in-
Infection was not observed in any of our patients, even in immune suppressive phases.

The technique we describe is a new biologic reconstruction method for defects after resection of tumors which combines the advantages of using locked plates, bone cement, and external fixators, with minimal disadvantages.

**Conflicts of Interest:** No conflicts declared.

**References**


