Total Condylar Unipolar Expandable Prosthesis for Proximal Tibia Malignant Bone Tumors in Early Childhood

SANTIAGO A. LOZANO-CALDERÓN, MD, PHD; SAMUEL KENAN, MD

abstract

Full article available online at ORTHOSuperSite.com. Search: 20111021-05

Wide resection and reconstruction of tumors of the proximal tibia in the pediatric population are challenging procedures. The use of hinged, expandable prostheses may cause early closure of the distal femoral growth plate, which may increase the risk of limb discrepancy already present in this population.

Between 1991 and 2001, 2 girls and 1 boy, aged 6, 6, and 4 years, respectively, were diagnosed with osteosarcoma of the proximal tibia and treated with wide resection and reconstruction with a condylar unipolar expandable tibial prosthesis. A press-fit technique was used for component insertion. All patients received neoadjuvant and adjuvant chemotherapy. Radiographic and functional follow-up took place at least once a year for a minimum of 4 years. Adequate pain control, limb-length equality, and acceptable function were obtained in all patients. One patient presented with significant range of motion reduction (0°-30°) in the affected knee. Limb lengthening was performed as needed to maintain balanced limb length. All patients had a good Musculoskeletal Tumor Society category score. No complications occurred in terms of component loosening or infection. One patient died shortly after 4-year follow-up because of doxorubicin-induced leukemia.

Currently used hinged, expandable prostheses can jeopardize the unaffected distal femoral growth plate. This article describes a technique of reconstruction that spares the distal femoral growth plate. Adequate limb length can be expected with acceptable functional outcome. However, it is imperative to keep in perspective the expectations of the physician, the physician’s team, the patient, and the patient’s family.

Figure: Intraoperative photographs demonstrating insertion of the proximal tibia prosthesis after reaming using a press-fit technique (A); the prosthesis in place with recreation of the medial and lateral collateral ligaments with nonabsorbable sutures before closure of the entire capsule with additional nonabsorbable sutures, as well as the medial head of the gastrocnemius muscle prior to completion of rotational flap (B); and the capsule after 360° closure, gastrocnemious rotational flap in place, and remaining extensor mechanism attached to the fascia of the rotational flap (C).
In the pediatric population, the proximal tibia is the second most common location for primary malignant tumors originating from the bone. Reported series have determined that up to 25% of conventional osteosarcomas originate from this area. The current protocols of treatment for this malignancy include neoadjuvant and adjuvant chemotherapy cycles, in addition to surgical resection. Current survival rates are as high as 70%.

Surgical treatment options in children include tumor radical resection, above-knee or through-knee amputations, resection arthrodesis, and the Van Ness rotationplasty. The most recent treatment modalities using limb-sparing procedures include the use of allograft replacement, bone transport, or bone endoprostheses. Usually, these are more appealing to patients and their families because the affected limb and its function can be adequately maximized. In addition, their recurrence rates are considered low as long as resection margins are negative.

In children, the challenges of limb-sparing surgery are substantial because it is necessary to maintain limb equality and provide reconstruction that restores adequate function.

Endoprostheses of the proximal tibia are commonly used. However, when compared with other sites, these have a higher complication rate, including infection and problems with the knee extensor mechanism. In addition, these hinged prostheses may cause early growth plate closure of the distal femur, leading to additional loss of future growth and, therefore, subsequent greater limb-length differences. In young children, this may lead to unacceptable limb shortening and discrepancy that makes a length-restoring procedure almost impossible once skeletal maturity has been reached.

This article presents our experience with 3 cases in which a wide resection of the proximal tibia was performed for the treatment of conventional osteosarcoma. Reconstruction was performed using a total condylar unipolar expandable tibial prosthesis, which spares the distal femoral growth plate. Adequate limb length and acceptable function was achieved in all patients at a minimum 4-year follow-up.

**MATERIALS AND METHODS**

Between 1991 and 2001, two girls and 1 boy, aged 6, 6, and 4 years, respectively, were diagnosed with conventional osteosarcoma of the proximal tibia. All 3 patients underwent neoadjuvant and adjuvant chemotherapy in addition to limb salvage through wide resection of the proximal tibia and reconstruction with a total condylar unipolar tibial replacement. All patients were overlengthened an average 1.5 cm at the index procedure. Subsequent lengthenings took place according to the patient’s growth curve and development. At skeletal maturity, 1 patient underwent revision to a total knee hinged, expandable prosthesis. Limb lengthenings after the revision were performed as needed to maintain limb length without significant discrepancy. Minimal follow-up was at least 4 years. All patients were evaluated radiographically and functionally per the Musculoskeletal Society Tumor (MSTS) score at latest follow-up (Table).

Preoperative planning before mass excision and reconstruction requires measurements obtained from the preoperative computed tomography scan of the affected lower extremity. Imaging extends from the distal third of the femur to the proximal talus, including the tibia in its entirety.

The measurements from the distal femur are used to create plastic testing models of the tibial component (Figures 1A-D). This type of prosthesis is designed to be fully congruent, with the metallic tibial plateau gliding under the femoral articular cartilage in the same way as bipolar hip prostheses. A built-in posterior lift is added in almost all cases to minimize anteroposterior (AP) translation because this design does not recreate or replace the cruciate ligaments (Figures 1E, F).

The amount of lengthening is calculated by obtaining a carpogram (hand AP radiograph) to determine the patient’s bone age. The height of the parents and the expected height and limb length according to the years left to grow are also taken into consideration. At the index surgery, the reconstruction is planned in a manner that the reconstructed limb is between 1.5 and 1.8 cm longer than the unaffected extremity. If necessary, the patient is prescribed removable shoe inserts to correct this discrepancy and optimize gait physiology. As the patient grows, this discrepancy corrects. When the reconstructed limb becomes shorter by at least 2 cm than the contralateral extremity, a lengthening procedure is performed following the same over-lengthening principle to a maximum of 1.8 cm. The amount of lengthening is recalculated each time that a lengthening procedure is required, taking into consideration the variables listed above.

---

**Table**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Patient 1</th>
<th>Patient 2</th>
<th>Patient 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Function</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Emotional</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Support</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Walking</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Gait</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>27</td>
<td>27</td>
</tr>
</tbody>
</table>

Benchmark: Good Excellent Excellent

**Abbreviation:** MSTS, Musculoskeletal Tumor Society.
SURGICAL TECHNIQUE

The anteromedial approach is used to expose the proximal tibia mass and to excise it following the principles of wide resection. Once removal is complete, the cobalt-chrome prosthesis is inserted in the remaining tibia after size reaming using a press-fit technique (Figure 2A). The prosthesis is subsequently stabilized to the knee using multiple nonabsorbable sutures around the entire knee capsule. Stabilizing structures such as the medial and lateral collateral ligaments are recreated by using additional multiple nonabsorbable sutures (Figure 2B). Over time, scar tissue forms around these areas, providing the additional stability in the AP and lateromedial planes.

Soft tissue coverage includes a gastrocnemius rotational flap using the medial head of this muscle (Figure 2C). The extensor mechanism is reconstructed by securing the remaining segment of the patellar tendon to the rotational flap’s fascia using absorbable sutures (Figure 2C). Closure is performed in a standard fashion using absorbable sutures for deep and subcutaneous tissues; nonabsorbable staples are used for skin closure.

Subsequent lengthening procedures take place as indicated in each individual case. Under general anesthesia, a small incision is done in the proximal and medial aspect of the tibia, just above the extensor mechanism (Figure 3). An Allen key is inserted and turned clockwise. One millimeter in
length is obtained after 10 clockwise turns. To obtain 1.5 cm in lengthening, 150 complete turns are needed. After the procedure, the patient is kept overnight in the hospital. The patient is also maintained in a toe-touch weight-bearing status with the assistance of crutches for 1 week. After this, the patient resumes progressively to full weight-bearing status. Once skeletal maturity is achieved, revision of the total condylar unipolar tibial replacement to a total hinged, expandable prosthesis is performed if necessary.

Postoperatively, patients receive a standardized rehabilitation protocol based on full extension immobilization with protected weight bearing for 6 weeks. Active and active-assisted range of motion (ROM) is started at 2 weeks postoperatively. After 6 weeks, patients are allowed to progressively advance weight bearing and return as much as possible to their previous level of activity.

RESULTS
Patient 1
A 4-year-old boy was diagnosed with conventional osteosarcoma of the proximal tibia in 1991 (Figures 4A-D). After neoadjuvant chemotherapy for 6 weeks, the patient underwent wide resection of the proximal tibia and reconstruction with the total condylar unipolar expandable tibial prosthesis (Figure 4E). Treatment was continued with adjuvant chemotherapy for 12 weeks. Subsequently, 2 lengthening procedures were performed (Figures 4F, G). The patient reached skeletal maturity without significant limb-length discrepancy (<2 cm) and was able to ambulate despite decreased ROM at the knee joint (0°-30°). There was no extension lag.

At age 13, the patient underwent revision of the total condylar unipolar expandable tibial prosthesis with an expandable total knee hinged prosthesis (Figure 4H). Soft tissue coverage was obtained with a latissimus dorsi myocutaneous free flap. Further lengthening was obtained at the moment of revision and in 2 subsequent procedures (Figure 4I).

At age 22, at 17-year follow-up, the patient presented with no functional or pain complaints. Limb length was found to be equal (Figure 4J). However, decreased ROM at the knee joint persisted up to this point, 0° to 30°, with no extension lag. This limited ROM caused difficulties during the swing phase. With ipsilateral hip hyperflexion, the patient was able to compensate and successfully clear the ground during this phase. Despite no physiological gait, the patient did not require the use of assistive devices for ambulation. There was no knee instability. Musculoskeletal Tumor Society score was 24 points at latest follow-up (Table).

Patient 2
In 1994, a 6-year-old girl was diagnosed in 1994 with conventional osteosarcoma of the proximal tibia extending into the epiphysis (Figures 5A-D). After neoadjuvant chemotherapy protocol for 12 weeks, the patient underwent wide resection and reconstruction with the total condylar unipolar expandable tibial prosthesis (Figures 5E, F). Subsequent adjuvant chemotherapy was given for 14 weeks. The recovery period was uneventful, and
during follow-up evaluations, the patient presented with normal growth of the femur with no significant limb-length discrepancy and preserved ROM, 0° to 110°, with no extension lag. There was no knee instability. Musculoskeletal Tumor Society score at latest follow-up was 27 points (Table). In 1998, at 4-year follow up, the patient was unchanged from the musculoskeletal perspective, but she was also found to have doxorubicin-related leukemia. The patient died months after final follow-up.

**Patient 3**

In 2001, a 6-year-old girl was diagnosed with osteosarcoma of the proximal tibia extending into the epiphysis (Figures 6A-E). After neoadjuvant chemotherapy for 12 weeks, the patient was treated with wide resection of the mass in the proximal tibia and reconstruction with the total condylar unipolar expandable tibial prosthesis (Figures 6F, G). As in the previous cases, the patient received an intraoperative lengthening at the index procedure and adjuvant chemotherapy for 14 weeks. In addition, the patient underwent 2 lengthening procedures with no complications. At 8-year follow up, the patient had no limb discrepancy or complaints in terms of function. She had full active extension and a ROM from 0° to 90° of knee flexion, with no extension lag. She was able to resume normal activities of daily living (Figures 6H-J). Her MSTS score at latest follow-up was 27 points, for an excellent result. Her gait is completely normal, and she does not require the use of assistive devices for ambulation (Table). Because the patient has maintained excellent function, revision to a hinged prosthesis has been postponed until symptoms or necessity of revision occur.

**DISCUSSION**

Limb reconstruction after resection of tumors of the proximal tibia is challenging in pediatric patients, especially those younger than 8 years. The potential limb-length discrepancy in this subpopulation following limb-sparing procedures about the knee joint represents a major concern.9,24,26 This has been addressed with the use of expandable, hinged knee prostheses that allow for lengthening and, therefore, compensate limb discrepancy as the patient continues to grow after the index surgery.2,8,15,16,23,24 However, the use of these prostheses in early childhood may jeopardize the unaffected femoral growth plate, causing additional limb shortening dependent from the femur instead. Although overall limb length might be corrected with this prosthetic design, significant concerns remain because unlevelled knee articular lines that impair gait might be also present.5,9,11

Because of these difficulties related to bone growth and other potential complications, expandable, hinged knee prostheses in the pediatric population do not have the same predictable and acceptable functional outcome seen in the adolescent or adult population. In fact, they are considered by many as a highly morbid procedure. Grimer et al reported their experience with a case series of 20 patients who underwent limb-sparing procedures with extendable, hinged endoprostheses. Of the 20 patients, 5 died from their disease; 4 of the surviving 15 patients had an amputation. Only 11 patients had intact limbs and were alive. Of these, 9 patients required revision of their procedure or had major complications. These included infection, loosening, and/or revision of components. The 2 patients who did not present with complications were older than 11 years.2

Others series have reported similar complications. Kenan and Lewis16 and Kenan et al24 published their results after treating 13 children with expandable prostheses. Three patients presented with
infection and 1 had a subsequent amputation. Delepine et al\textsuperscript{22} reported an infection rate of 17% in 28 patients in whom extendible replacements of the knee (distal femur and proximal tibia) were used. Schiller et al\textsuperscript{27} reported a complication rate of 15%. Other less common complications, such as breakage of the extensor mechanism, have also been reported.\textsuperscript{28}

Despite the difficulties and complication rate with procedures of this nature, functional outcome and patient satisfaction have been found to be high by several authors.\textsuperscript{2,17,23,24} These findings justify the use of these techniques in adequately selected patients.

We present a new surgical technique that involves the use of a proximal tibia condylar unipolar extendible prosthesis that is not hinged and preserves the femoral growth plate. Adequate lengthening of the involved extremity and maintenance of the articular line height can be achieved with this technique in the challenging clinical scenario of young children with substantial potential to grow.

Using a noncemented modality for implant fixation, we observed no loosening of components. This was an expected observation because osteointegration of the component in this young population is solid. In terms of stability, this system based on high congruency between both femoral and tibial articular surfaces proved to be sufficient in replacing the function of the cruciate ligaments. Additional obtained stability by complete repair of the capsule (360°) and recreation of the medial and lateral collateral ligaments increased stability in both AP and valgus-varus planes, respectively. Adequate function, motion, pain control, and symmetric limb length can be obtained and maintained until skeletal maturity is reached. At this point, if necessary, revision to an expandable, hinged knee prosthesis can be performed to complete treatment.

This treatment is technically demanding and requires compliance from both the patient and his or her family. They need to be aware of the necessity of multiple procedures that involve lengthening of the prosthesis and at least 1 revision of the components to a hinged prosthesis, assuming that loosening is not going to occur. Complete patient and family understanding of potential complications such as infection, knee instability, component loosening, and periprosthetic fractures is imperative. Also, realistic expectations in terms of quality and quantity of knee function, ROM, stability, and other objective and subjective parameters are necessary on the part of the treating physician, the physician’s team, the patient, and the patient’s family. Future larger series and prospective cohort studies evaluating this technique.
are necessary to better assess its performance, complications, and outcome.

**CONCLUSION**

Potential limb-length discrepancy in young children after limb-sparing procedures about the knee joint represent a major problem. Current hinged, expandable prostheses might endanger the unaffected limb. Our reconstruction technique spares the distal femoral growth plate, adding shortening risk to the affected limb. Our reconstruction technique spares the distal femoral growth plate and, therefore, satisfactory limb length can be expected. Adequate functional outcome with sufficient ROM and stability can be obtained.

**REFERENCES**