

A rare case of Ewing's sarcoma in a 4-year-old child treated by tumor endoprosthetics using 3D printing

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Abstract— Orthopedic oncology surgery often requires, by its very nature, precise and often extensive resections of bone and soft tissue involved in or near the tumor mass.

One of the most recent and promising innovations is represented by 3D printing technology, whose main advantage in this field of application is patient specificity, which is essential in an operation that requires high precision and maximum respect for the individuality of his bones and soft tissues.

Material and methods: In the present report, we present a 4-year-old boy diagnosed with Ewing's sarcoma involving $\frac{3}{4}$ of the right tibia. In another medical facility, he was offered amputation. Our team decided to use the "3D printed tumor megaendoprosthesis, double growing, from the Czech company Prospan. For reinsertion of the muscle groups to the endoprosthesis, we used a LARS textile tube that was attached to the femoral and tibial components of the endoprosthesis. A vascular surgeon also participated in the team. The patellar ligament was reinserted to the tibial component, and myoplasty was additionally performed with the medial head of the m. gastrocnemius. Intraoperatively, we lengthened the lower limb by 1.5 cm to delay the upcoming staged lengthening.

Results: The postoperative period was uneventful, with sutures removed on the 12th postoperative day. For 3 weeks, a tutor orthosis was placed. Active physiotherapy was started after removal of the orthosis 21 days after surgery.

Conclusion: Our goal is to perform a total revision at the end of skeletal growth if possible and replace the current implant with a non-growing tumor megaendoprosthesis in the absence of near or distant metastases and long-term patient survival.

Future expectations are that non-invasive lengthening mechanisms or a biological approach will be able to meet the special needs of this population.

Keywords— Ewing's sarcoma, tumor endoprosthetics, 3D printing

1 Introduction

Currently, the main applications for 3D printing are the production of anatomical models for planning and simulation of surgery, patient-specific instruments, and custom-made prostheses ^(1,2,3,4,5).

Orthopedic oncological surgery often requires, by its very nature, precise and often extensive resections of bone and soft tissue involved in or near the tumor mass ⁽⁶⁾.

One of the most recent and promising innovations is represented by 3D printing technology, whose main advantage in this field of application is patient specificity, which is essential in an operation that requires high precision and maximum respect for the individuality of his bones and soft tissues.

As a rule, the 3D printing technique finds application in oncological orthopedics in the following main areas: 1) 3D printing for preoperative planning and training in oncological orthopedics⁽⁷⁾; 2) Individual resection blocks made by 3D printing 3) 3D printed individual endoprostheses⁽⁸⁾.

Most children today with bone sarcomas undergo organ-preserving surgery.

When treating children under 12 years of age, the result is significant limb length discrepancy (LLD)⁽⁹⁾.

One solution is the use of a growing endoprosthesis.

Bone sarcomas are rare malignancies that mainly affect children and young adults (5–25 years)⁽⁹⁾.

In the past, the only treatment option was amputation surgery.

Survival was 0–15% and most patients died without their limbs.

The cause of death is usually lung metastases (95% of sarcoma metastases are in the lungs)⁽¹⁰⁾.

Over the past 30 years, we have witnessed many advances in various disciplines.

This contributed to the emergence of the modern concept of limb-sparing surgery (LSS)^(11,12).

Effective systemic chemotherapy is extremely important.

Today, 85% of bone and soft tissue sarcoma procedures are by LSS compared with 15% for amputation, and the overall 5-year survival rate is about 60%.

LSS in young children is challenging because of the expected future longitudinal and radial growth of the remaining limb, resulting in limb length discrepancy (LLD) that profoundly affects function.

For example, resection of the distal femur in children less than 10 years of age results in a loss of up to 1.6 cm each year, where LLD can reach 10–20 cm by the time of skeletal maturity.

There are several surgical approaches to dealing with LLD:

1. Amputation and rehabilitation with external prosthetics.
2. A rotationplasty procedure for tumors in the distal femur in which the remaining leg is rotated 180° so that the ankle functions as a knee joint, allowing flexion and extension, while the foot is supported with a relatively short and stable external prosthesis providing good function but strange appearance⁽¹³⁾.
3. Osteoarticular allograft that lacks the ability to grow and is associated with complications including nonunion, fractures, and infections⁽¹⁴⁾.
4. Combining standard non-growing endoprostheses with epiphysiodesis of the contralateral physis, thereby eliminating LLD but causing shorter stature.
5. Arthrodesis techniques using a combination of allograft and autografts (vascularized or not) followed by a conventional lengthening technique such as an Ilizarov external fixator.

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Each of these solutions has deep flaws.

The optimal surgical solution is different for each age group.

LSS is almost impossible for children under the age of 5, leaving amputation as the only reasonable option for most cases.

LSS for the 5–14 age group is possible if LLD is managed (eg by growing endoprosthesis).

A standard non-growing tumor endoprosthesis is usually preferred in patients over 14 years of age, when most of the growth is usually complete.

Growing endoprostheses with different stretching mechanisms have been used since the late 1970s^(15,16).

They are usually made of two main parts; stem and articulation.

The extension system is usually located in the stem part.

The first models had to be fully exposed during surgery with the patient under anesthesia to perform the lengthening, and the lengthening was achieved by a distractor and retained by a sleeve (Fig.1).

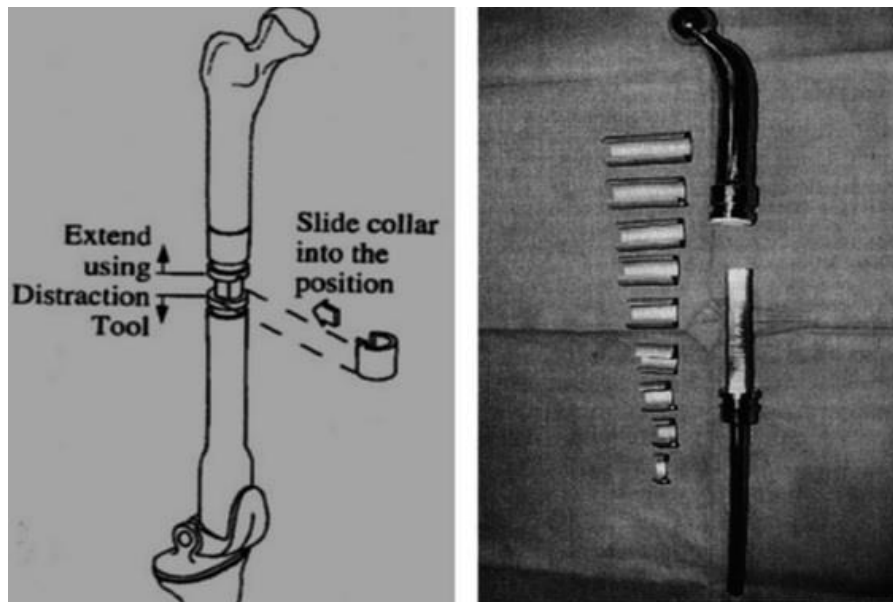


Figure 1.

Second-generation devices are minimally invasive and have an extendable screw mechanism that is accessed through a small incision and positioned with a C-arm, but also requires an operating room and general anesthesia (Fig.2).

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Figure 2.

The third generation of growing endoprostheses are a non-invasive type in which the lengthening stem is manipulated by an external force consisting of either a rotating external magnet or an electromagnetic field.

The latter have been used only in the last 5-10 years, so the follow-up is relatively short-term, and their growth potential is a maximum of 4 cm (Fig. 3).

All systems carry a high rate of complications, which are often treated through multiple surgical procedures and revisions until the patient reaches maturity.

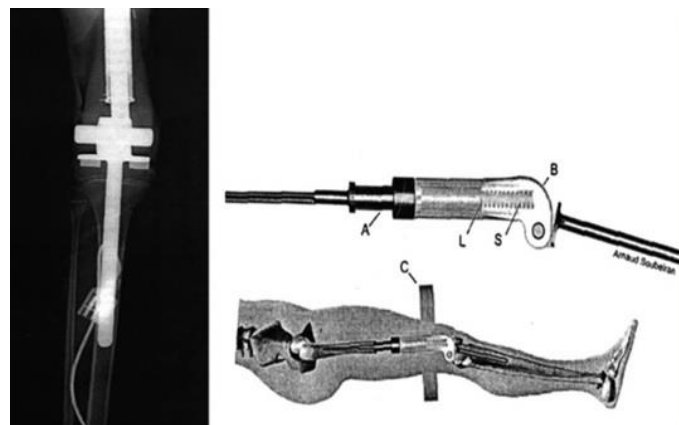


Figure 3.

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2 Materials and methods

We had to use the possibilities of 3D printing to make an individual double-growing knee endoprosthesis of the second generation with a view to preserving the lower limb in a 4-year-old child.

The child was biopsied and diagnosed with Ewing's sarcoma covering $\frac{3}{4}$ of the right tibia in another medical facility (Fig. 4, 5).

There, an above-the-knee amputation was proposed, which the parents categorically refused, as the father had a lower limb amputee after a work accident.



Figure 4. Figure 5.

In the initially constructed plan, we were offered an endoprosthesis with an assumed growth of 8 cm only on the tibial component (Fig.6,7).

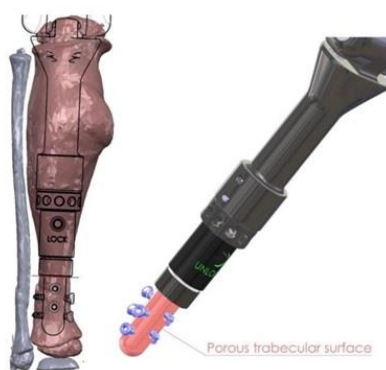


Figure 6.

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Figure 10.

The implant wedges were made of porous titanium and were additionally fixed in one plane proximally and in two planes distally with titanium locking screws (Fig.11,12).

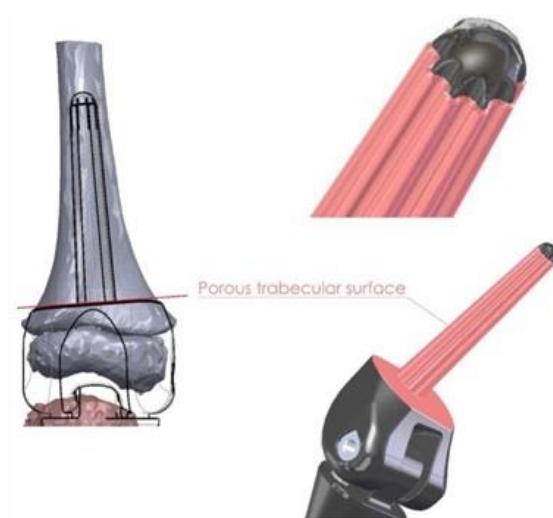


Figure 11.

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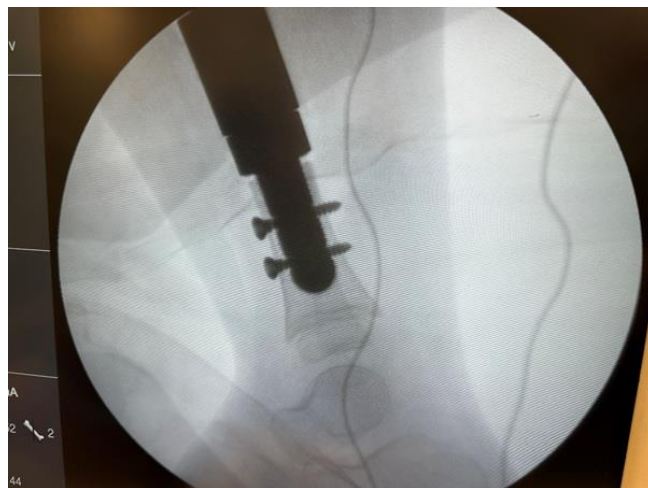


Figure 12.

During the operation, we were assisted by a vascular surgeon in order to minimize the risk of vascular damage. The patellar ligament was reinserted to the tibial component, and myoplasty was additionally performed with the medial head of the m. gastrocnemius. Intraoperatively, we lengthened the lower limb by 1.5 cm to delay the upcoming staged lengthening (Fig.13,14,15,16).



Figure 13.

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Figure 14.

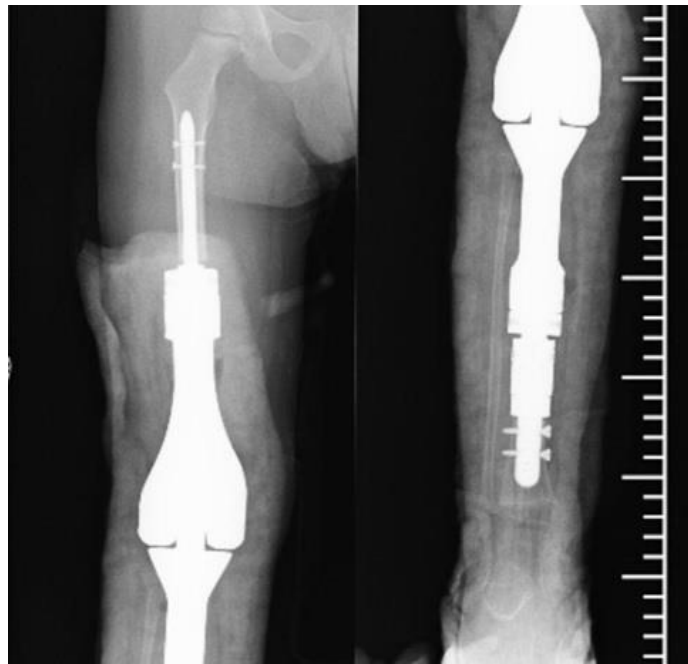


Figure 15.

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Figure 16.

3 Results

The postoperative period was uneventful, with sutures removed on the 12th postoperative day. For 3 weeks, a tutor orthosis was placed to ensure the reinsertion of the lig. patellae proprium to the endoprosthesis. Active physiotherapy was started after removal of the orthosis 21 days after surgery. At the moment, the child moves independently without aids, undergoing chemotherapy according to the protocol.

Staged lengthenings of the femoral and tibial components of the endoprosthesis through miniincisions are planned when the difference in limb lengths reaches 2 cm.

4 Conclusion

Our goal is to perform a total revision at the end of skeletal growth if possible and replace the current implant with a non-growing tumor megaendoprosthesis in the absence of near or distant metastases and long-term patient survival.

Future expectations are that non-invasive lengthening mechanisms or a biological approach will be able to meet the special needs of this population.

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