Combining Advanced Technologies: The Compress-Repiphysis Prosthesis for Pediatric Limb Salvage

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A novel implant combination achieved by fusing 2 unique implants—the Repiphysis and the Compress—with a custom adaptor is a successful option for limb salvage in skeletally immature patients.

Pediatric sarcomas are relatively rare in comparison to other childhood cancers. As with many childhood cancers, there is often a good chance for long-term survival. With the advent of effective chemotherapeutic regimens, survival of osteosarcoma has seen a substantial improvement. Disease-free survival rates now approach 70% when resection of the tumor with a wide margin is possible in the context of localized (nonmetastatic) disease and a high chemotherapeutic necrotic response of the tumor.1,3

Inherent in the increased survival of young patients with extremity sarcomas with limb salvage, however, is the problem of durable, functional extremity reconstruction. This is an especially difficult problem in skeletally immature patients when normal growth of the contralateral limb is expected to result in a substantial leg-length discrepancy as the major contributing physis of the affected limb are resected. While amputation is still a useful modality in a minority of cases (<10%), limb salvage is now the standard of care and is used in the vast majority of cases.4,6 However, no clear answer exists to the problem of extremity reconstruction (limb salvage) in pediatric patients after resection of tumors from growing bones to achieve maximal functional outcome.

This article presents a case using a novel implant combination achieved by fusing 2 unique implants—the Repiphysis (Wright Medical Technology, Inc, Memphis, Tennessee) and the Compress (Biomet, Warsaw, Indiana)—with a custom adaptor (Figure 1). Each of the implants is used commonly in pediatric limb salvage with varying degrees of success and confidence from treating surgeons. The Compress technology is unique in its osseous integration at the host/implant interface using compression at the interface. It is used in place of long stems, with much literature supporting its success.6,8 The Repiphysis is novel in its ability to expand to allow lengthening without the need for invasive surgery. This is achieved by using ultrasound to heat a spring mechanism,
which results in expansion of the device and lengthening of the limb.

The importance of this case is two-fold. First, the resultant device is a potentially excellent alternative for limb salvage with regard to extremity reconstruction in pediatric patients. It has the potential to achieve equal leg lengths and allow a smooth transition into an adult prosthesis when skeletal maturity occurs. Secondly, it is a unique collaboration between 2 companies to achieve a benefit for 1 patient, and has the potential to positively affect the lives and outcomes of many patients.

**CASE REPORT**

A skeletally immature 9-year-old girl presented with an enlarging mass in her left distal thigh (Figure 2). The mass was biopsy-proven to be a conventional osteosarcoma (stage IIB) and was treated with standard neoadjuvant chemotherapy. Surgical treatment consisted of a wide resection followed by reconstruction using a distal femoral endoprosthesis. This implant consisted of the Repiphysis expandable implant, a custom adaptor, and the Compress device for femoral fixation (Figure 3). At most recent follow-up, the Compress was functioning well with expected bony hypertrophy and ingrowth at the spindle (Figures 4-6). The Repiphysis has been expanded 5 times without complication, for a total of approximately 5 cm of overall length. Knee range of motion (ROM) is 0° to 100° (Figures 4-6). The patient is ambulating with full weight bearing without pain. Two years after resection and reconstruction, the patient is without implant failure and without local or systemic recurrence.

**DISCUSSION**

Limb salvage in pediatric patients is challenging. It is demanding with regard to surgical resection and reconstruction. The type of surgical procedure in pediatric limb salvage depends on a number of factors, including the patient’s age, general condition, goals, expectations, quality of life, and life expectancy. The goal inherent in these procedures is resection of the tumor with adequate margins.9,12 as this is one of only a few factors that is predictive of outcome in patients with osteosarcoma.13,14

Reconstructive options after limb salvage surgery continue to evolve, and include allografts, autografts, composite reconstructions, rotationplasties, and endoprostheses. Allografts are used alone or in combination with prostheses (alloprosthetic composites). The advantages include the ability to attach soft tissue to the allograft and reconstruction of the joint with similar size and function to the original. The major drawback with large bone allografts is the significant chance of infection, nonunion, and stress fracture.
Rotationplasty is a resection of the hip or knee with reconstruction of the lost joint with the adjacent joint below by rotating it 180°. Most commonly, this is done for resection of the knee, where the ankle subsequently functions as a knee joint. The foot then requires a below-knee amputation-like prosthesis on the foot. Rotationplasty is a preferred method for some skeletally immature patients with a large lesion about the knee and patients with large lesions who are not candidates for limb salvage, and as an alternative to above-knee amputation and a salvage procedure for chronically infected prosthetic implants.22-26

Endoprosthetics are composed of various materials with modular components linked together. In the skeletally mature, the immediate functional results are excellent, with minimal early complications. Flexion contractures and complications inherent in using this device and the potential for limb salvage in the pediatric sarcoma population. While abundant literature does not exist regarding either implant described above, there are encouraging data for both.6,8,33,37,38 Both the Repiphysis and Compress have reported success rates that make them acceptable choices for expandable distal femoral reconstruction or bone ingrowth fixation, respectively.

While discussing this technology fusion, it is important to discuss the potential complications inherent in using this device and the potential ways to prevent these. First, concerns exist regarding the femoral fixation of the nonrotating hinged Repiphysis. There is widely accepted biomechanical dogma in arthroplasty that the more constraint (hinged prosthesis), the more likely an implant fixation is to occur in up to 30% of cases. However, functional outcomes are good to excellent in nearly all long-term outcome studies of children reconstructed with endoprosthetics, with 10-year implant survival approaching 70%.9,27-31

While endoprosthetics give a functional, mobile, cosmetically appealing extremity, many issues are inherent in pediatric arthroplasty. First, the problem of leg-length inequality is an issue in nearly all skeletally immature children who undergo limb salvage with an endoprosthesis. Epiphysiodeses on the contralateral extremity is also an acceptable option when the anticipated limb-length inequality is not anticipated to be great. However, when there is an expected large leg-length inequality, more invasive techniques in the form of lengthening of the affected limb, shortening of the unaffected limb, or use of an expandable prosthesis may be warranted.27,32-34

Many expandable prostheses are available. Historically, most of these have been in the form of implants that required invasive methods to lengthen. However, in 2002, the US Food & Drug Administration (FDA) approved the Repiphysis expandable prostheses, a noninvasively expanding endoprosthetic that uses energy stored in a spring that is held compressed by a locking mechanism. Controlled release of the locking mechanism via an external electromagnetic field allows for lengthening of the device. This allows a controlled slide and elongation of 6 to 20 mm with no undue heating of the surrounding tissues.35 A number of reports on the experience with this device have been, for the most part, favorable, although not without complications.35-38

Gitelis et al26 reported on 18 patients with osteosarcoma undergoing limb salvage using the Repiphysis with an average 25-month follow-up and an average expansion of 38 mm per patient. Average International Symposium of Limb Salvage functional scores were 83.5%, with complications in 7 patients. They reported functional scores >90% in patients with functional prostheses. Complications were component fracture and loosening. Modifications are continually being made to the prosthesis to improve long-term survival of the implant until patients are ready to be transitioned to an adult endoprosthesis.

Choosing the optimal host/prosthetic interface is another important issue in pediatric arthroplasty. Historically, most implants have been fixed into the host bone with a stem using either cement or a press-fit technique. However, the Compress is now a commonly used implant for diaphyseal fixation for limb salvage after wide sarcoma resection. The Compress uses compression at the host/prosthetic interface to promote bone hypertrophy and osseous integration of the host into the hydroxyapatite-coated implant surface. The purpose of the design is to provide immediate, stable anchorage to help avoid aseptic loosening secondary to stress shielding and particle-induced osteolysis seen in stemmed megaprostheses. Many authors have reported a low failure rate and osseous integration at the host/prosthetic interface.6

In a large retrospective review by Tyler et al,7 221 patients with osteosarcoma undergoing limb salvage using the Repiphysis with an average 25-month follow-up of 50 months. Six patients sustained periprosthetic fractures and 8 had nonperiprosthetic ipsilateral limb fractures. The osseo-integrated interface, however, was radiographically stable in all 14 cases. While periprosthetic fracture has been a concern with this device, the low incidence and the fact that osseous integration was noted at the bone/implant interface gives good evidence that the implant is achieving its desired function. Another advantage of the Compress is the short intramedullary stem that helps preserve bone for further revision in the future as necessary. Alternatively, if there is a need for implant revision and a stable bone interface remains on the Compress, revision could potentially proceed without the need for revision fixation. This would be most useful when converting from a pediatric-sized implant to a full-sized implant at skeletal maturity.

There is no definite answer as to the best option for limb salvage in the pediatric sarcoma population. While abundant literature does not exist regarding either implant described above, there are encouraging data for both.6,8,33,37,38 Both the Repiphysis and Compress have reported success rates that make them acceptable choices for expandable distal femoral reconstruction or bone ingrowth fixation, respectively.
fail. With regard to the Compress, failure is thought to increase when implanted under angular or torsional stress, as is increased without the rotating hinge, which is lacking in the Repiphysis. Despite these concerns, the implant reported here has resulted in successful osseointegration for fixation despite torsional stresses from the constrained hinge implant. This concern necessitated meticulous technique and custom trials for both the hinged knee implant and Compress fixation device, which were used to assure ideal rotation. Furthermore, an appropriate time with limited weight bearing is paramount to allow stable fixation prior to stressing the interface. Both abundant hypertrophy and ingrowth occurred at the Compress spindle, and knee ROM has remained excellent. However, this must be addressed should this type of implant be used in the future.

Another concern is that the adaptor required additional bone resection to optimize potential lengthening through the implant. Since each Repiphysis is custom manufactured, total potential elongation increases with the size of the implant. If the implant was constructed smaller to allow placement of an adaptor, the total potential lengthening through the implant would decrease. To not lose potential lengthening, we resected extra diaphyseal bone to accommodate for the adaptor. Despite this, the combined length of the extra bone resection (3.5 cm), combined with the Compress spindle and anchor plug length (4.0 cm), involved less bone than a standard 90-mm stem. Furthermore, since bone is often removed when revising stemmed implants to full-sized implants at skeletal maturity, and since the biologic fixation of the Compress is not expected to require revision at that time, this implant combination should result in relative bone preservation.

With regard to future revision, there is concern that the appropriately-sized Compress for a child may be too small for the adult implant. Although important, long-term follow-up data are not complete. However, the osseointegration portion of the Compress is generally oversized by 5 to 10 mm, and bone growth is often seen to the edges of the implant. Therefore, osseous integration at the bone/prosthetic interface is anticipated to be adequate to support an adult-sized implant, but this has not been proven to date.

Finally, it is likely that competing companies will not share implant specifications to allow adaptors to be designed and manufactured. This is a key to the future of reconstruction and the industry in general. Direct communication by the surgeon with the company engineers and designers is necessary to navigate this hurdle. It should be noted that there is a limited number of identical implants (ie, Compress-Rephysis adaptor) each company can manufacture per year without formal FDA testing and approval.

**References**


