



Original Research

# A comparison of function after limb salvage with non-invasive expandable or modular prostheses in children



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## KEYWORDS

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**Abstract Background:** Modular and non-invasive expandable prostheses have been developed to provide a functional knee joint that allows future expansion as growth occurs in the contralateral extremity in children with bone sarcomas that require removal of the growth plate. This study aimed to evaluate the functional outcomes of paediatric patients who received either a non-invasive expandable or modular prosthesis for bone sarcomas arising around the knee.

**Methods:** We evaluated clinician-reported, patient-reported and measured function in 42 paediatric patients at least one year (median age at assessment 19.1 years) after limb salvage surgery, and compared patients who received modular system prostheses ( $N = 29$ , median age 15.5), who did not require lengthening procedures to those who received non-invasive expandable prostheses ( $N = 13$ , median age 11.1) requiring lengthening procedures (median 5).

**Results:** The number of revisions and time to first revision did not differ between the two groups. There were no differences between the two groups in total scores on the Enneking Musculoskeletal Tumor Society Scale, the Toronto Extremity Salvage Scale, and the Functional Mobility Assessment. Children with non-invasive expandable prostheses climbed stairs

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( $11.93 \pm 4.83$  versus  $16.73 \pm 7.24$  s,  $p = 0.02$ ) in less time than those with modular prostheses.

**Conclusion:** Our results suggest that the non-invasive expandable prosthesis produces similar functional results to the more traditional modular prosthesis.

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## 1. Introduction

Bone sarcomas frequently involve the metadiaphyseal junction and the growth plate of the long bones of children and adolescents. Surgical management of these tumours requires a wide resection with margins that extend into the normal tissue surrounding the tumour [1]. This may necessitate removal of the physis in the skeletally immature child when the tumour abuts or crosses the growth plate [2]. Reconstruction of the knee typically involves placement of a hinged knee type endoprosthesis [3]. In the skeletally immature patient, this creates a limb length inequality as the contralateral extremity continues to grow unabated [4]. Custom prosthetic designs were initially unable to address this problem. Many children had to undergo amputation [5] or rotationplasty [6] to avoid future leg length discrepancy and to allow optimum mobility with an external prosthetic limb.

Technological advances to address this problem have resulted in the development of modular oncology prostheses which allow surgeons to periodically replace modular midsections with larger ones to compensate for differences in leg length [7]. This design decreases the necessity for amputation and increases patient satisfaction by preserving the limb and cosmesis. However, the exchange of components requires multiple surgical procedures to be performed over time, and predisposes the patient to significant morbidity [5]. Repeated bouts of tissue damage related to surgery, muscle atrophy related to post-surgical disuse and a general decrease in mobility related to recovery-period immobility may impact optimal limb function and contribute to long-term physical disability and lower quality of life [8].

Among children with remaining growth potential, in an effort to avoid additional surgery, non-invasive expandable prostheses were designed to allow expansion of the prosthesis without an open procedure [9]. The Repiphysis<sup>®</sup> non-invasive expandable prosthesis is an implant that allows expansion via external activation of a spring mechanism housed in the body of the implant. This device, like the modular systems appropriate for older children with little remaining growth potential, avoids amputation, allows the limb to be lengthened for optimal function and eliminates the potential complications associated with an open surgical procedure. Although it was anticipated that the use of this device would optimise limb function and mobility in these

children as they grew and reached final adult height, data about the functional outcomes after using this type of prosthesis versus the modular system prosthesis were not available.

In this study, our aim was to compare range of motion and functional mobility outcomes among patients with bone sarcoma about the knee who underwent limb salvage surgery and insertion of modular system prostheses to those who underwent limb salvage surgery and insertion of non-invasive expandable prostheses.

## 2. Patients and methods

### 2.1. Participants

Participants included children treated for lower extremity bone sarcoma at St. Jude Children's Research Hospital. Forty-two children who underwent limb salvage surgery and received neoadjuvant chemotherapy and who returned for a follow-up visit during 18 consecutive months participated in this study. Inclusion criteria were: (1) diagnosis of lower-extremity bone sarcoma (Ewing sarcoma, osteosarcoma) after 1992; (2) limb-sparing surgical procedure at least one year prior to the scheduled visit; (3) completed chemotherapy and/or radiation; (4) at least 13 years of age or currently in the seventh year of school at time of the functional assessment; (5) no diagnosis of a neuromuscular disorder, developmental delay or genetic disorder; (6) no local recurrence of disease; (7) no known cardiorespiratory abnormalities expected to affect physical function; and (8) no current injury to the lower-extremity such as a fracture. Patients who underwent amputation or rotationplasty were excluded. Study procedures and materials were approved by the Institutional Review Board. Consent/assent was obtained from all participants and guardians as appropriate prior to administration of study procedures.

Table 1 shows the characteristics of the patients. Twenty-nine (69%) patients had modular prostheses. The remaining 13 patients had non-invasive expandable prostheses (31%). The median age of the patients at the time of limb salvage surgery was 13.7 (range, 6.1–21.7) years, and the median age at Functional Mobility Assessment was 19.1 (range, 10.5–26.8) years. Most patients were white ( $n = 36$ ; 86%) and the majority were male ( $n = 23$ ; 55%). Ninety percent of patients had osteosarcoma ( $n = 38$ ).

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