Received: 25 April 2020 | Accepted: 19 May 2020

DOI: 10.1002/jso.26060

RESEARCH ARTICLE

Journal of SURGICAL ONCOLOGY WILEY

Expandable distal femur megaprosthesis: A European Musculoskeletal Oncology Society study on 299 cases

Eric Lodewijk Staals MD[1] | Andrea Sambri MD[2] | Domenico Andrea Campanacci MD[3] | Francesco Muratori MD[3] | Andreas Leithner MD[4] | Magdalena Maria Gilg MD[4] | Yair Gortzak MD[5] | Michiel Van De Sande MD[6] | Edwin Dierselhuis MD[7] | Eric Mascard MD[8] | Reinhard Windhager MD[9] | Philipp Funovics MD[9] | Martina Schinhan MD[9] | Oleg Vyrva MD[10] | Gwen Sys MD[11] | Nikolay Bolshakov MD[12] | Will Aston MD[13] | Panagiotas Gikas MD[13] | Thomas Schubert MD[14] | Lee Jeys MD[15] | Adesegun Abudu MD[15] | Marco Manfrini MD[1] | Davide Maria Donati MD[1]

[1]Orthopedic Surgery, IRCCS Istituto Ortopedico Rizzoli, Bologna, Italy

[2]Orthopedic Surgery, AOSP Sant'Orsola-Malpighi, Bologna, Italy

[3]Orthopedic Surgery, Azienda Ospedaliera Universitaria Careggi, Firenze, Italy

[4]Orthopedic Surgery, Medical University of Graz, Graz, Austria

[5]Orthopedic Surgery, Tel Aviv Medical Center, Tel Aviv, Israel

[6]Orthopedic Surgery, LUMC, Leiden, The Netherlands

[7]Orthopedic Surgery, Radboud UMC, Nijmegen, The Netherlands

[8]Orthopedic Surgery, hôpital-Necker, Paris, France

[9]Orthopedic Surgery, Medical University of Vienna, Wien, Austria

[10]Orthopedic Surgery, Sytenko Institute of Spine and Joint Pathology, Kharkiv, Ukraine

[11]Orthopedic Surgery, Universitai Ziekenhuis Gent, Gent, Belgium

[12]Orthopedic Surgery, National Medical Research Center of Pediatric Hematology, Oncology and Immunology, Moscow, Russia

[13]Orthopedic Surgery, Royal National Orthopaedic Hospital, Stanmore, United Kingdom

[14]Orthopedic Surgery, Clinic Universitaires Saint-Luc, Brussels, Belgium

[15]Orthopedic Surgery, Royal Orthopaedic Hospital, Birmingham, United Kingdom

Correspondence
Eric Lodewijk Staals, MD, Orthopedic Surgery, IRCCS Istituto Ortopedico Rizzoli, Via Pupilli 1, 40136 Bologna, Italy.
Email: ericlodewijk.staals@ior.it

Abstract

Background and Objectives: Expandable distal femur prostheses have become more popular over the last decades, but scientific data is limited.

Methods: A retrospective study was performed, including cases treated between 1986 and 2019 in 15 European referral centers for bone sarcomas.

Results: A total of 299 cases were included. Average follow-up was 80 months (range, 8-287 months). Mean patient age was 10 years. Most (80%) of the implants were noninvasive growers and a fixed hinge knee was used more often (64%) than a rotating hinge. Most prosthetic designs showed good (>80%) implant survival at 10 years, but repeat surgery was required for 63% of the patients. The most frequent reason for revision procedure was the completion of lengthening potential. Noninvasive expandable implants showed less risk of infection compared to invasive growers (11.8% vs 22.9% at 10 years). No difference in aseptic loosening was found between cemented and uncemented stems.

Conclusions: This study shows the increasing popularity of expandable distal femur prostheses, with overall good results for function and implant survival. However, repeat surgery is frequently required, especially in patients under the age of 10 years old. Infection is less frequent in noninvasive growers compared to implants that require invasive lengthening procedures.

KEYWORDS

bone tumor, distal femur, lengthening prosthesis, magnetic, pediatric tumor

1 | BACKGROUND

Expandable prostheses have become an important reconstructive technique in the treatment of children with bone sarcomas of the lower limb. According to a recent survey by the European Musculoskeletal Oncology Society (EMSOS), more than 60% of orthopedic oncologists have used this technique.[1] However, less than 5% of these consultants have implanted more than five expandable prostheses. Therefore, scientific data on these implants remains limited. The current literature includes mainly small series, or mono-institutional studies with inevitable selection bias.[2-8] According to these reports, complications are relatively common and outcome is difficult to predict compared to adult-type megaprostheses.

We, therefore, performed an international EMSOS study on expandable prostheses of the distal femur. The objective of this study was to increase scientific data on this type of reconstruction, to provide patients with reliable information on indications, complications, functional outcome, and need for further surgery.

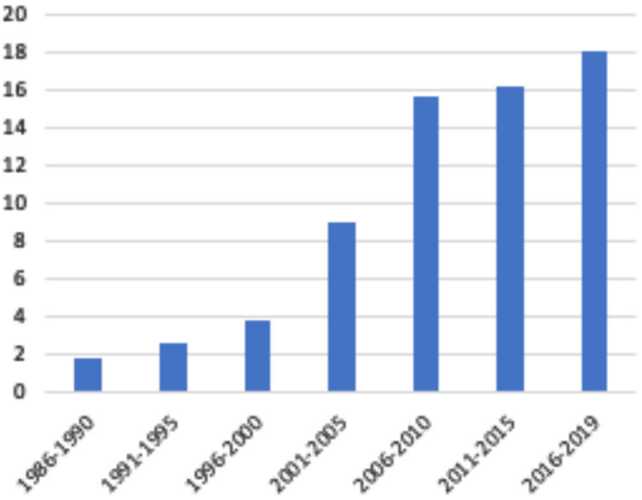

FIGURE 1 Expandable distal femoral prostheses implanted per year, according to the EMSOS database [Color figure can be viewed at wileyonlinelibrary.com]

2 | METHODS

All members of the European Musculoskeletal Oncology Society were invited to participate to this study by sending in data on their cases of expandable reconstructions of the distal femur. Cases were included regardless of patient age, indication, and expansion mechanism. The study period was between 1986 and 2019. All complications requiring further surgery were recorded and classified according to Henderson et al.[9]

At final follow-up, functional results of surviving patients with implant in situ were evaluated according to the Musculoskeletal Tumor Society (MSTS) Score. Limb-length discrepancy was evaluated on panoramic radiographs of the lower limbs at final follow-up.[10]

The Kaplan-Meier method was used to estimate overall survival (OS) of the implant. The implant failure rate was defined as the removal of the expandable prosthesis for any reason, and it was calculated by competing risk analysis with expandable prosthesis censored at the time of failure or last follow-up. Infection free and amputation free-rates were also calculated by Kaplan-Meier survival analysis. Categorical variables were compared between groups by contingency tables and chi-square test. Significance was set with P values <.05 in all statistical analyses, which were completed using the Statistical Package for Social Science (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp).

3 | RESULTS

A total of 299 cases were included from 15 different referral centers for orthopedic oncology in 9 different European countries (Italy, the Netherlands, Belgium, France, United Kingdom, Austria, Russia, Ukraine, Israel). Before the year 2000, expandable prostheses were very rarely used, with an annual incidence of less than four implants per year. After the year 2000 there was a quick increase in the number of implants. Since 2010, there is a slow but gradual increase of the yearly implanted distal femoral expandable prostheses according to the data sent in by the participating EMSOS centers (Figure 1).

Median follow-up in this study was 80 months (range, 8-287 months). The mean age of patients at the time of surgery was 10 years (range, 4-63 years). The most frequent diagnosis was osteosarcoma, in 271 (90.6%) patients, followed by Ewing sarcoma in 20 (6.7%) patients. Other diagnoses were chondrosarcoma (two patients), undifferentiated pleomorphic sarcoma (two patients), and secondary bone loss due to prosthetic loosening (three patients) or infection (one patient). The average tumor size (length) was 117 mm (range, 35-238 mm).

Fifty-two (17.4%) patients had metastatic disease at the time of diagnosis. All but six patients underwent (neo-)adjuvant chemotherapy. A total of eleven patients received also radiotherapy for the primary tumor. At the final follow-up, 76% of the tumor patients had no evidence of disease.

Sixty (20%) of the implants required (mini-)invasive surgical procedures for lengthening, the remainder were noninvasive growers. In almost two thirds (64%) of the cases, a fixed hinge joint mechanism was implanted, the others received a rotating hinge prosthesis.

More than half of the prostheses (53%) in this database, were manufactured by Stanmore Implants Worldwide (Elstree, UK). Other frequently used implants were manufactured by Stryker/Howmedica (Mahwah), Implantcast (Buxtehude, Germany) and Wright Medical Technology (Arlington) (Table 1).

Complications were classified according to the modified Henderson classification of implant failure.[9] The most frequent reason for revision procedure in this database was the completion of lengthening potential, which was considered a pediatric failure (Table 2).

Kaplan-Meier survival analysis of invasive vs noninvasive growing prostheses against infection, showed significantly (P = .015)

TABLE 1 Implants manufacturers

Prosthesis manufacturer	Nr (%)
Implantcast	43 (14%)
Wright	38 (13%)
Stanmore	157 (53%)
Stryker/Howmedica	48 (16%)
Other	13 (4%)

TABLE 2 Complications

Complication	Number of surgeries
Soft tissue complications	35
Aseptic loosening	70
Structural failure	62
Infection	61
Tumor progression	20
Pediatric failures	102

higher risk of infection for the implants that required a surgical procedure for lengthening (Figure 2) (88.2% vs 77.1% at 10 years).

Cemented and uncemented stems, had a comparable survival; aseptic loosening was seen respectively in 19.6% and 13.7% at 10 years ($P = .394$) (Figure 3).

There was no statistically significant difference in implant survival between fixed hinge and rotating hinge systems ($P = .526$).

Total length achievement was more often reason for implant revision in young children (Figure 4). The revision rate was 37.3% in patients up to 10 years of age, and 23.6% in those older than 10 ($P = .047$).

The Wright prostheses showed worse survival (57.9% at 5 years and 40.9% at 10 years), when looking at mechanical implant failure (type 2 and 3). The Stanmore, Stryker and Implantcast prostheses all had an implant survival of more than 80% at 5 and 10 years (Figure 5).

At the final follow-up, sixty-eight percent of the patients had an expandable implant in situ. For 194 patients, information was available on limb length compared to the opposite limb. Sixty-seven of these had no limb length discrepancy (LLD) at the final follow-up. For the remaining 127 patients the LLD was on average 23 mm (range, 4-87 mm). A total of 23 patients underwent a contralateral epiphysiodesis of at least one of the growth plates around the knee. The average MSTS score was 25 (range, 9-30). Excluding mini-invasive lengthening procedures, one hundred and eighty-eight (63%) patients required further surgery, and an average of 2.2 surgeries per patient were performed during the study period. Also, 12% (36 patients) developed a deep infection of the expandable prosthesis during follow-up, and a total of 20 patients (7%) required demolitive surgery.

4 | DISCUSSION

Expandable distal femoral replacements have been used since the 70 seconds, when limb salvage surgery started to become more

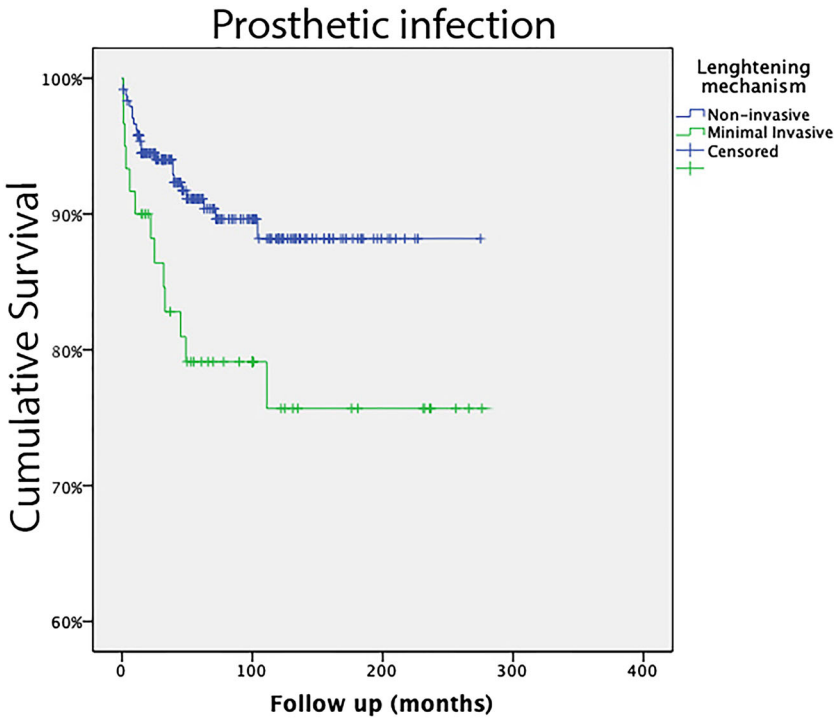

FIGURE 2 Implant survival of invasive vs noninvasive prosthesis against infection showed better outcome for non-invasive expandable implants [Color figure can be viewed at wileyonlinelibrary.com]

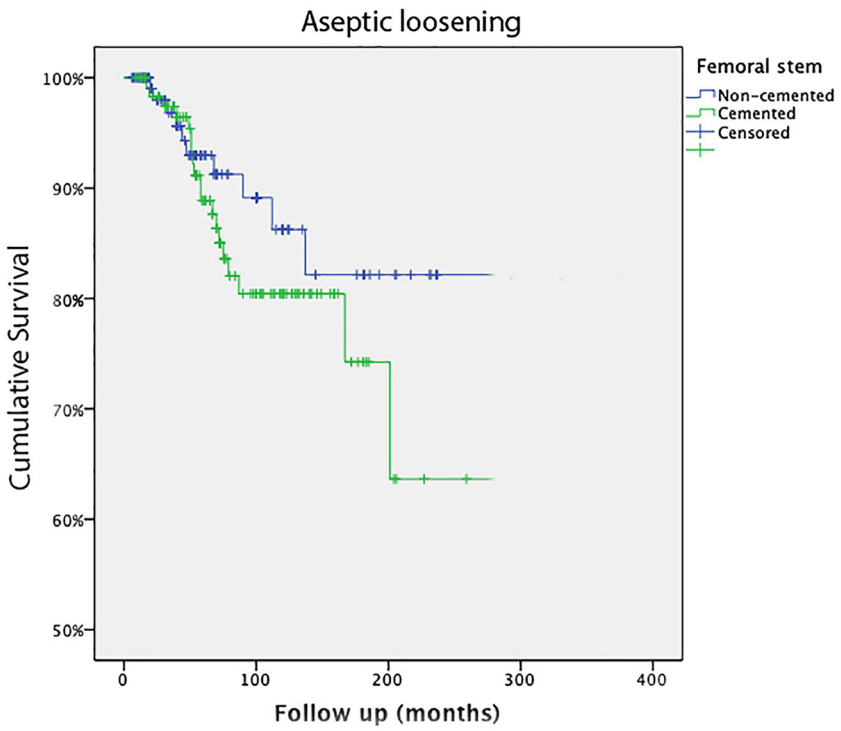

FIGURE 3 Implant survival of cemented vs uncemented stem fixation did not show a significant difference [Color figure can be viewed at wileyonlinelibrary.com]

frequent and required special reconstructions in children to overcome the problem of growth loss. However, the early expandable prosthetic designs showed disappointing results, and required multiple invasive surgeries.[4,11,12] For this reason, expandable reconstructions were rarely used before the end of the 21st century. Since the introduction of noninvasive expandable implants, the popularity of this reconstructive technique has increased significantly. This study showed how the incidence of this indication raised almost

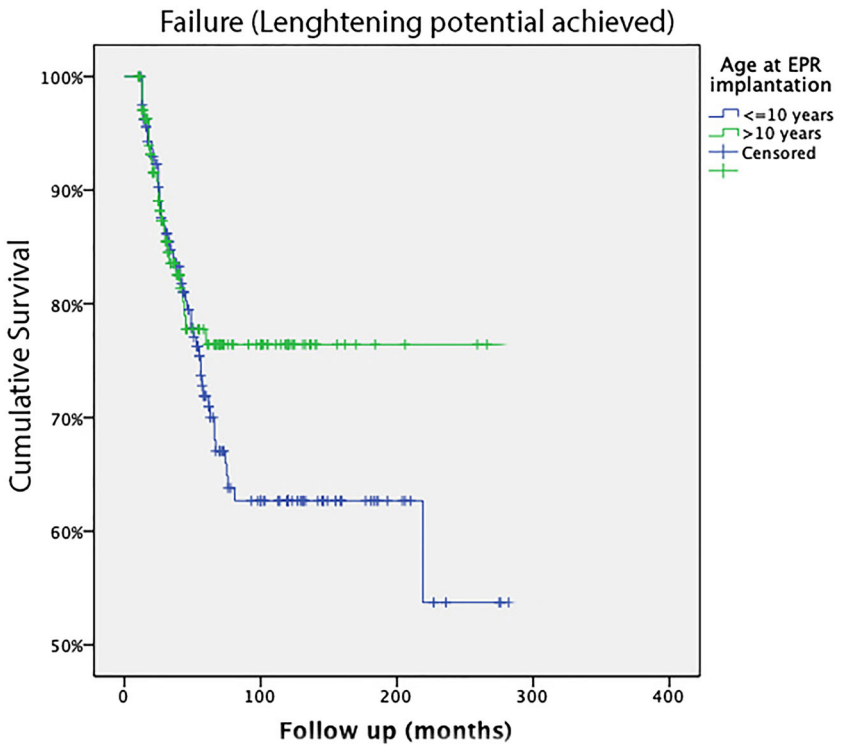

FIGURE 4 Children up to 10 years had significantly higher risk for revision surgery due to completion of total length potential [Color figure can be viewed at wileyonlinelibrary.com]

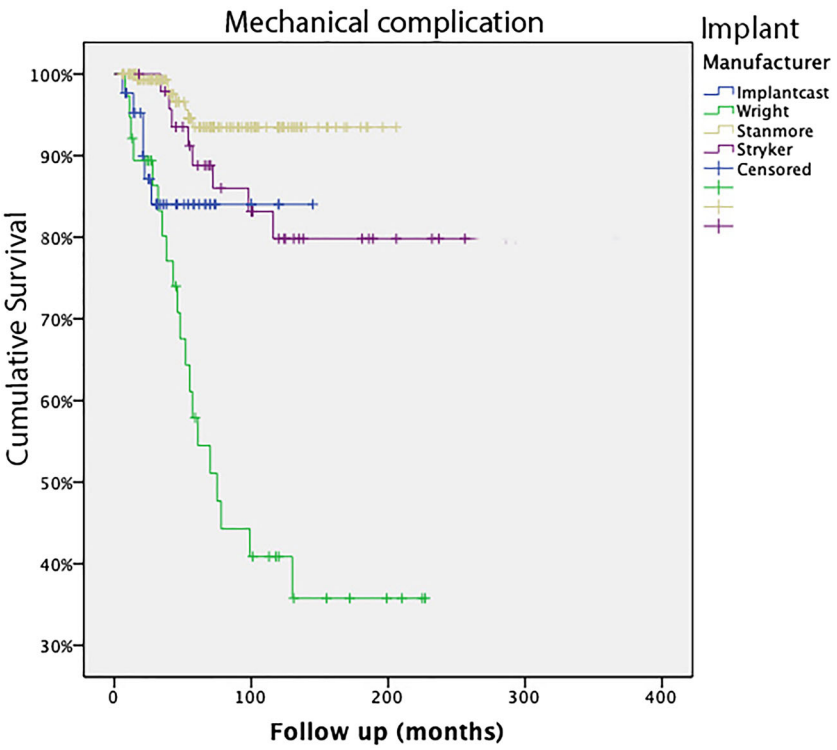

FIGURE 5 Stanmore, Stryker, and Implantcast prostheses all showed good implant survival against mechanical failure. The Wright prosthesis did worse [Color figure can be viewed at wileyonlinelibrary.com]

exponentially since the year 2000, and is still increasing, although at a slower rate, over the last decade. Reason for this, is certainly the improved implant design, with higher mechanical reliability and lower infection risk for the most recent generation of expandable implants.[3,5,8,13]

In the current database, which represents the largest series of expandable distal femoral prostheses, the mean age of patients was 10 years. This is similar to data reported in the previous series of expandable implants.[3,5,8,13] Very young patients, under the age of 5 or 6 years, require a lengthening potential that is difficult to obtain with a single expandable implant. Furthermore, at this age, a reliable implant fixation is very challenging due to the small diameter and length of the residual femur after tumor resection. For this reason, amputation and rotationplasty are thought to be valid alternatives for patients in this very young age group. At the same time, for pediatric patients who are close to skeletal maturity, an expandable implant is often not necessary. For these patients, the limited loss of growth potential can be easily compensated by less invasive and less expensive measures such as a shoe lift, overlengthening with a modular non-expandable implant, and contralateral epiphysiodesis.[14]

Over the years, there has been a tendency to reduce the invasiveness of the lengthening procedures and the most recently introduced implants are all noninvasive growers. This study confirms the theoretical advantage of noninvasive growers over invasive growers, with significantly less infections in the first group.

In this database, the Stanmore JTS prosthesis was the most popular expandable distal femoral implant. This specific implant has the advantage of a noninvasive lengthening mechanism. Stem fixation is either cemented or uncemented and the hinge mechanism can be either fixed or rotating. In the previous series, this implant has shown reliability of the lengthening mechanism in an outpatient setting and overall implant survival was relatively high.[5,8,13] Also in the current study, the Stanmore expandable implant showed good overall survival. Both, Stryker and Implantcast expandable prostheses showed similar durability to that of the Stanmore implants and no statistical difference in implant survival could be detected between these implants in the current study. However, this analysis confirmed a poor implant survival for the Wright prosthesis, as was reported in previous series.[15]

Stem fixation for megaprosthesis in children remains a controversial issue. In this database, we did not find a significant difference for aseptic loosening, when comparing cemented and uncemented stem fixation. However, as most patients in this series required further major revision surgery during follow-up, it is important to take into consideration the loss of bone stock during future stem revisions, as well as the risk for stress shielding in pediatric patients, in the decision-making process on stem choice and fixation.

The most frequent reason for implant revision in this study was completion of the lengthening potential. Whether this is a real complication remains questionable, as this event is often predictable in young children who are reconstructed with implants that have a limited lengthening potential. However, it is a reason for major revision surgery and therefore was classified as a pediatric failure in this study. As expected, this was more frequent in the younger patients, and the difference was most pronounced when a cut-off age of 10 years was considered. The limited lengthening potential of relatively short implants is a critical issue in very young patients that should be taken into consideration at the time of the treatment decision and discussed with the parents of the patients.

Overall, more modern implants showed relatively good outcomes. Functional scores, measured according to the MSTS scoring system, were on average good. Yet, the high need for further surgery, high risk of infection (12%) and amputation (7%) during follow-up, warrant for further implant development.

5 | CONCLUSIONS

This study represents the largest database on expandable megaprostheses in the literature. It shows how this reconstructive technique has been used more frequently over the last decades and still increases in popularity. Implants that are currently available in the market show overall good implant survival and good functional outcome, but repeat surgeries are frequent and major complications still represent a concern. Noninvasive implants are associated with a lower infection risk compared to implants that require invasive procedures. Cemented and cementless stem fixation show comparable results in terms of implant survival against aseptic loosening.

CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data re not publicly available due to privacy or ethical restrictions.

ORCID

Eric Lodewijk Staals http://orcid.org/0000-0001-8189-3055
Andrea Sambri http://orcid.org/0000-0002-2099-8547

REFERENCES

1. Gilg MM, Wibmer C, Bergovec M, Grimer RJ, Leithner A. When do orthopaedic oncologists consider the implantation of expandable prostheses in bone sarcoma patients? *Sarcoma*. 2018;201:3504075.
2. Beebe K, Benevenia J, Kaushal N, Uglialoro A, Patel N, Patterson F. Evaluation of a noninvasive expandable prosthesis in musculoskeletal oncology patients for the upper and lower limb. *Orthopedics*. 2010;33(6):396.
3. Decilveo AP, Szczech BW, Topfer J, Wittig JC. Reconstruction using expandable endoprostheses for skeletally immature patients with sarcoma. *Orthopedics*. 2017;40(1):e157-e163.
4. Eckardt JJ, Kabo JM, Kelley CM, et al. Expandable endoprosthesis reconstruction in skeletally immature patients with tumors. *Clin Orthop Relat Res*. 2000;373:51-61.
5. Gilg MM, Gaston CL, Parry MC, et al. What is the morbidity of a non-invasive growing prosthesis? *Bone Joint J*. 2016;98-B(12):1697-1703.
6. Gupta A, Meswania J, Pollock R, et al. Non-invasive distal femoral expandable endoprosthesis for limb-salvage surgery in paediatric tumours. *J Bone Joint Surg Br*. 2006;88(5):649-654.
7. Hwang N, Grimer RJ, Carter SR, Tillman RM, Abudu A, Jeys LM. Early results of a non-invasive extendible prosthesis for limb-salvage surgery in children with bone tumours. *J Bone Joint Surg Br*. 2012;94(2):265-269.
8. Picardo NE, Blunn GW, Shekkeris AS, et al. The medium-term results of the Stanmore non-invasive extendible endoprosthesis in the treatment of paediatric bone tumours. *J Bone Joint Surg Br*. 2012;94(3):425-430.
9. Henderson ER, O'Connor MI, Ruggieri P, et al. Classification of failure of limb salvage after reconstructive surgery for bone tumours: a modified system Including biological and expandable reconstructions. *Bone Joint J*. 2014;96-B(11):1436-1440.
10. Stanitski DF. Limb-length inequality: assessment and treatment options. *J Am Acad Orthop Surg*. 1999;7(3):143-153.
11. Schindler OS, Cannon SR, Briggs TW, Blunn GW. Stanmore custom-made extendible distal femoral replacements. Clinical experience in children with primary malignant bone tumours. *J Bone Joint Surg Br*. 1997;79(6):927-937.
12. Abudu A, Grimer R, Tillman R, Carter S. The use of prostheses in skeletally immature patients. *Orthop Clin North Am*. 2006;37(1):75-84.
13. Sambri A, Staals E, Medellin MR, et al. Stanmore noninvasive extendible endoprosthesis in the treatment of bone sarcoma in the preadolescent. *J Surg Oncol*. 2019;120(2):176-182.
14. Gonzalez-Herranz P, Burgos-Flores J, Ocete-Guzman JG, Lopez-Mondejar JA, Amaya S. The management of limb-length discrepancies in children after treatment of osteosarcoma and Ewing's sarcoma. *J Pediatr Orthop*. 1995;15(5):561-565.
15. Staals EL, Colangeli M, Ali N, Casanova JM, Donati DM, Manfrini M. Are complications associated with the repiphysis((R)) expandable distal femoral prosthesis acceptable for its continued use? *Clin Orthop Relat Res*. 2015;473(9):3003-3013.

How to cite this article: Staals EL, Sambri A, Campanacci DA, et al. Expandable distal femur megaprosthesis: A European Musculoskeletal Oncology Society study on 299 cases. *J Surg Oncol*. 2020;1–6. https://doi.org/10.1002/jso.26060