Reconstruction with Unconventional Endoprostheses after Resection of Primary Distal Femoral Bone Tumors: Implant Survival and Functional Outcomes

Reconstrução com endoprótese não convencional após ressecção de tumores ósseos primários de fêmur distal: sobrevida do implante e resultados funcionais

Cibele Marino Pereira[1] Fábio Fernando Elói Pinto[1] Suely Akiko Nakagawa[1] Wu Tu Chung[1]

[1] Department of Orthopedics, AC Camargo Cancer Center, São Paulo, SP, Brazil

Rev Bras Ortop 2022;57(6):1030–1038.

Address for correspondence Cibele Marino Pereira, Rua Professor Antônio Prudente, 211–Liberdade, São Paulo, 01509-900, SP, Brazil (e-mail: dra.c.marino@gmail.com).

Abstract

Objective To evaluate the survival time, the failure rate and its causes, and the functional results of cemented endoprostheses, with a polyethylene body, used after resection of primary bone tumors of the distal femur.

Methods A retrospective study including 93 primary and 77 review procedures performed between 1987 and 2014. Survival was obtained by the Kaplan Meyer analysis, and the risk factors for implant failure were assessed through the Cox proportional risk model. The causes of endoprosthesis failure were classified according to Henderson et al. into five types: soft-tissue failure, aseptic loosening, structural fracture, infection, and tumor recurrence. The functional evaluation was performed using the functional classification system of the Musculoskeletal Tumor Society (MSTS) of bone sarcomas of the lower extremity, Brazilian version (MSTS-BR).

Results Osteosarcoma was the most common diagnosis; 64.5% of the patients were younger than 20 years of age; the mean follow-up was of 124.3 months. The failure rate of the primary implant was of 54.8%, and the mean survival was of 123 months. The estimated survival of the primary implant was of 63.6%, 43.5%, 24.1%, and 14.5% in 5, 10, 15, and 20 years respectively. The most common cause of failure was type 2 (37.3%). Age $\leq$ 26 years and right side were risk factors for failure. The mean MSTS-BR score was of 20.7 (range: 14 to 27).

Keywords

- endoprostheses
- femur
- bone neoplasms
- osteosarcoma
- reconstructive surgical procedures
- limb salvage

received
November 29, 2021
accepted
March 4, 2022

DOI https://doi.org/10.1055/s-0042-1748966.
ISSN 0102-3616.

© 2022. Sociedade Brasileira de Ortopedia e Traumatologia. All rights reserved.
This is an open access article published by Thieme under the terms of the Creative Commons Attribution-NonDerivative-NonCommercial-License, permitting copying and reproduction so long as the original work is given appropriate credit. Contents may not be used for commercial purposes, or adapted, remixed, transformed or built upon. (https://creativecommons.org/licenses/by-nc-nd/4.0/)

Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

Conclusion The results obtained for the failure rate and survival of the implant are in accordance with those of the literature, so the procedure herein studied is adequate and yields satisfactory functional results, even in the long term.

Resumo

Objetivo Avaliar o tempo de sobrevida, a taxa de falha e suas causas, e os resultados funcionais de endopróteses cimentadas, com corpo em polietileno, empregadas após ressecção de tumores ósseos primários do fêmur distal.

Métodos Estudo retrospectivo, que incluiu 93 procedimentos primários e 77 de revisão, realizados entre 1987 e 2014. A sobrevida foi obtida pela análise de Kaplan Meyer, e os fatores de risco para falha do implante foram avaliados por meio do modelo de riscos proporcionais de Cox. As causas de falha da endoprótese foram classificadas segundo Henderson et al. em cinco tipos: falha de partes moles, soltura asséptica, fratura estrutural, infecção e recorrência do tumor. A avaliação funcional foi realizada por meio do sistema de classificação funcional da Musculoskeletal Tumor Society (MSTS) para sarcomas ósseos da extremidade inferior, versão brasileira (MSTS-BR).

Resultados Osteossarcoma foi o diagnóstico mais comum; 64,5% dos pacientes tinham menos de 20 anos; e o seguimento médio foi de 124,3 meses. A taxa de falha do implante primário foi de 54,8%, e a sobrevida média foi 123 meses. A estimativa de sobrevida do implante primário foi de 63,6%, 43,5%, 24,1%, 14,5% em 5, 10, 15 e 20 anos, respectivamente. A causa de falha mais comum foi a do tipo 2 (37,3%). Idade $\leq$ 26 anos e lado direito foram fatores de risco para falha. A pontuação média no MSTS-BR foi de 20,7 (variação: 14 a 27).

Conclusão Os resultados obtidos para a taxa de falha e o tempo de sobrevida do implante estão de acordo com os da literatura, de forma que o procedimento estudado é adequado e apresenta resultados funcionais satisfatórios, inclusive em longo prazo.

Palavras-chave
- endopróteses
- fêmur
- neoplasias ósseas
- osteossarcoma
- procedimentos cirúrgicos reconstrutivos
- salvamento de membro

Introduction

For many years, amputation has been the treatment of choice for malignant bone tumors.[1] In recent decades, there has been a great evolution in the treatment of these neoplasms in terms of effective systemic therapies, new surgical reconstruction techniques, and advances in the quality of imaging tests, which have resulted in increased survival of the patients with neoplasms such as osteosarcoma, chondrosarcoma, and Ewing tumor.[2–4] Resection of these tumors often results in significant bone failure that must be reconstructed, and unconventional endoprostheses play a central role in limb-preserving surgery[5] (►**Figure 1**).

Replacement by unconventional endoprosthesis is the most used reconstruction method in limb-preserving surgeries after segmental bone resections.[6] Its advantages include: immediate weight discharge, good cost-benefit ratio, and availability.[7] However, the failure rate of these implants exceeds that of conventional prostheses, due to the higher morbidity of the oncological procedures (extensive dissections, prolonged surgical time) and of the oncological patient (chemotherapy treatment, frequent hospitalizations, immunological impairment, comorbidities).[1,8] The causes of endoprosthesis failures were classified by Herderson et al.[9] as follows: 1) soft-tissue failure; 2) aseptic loosening; 3) structural fracture; 4) infection; and 5) tumor recurrence. Currently, there are few studies with medium and long-term results analyzing the use of endoprostheses in resections of periarticular tumors around the knee.[7,10,11]

The aim of the present study is to evaluate the survival time and causes of failures of the distal femur unconventional endoprostheses and, when possible, the functional results.

Materials and Methods

After the project was approved by the institutional Ethics in Research Committee, a retrospective research was performed on the institutional electronic databases regarding the medical records of patients submitted to resection of neoplasms of the distal segment of the femur and reconstruction with cemented unconventional endoprostheses with a polyethylene body, custom-made or modular, for primary or revision procedures, partial or with a knee joint, provided by the same manufacturer, used in the surgical treatment of primary bone neoplasms of the distal femur, in the same cancer center, from 1987 to 2014. Cases of metastatic disease and soft tissue neoplasia were excluded. Thus, 92 medical records were included in the study, with one bilateral case, totalling 93 primary endoprostheses and 77 revision endoprostheses.

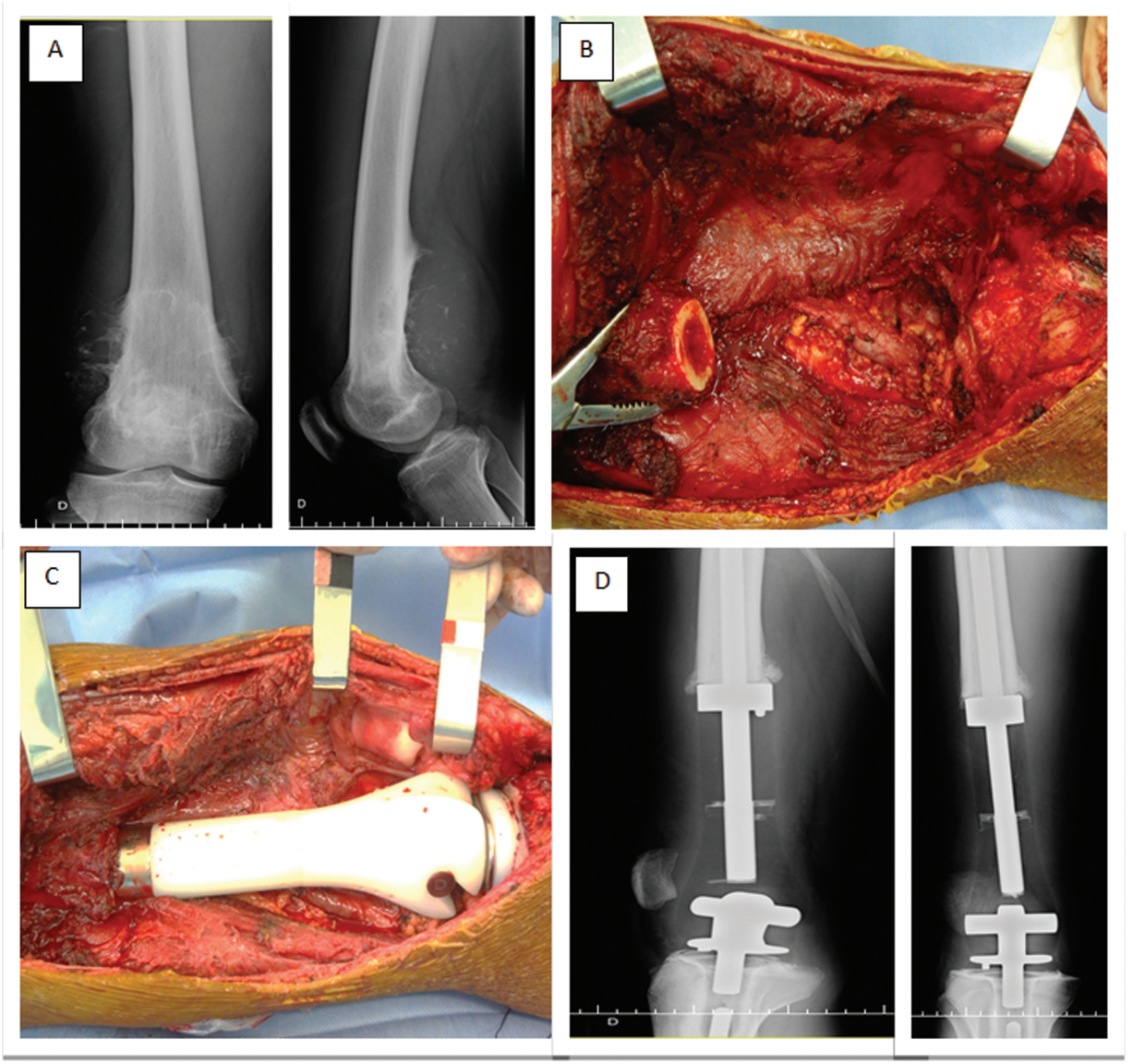

Fig. 1 Cemented distal femur endoprosthesis with polyethylene body and titanium rod with articulated knee, custom-made. (**A**) Anteroposterior (AP) and profile (P) radiographs of a case of periosteal osteosarcoma of the distal femur. (**B**) Intraoperative imaging of bone failure. (**C**) Intraoperative imaging after reconstruction. (**D**) Anteroposterior and P radiographs after reconstruction.

The variables analyzed were: gender, age, tumor size, laterality, Enneking classification, types of treatment, types of endoprosthesis, histological types, histological degree, surgical margins, tumor invasion, Huvos classification, follow-up duration, deaths, metastases, and patient survival.

Regarding the endoprostheses, we analyzed the failure rate, the survival time, and the types of failure according to the classification by Herderson et al.[9]

The functional evaluation was performed by applying the functional classification system of the Musculoskeletal Tumor Society (MSTS) of bone sarcomas of the lower extremity, Brazilian version (MSTS-BR),[12] which consists of a questionnaire with six questions that address the following aspects: pain, limb function, emotional acceptance, use of walking aid device, ability to walk, and gait. The maximum score for each question is 5, and the maximum score is 30.

Statistical analysis

We performed a descriptive analysis of the variables: absolute (n) and relative frequency (%) for the qualitative variables, and the main summary measures (mean, standard deviation, median, minimum, and maximum values) for the quantitative variables. To evaluate the survival of the implants, the Kaplan-Meier estimator was considered, and the log-rank test was applied to compare the survival curves. The cutoff points for the variables age and tumor size in relation to the outcome (implant failure) were obtained through the log-rank statistic maximization technique.[13] Possible risk factors were evaluated using the Cox proportional risk model.[14–16] The level of significance adopted was of 5%; thus, results whose *p-value* were lower than 0.05 were considered statistically significant. For the statistical

analysis, we used the Statistical Package for the Social Sciences (IBM SPSS Statistics for Windows, IBM Corp., Armonk, NY, United States) software, version 24.0, and the R (R Foundation for Statistical Computing, Vienna, Austria) software, version 3.5.

Results

Demographic and Clinical Characteristics

Data from 92 patients and 93 primary distal femur endoprostheses were analyzed, and they are described as follows.

In total, 45 patients (49%) were male, and 47 (51%) were female. Regarding age, 8 patients (8.6%) were between 0 and 10 years old, 52 (55.9%), between 11 and 20 years, 16 (17.2%), between 21 and 30 years, 6 (6.5%), between 31 and 40 years, 9 (9.7%), between 41 and 50 years, and 1 (1.1%), older than 50 years of age. Regarding laterality, 54.8% of the cases were on the right side, and 44.1%, on the left side. Of the 92 patients, 77 did not present metastasis at diagnosis, and 15 (16.3%) did.

Most diagnoses were of high-grade central osteosarcoma: 63 cases (67.7%), followed by parostal osteosarcoma, with 12 (12.9%) cases, chondrosarcoma and giant cell tumor, with 4 (4.3%) cases each, Ewing tumor, with 3 (3.2%) cases, and periosteal osteosarcoma, malignant fibrohistiocytoma, leiomyosarcoma, lymphoma, enchodroma, non-ossifying fibroma, and metaphysary malignant histiocytoma, with 1 case (1.1%) each.

The mean follow-up of the patients was of 145.3 months (12 years and 3 months), and during the follow-up, postoperative complications were reported in 7 patients. They were: drug allergy, posttransfusion urticaria, sepsis, skin injury due to the immobilizer, agitation with dislocation of the endoprosthesis, sciatic-popliteal neuropraxia, skin necrosis, hematoma, and respiratory complication related to orotracheal intubation.

Of the 92 patients, 24 died during the follow-up. The overall survival of the patients at 5, 10, 15, and 20 years was of 78.9%, 75.7%, 69.4% and 67% respectively.

In the evaluation of the margins of the surgical specimen, 1 case of compromised margin was observed. Local recurrence occurred in 8 cases (8.6%), and, of these, 1 was submitted to resection of a soft-tissue mass, 1, to revision of the stent, 4, to amputation, 1, to chemotherapy, and 1, to palliative care. The patient who underwent review due to local recurrence had another recurrence and, finally, underwent amputation. The case submitted to resection of the recurrence in soft tissues was classified as type-3 endoprosthesis failure, as review was required due to breakage of the endoprosthesis, not recurrence.

The infection rate of the sample was of 6.4%; that of aseptic loosening, of 20.4%; that of local recurrence, of 8.6%; and the rate of implant breakage was of 11.8% (►**Tables 1** and **2**).

Table 1 Frequency – clinical data

Variables	Patients (n)	(%)
Gender	92	
Female	47	51.0%
Male	45	49.0%
Age	92	
0 to 10 years	8	8.6%
11 to 20 years	52	55.9%
21 to 30 years	16	17.2%
31 to 40 years	6	6.5%
41 to 50 years	9	9.7%
$>$ 50 years	1	1.1%
Age: cut-off point	92	
$\leq$ 26 years	69	75.0%
$>$ 26 years	23	25.0%
Tumor size		
$\leq$ 7cm	19	30.6%
$>$ 7cm	43	69.3%
Laterality	92	
Right	51	54.8%
Left	41	44.1%
Histological Types	93	
High-grade central osteosarcoma	63	67.7%
Parosteal osteosarcoma	12	12.9%
Chondrosarcoma	4	4.3%
Giant cell tumor	4	4.3%
Ewing tumor	3	3.2%
Periosteal osteosarcoma	1	1.1%
Malignant fibrous histiocytoma	1	1.1%
Leiomyosarcoma	1	1.1%
Lymphoma	1	1.1%
Encondroma	1	1.1%
Non-ossifying fibroma	1	1.1%
Metaphysary malignant histiocytoma	1	1.1%
Enneking	83	
Ia	1	1.2%
Ib	11	13.3%
IIa	1	1.2%
IIb	57	68.7%
III	13	15.7%

Survival of the Endoprostheses

Of the 93 primary endoprostheses analyzed, 51 (54.8%) failed, and 42 (45.2%) did not. The survival of primary endoprostheses at 1, 5, 10, 15, and 20 years was respectively of 93.4%, 63.6%, 43.5%, 24.1%, and 14.5%. Observing the Kaplan-Meyer curve, the mean survival of primary endoprostheses was of 123 months (10 years and 3 months)

Table 2 Frequency – treatment data

Variables	Patients (n)	(%)
Treatments performed	92	
Surgery	15	16.3%
Surgery + chemo- /radiotherapy	77	83.7%
Preoperative chemotherapy	91	
No	22	24.2%
Yes	69	75.8%
Type of endoprosthesis	90	
Partial	13	14.4%
Total	77	85.6%
Postoperative complications	93	
No	86	92.5%
Yes	7	7.5%
Tumor invasion	82	
No	6	7.3%
Yes	76	9.7%
Huvos classification	68	
1	12	17.9%
2	27	39.7%
3	17	25.0%
4	12	17.9%
Evaluation of the surgical margins	81	
Free	80	98.7%
Compromised	1	1.2%
Local recurrence	8	8.6%
Death during follow-up	24	26.0%
Infection	6	6.4%
Aseptic loosening	19	20.4%
Implant breakage	11	11.8%

(►**Figure 2**). Excluding patients who died during follow-up, the results regarding survival were of 95.6%, 68%, 46.9%, 24.8%, and 14.5% at 1, 5, 10, 15 and 20 years respectively. As the results of the statistical analysis excluding patients who died were similar to those of the analysis including all cases, we presented only the analyses including all patients in the study.

According to the classification of the types of endoprosthesis failure proposed by Herderson et al.,[9] the cause of failure most found in primary endoprostheses was type 2– aseptic loosening, with 19 cases (37.3%), followed by type 3– structural fracture, with 12 cases (23.5%), with 1 case of isolated periprosthetic fracture not involving structural failure of the endoprosthesis. There were also 7 cases (13.7%) of type-1 failures – soft-tissue failure, 7 cases (13.7%) of local recurrence – type-5 failure, and 6 cases (11.8%) of infection – type-4 failure.

Analyzing the survival according to the type of failure, we observed an average survival of 73.4 months for type-1 failures, 86.5 months for type-2, 89.5 months for type-3, 74.7 months for type-4, and 20.7 months for type-5 failures. When we analyze only the structural failures of the implant, the average survival obtained is of 87.3 months (►**Table 3**).

We did not observe statistically significant differences between the survival of endoprostheses in relation to gender, nor in relation to treatment – if only surgical or if combined with chemotherapy and radiotherapy, whether there was preoperative chemotherapy, the type of endoprosthesis (whether partial or with an articulated knee), regarding the Enneking staging, the histological degree, the Huvos classification, the tumor size, and the presence of tumor invasion. However, the survival in relation to laterality presented a statistically significant difference, with the right side presenting lower survival ($p = 0.036$) and in relation to age: individuals aged $\leq$ 26 years had lower survival of their implants ($p = 0.022$), when compared to older individuals (►**Table 4**).

Regarding the revisions: 45 patients underwent revision of the primary endoprosthesis. Of these, 21 (46.6%) experienced failure. The main type of failure was type 3, with 7 cases (15.6%), followed by type 2, with 6 cases (13.3%), type 4, with 4 cases (8.9%), type 1, with 3 cases (6.7%), and type 5, with 1 case (2.2%). In total, 18 patients underwent a second review, and 3 underwent amputation (1 due to tumor recurrence, 1, to infection, and 1 due to unknown cause – the procedure was performed in another service).

The survival of the first revision endoprosthesis at 1, 5 and 10 years was of 90.8%, 65.8%, 25.9% respectively. The mean survival of the first revision endoprosthesis was of 120.8 months ($\sim$ 10 years).

Regarding the number of revisions, 27 patients only underwent 1 revision, and 18, more than 1: 10 patients underwent 2; 4 patients, 3; 3 patients, 4; and 1 patient underwent 7 revisions.

The mean survival of the second revision endoprosthesis was of 136.4 months (11 years and 3 months), and the causes of failure were: 3 cases of aseptic loosening, 2 of soft tissue failure, 2 of structural fracture, and 1 case of infection. The results regarding implant survival are summarized in ►**Table 5**.

A total of 8 patients underwent a third revision; of these, 4 had failure, 3 due to aseptic loosening and 1 due to structural fracture. The three cases of aseptic loosening were submitted to four revisions until the last follow-up, and the case of structural fracture underwent seven revisions. There were 77 revision procedures in total.

Functional Results

A total of 14 patients were evaluated through the MSTS-BR questionnaire: 7 women and 7 men, with a mean age at admission of 20 years (range: 9 to 48 years) and a mean age at the evaluation of 38.5 years (range: 17 to 54 years). Regarding the procedures performed, 5 did not underwent revision, 3 underwent 1 revision, 4 underwent 2, and 2 patients underwent 4 revisions. The time since the last surgery ranged from 9 to 279 months. The mean score on the questionnaire was of 20.7

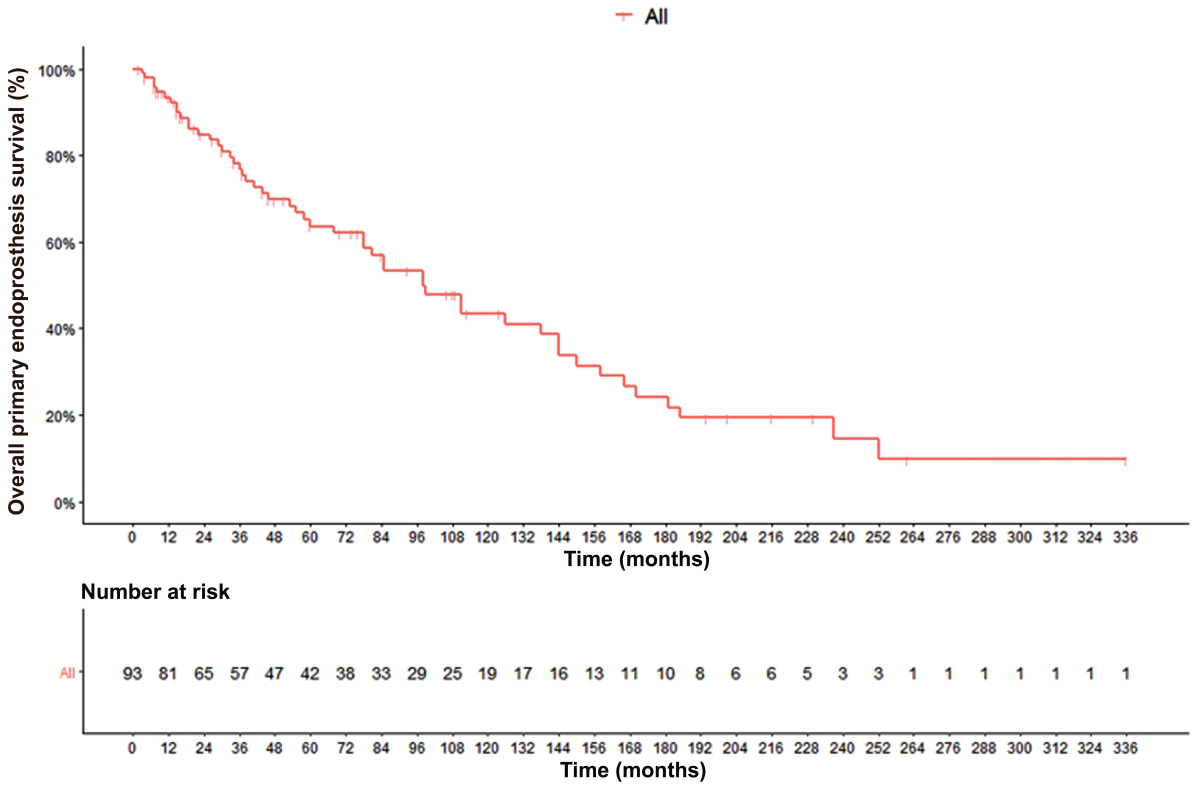

Fig. 2 Kaplan-Meyer curve for the survival of primary endoprostheses.

Table 3 Implant survival by type of failure

Type of failure	Average survival (months)	Estimated survival			
		1 year	2 years	5 years	10 years
1	73.429	0.857	0.571	0.286	0.286
2	86.526	1.000	0.947	0.421	0.263
3	89.5	0.917	0.917	0.750	0.250
4	74.167	1.000	0.667	0.500	0.333
5	20.714	0.429	0.143	0.000	0.000
2 and 3*	87.333	0.967	0.933	0.533	0.267

*The asterisk refers to the two types of structural failures: 2 and 3.

(range: 14 to 27) points. The question on 'gait aid device' presented an average score of 4.21 points (1 patient used a walking stick continuously, and 1 used it intermittently), and the one on the mean 'walking ability' had an average score of 4 points (2 patients described gait as limited). The other mean scores were: 'pain' – 3.28; 'function' –2.5; 'emotional acceptance' –3.71; and 'gait' – 3 points (►**Figure 3**).

Discussion

After resection of a bone tumor, the resulting defect should be reconstructed in order to preserve the affected limb as well as its function. In 1943, the first endoprosthesis was developed by Austin Moore, and, in fact, it was the first alternative to the traditional treatment of malignant and aggressive bone tumors until then: amputation.[1]

The aim of the present study was to evaluate the survival of primary endoprostheses of the distal femur after resection of primary bone tumors, to analyze the causes of failure and the functional results. The study has limitations due to the retrospective design and the heterogeneity in the cases, diagnoses, and types of treatment.

We found that the diagnosis that most commonly required the procedure analyzed in the present study was osteosarcoma in patients in the second decade of life.

In the literature, the failure of reconstruction with endoprostheses ranges from 40% to 73%.[17] We observed a failure rate of 54.8% in the primary implants.

Table 4 Survival estimate (Kaplan-Meier) and Cox regression model for primary implants

Variables	Categories	Survival estimate (Kaplan-Meier)			*p*-value*	Simple Cox regression model		
		5 years	10 years	15 years		HR	95%CI	*p*-value**
Gender	Female	0.755	0.516	0.282	0.225	Ref.		
	Male	0.509	0.347	0.149		1.403	0.807–2.439	0.230
Age	≤ 26 years	0.553	0.356	0.164	0.017	Ref.		
	> 26 years	0.905	0.724	0.579		0.392	0.176–0.871	0.022
Age	Continuous	–	–	–	–	0.970	0.942–0.999	0.041
Tumor size	≤ 7 cm	0.706	0.706	0.706	0.096	Ref.		
	> 7 cm	0.582	0.281	0.211		2.232	0.841–5.926	0.107
Laterality	Right	0.548	0.316	0.141	0.032	Ref.		
	Left	0.759	0.614	0.314		0.534	0.297–0.959	0.036
Enneking	Ib	0.656	0.394	0.263	0.180	–		
	IIb	0.621	0.441	0.240		–	–	–
	III	0.293	0.000	0.000		–	–	–
Treatment	Surgery	0.929	0.696	0.522	0.131	Ref.		
	Combined#	0.586	0.391	0.196		1.909	0.809–4.504	0.140
Preoperative chemotherapy	No	0.849	0.566	0.377	0.294	Ref.		
	Yes	0.571	0.397	0.198		1.415	0.735–2.721	0.299
Type of endoprosthesis	Partial	0.427	0.321	0.160	0.206	Ref.		
	Total	0.699	0.474	0.267		0.628	0.302–1.303	0.212
Histological grade	Benign/Low	0.805	0.447	0.298	0.433	Ref.		
	High	0.587	0.416	0.224		1.335	0.645–2.761	0.436
Tumor invasion[!]	No	1.000	0.750	0.375	0.238	Ref.		
	Yes	0.582	0.375	0.225		2.017	0.612–6.650	0.249

Abbreviations: CI, confidence interval; HR, hazard ratio; Ref., reference.
Notes: * *p*-value: log-rank test; ** *p*-value: Cox regression model; #chemotherapy or chemotherapy + neoadjuvant and/or adjuvant radiotherapy; ! invasion described in the pathological report of the surgical specimen: soft parts, vascular, lymphatic, neural.

We observed that some failures do not necessarily require the replacement of the endoprosthesis, such as some cases of type 1 (coverage failure, pain due to patellar osteoarthrosis or joint stiffness). In cases of type-1 failure, partial prosthesis instability, patellar instability, patellofemoral pain, and joint stiffness were observed.

Type-2 failures were the most frequent: 19 out of the 51 failures, and loosening occurred in both the femoral and tibial components.

Of the 12 cases of type-3 failure, 10 were due to implant breakage (femoral rod, rotation pin, and intermediate modules), and 2 involved periprosthetic fractures. One of the cases of structural failure also had local recurrence, but it was a soft-tissue mass, which was removed without the need for revision of the endoprosthesis. The revision procedure was performed due to breakage.

Of the 6 cases of infection, 3 were treated with a 2-stage revision, using a cement spacer with antibiotics, and the treatment of the infection was successful. Of the three cases that did not undergo two-stage revision, two evolved and had to be amputated after one revision. The other cases of amputation were due to local recurrence, as previously mentioned.

When we analyze only the structural failures of the implant – aseptic loosening and breakage of the endoprosthesis, there

Table 5 Implant failure and survival rate: primary and revision

Endoprosthesis	Failure rate	Average survival (months)	Kaplan-Meier survival estimate			
			5 years	10 years	15 years	20 years
Primary	54.8%	120.3	0.636	0.435	0.241	0.145
First revision	46.6%	120.8	0.658	0.259	0.259	0.259
Second revision	44.4%	136.4	0.619	0.619	0.413	0

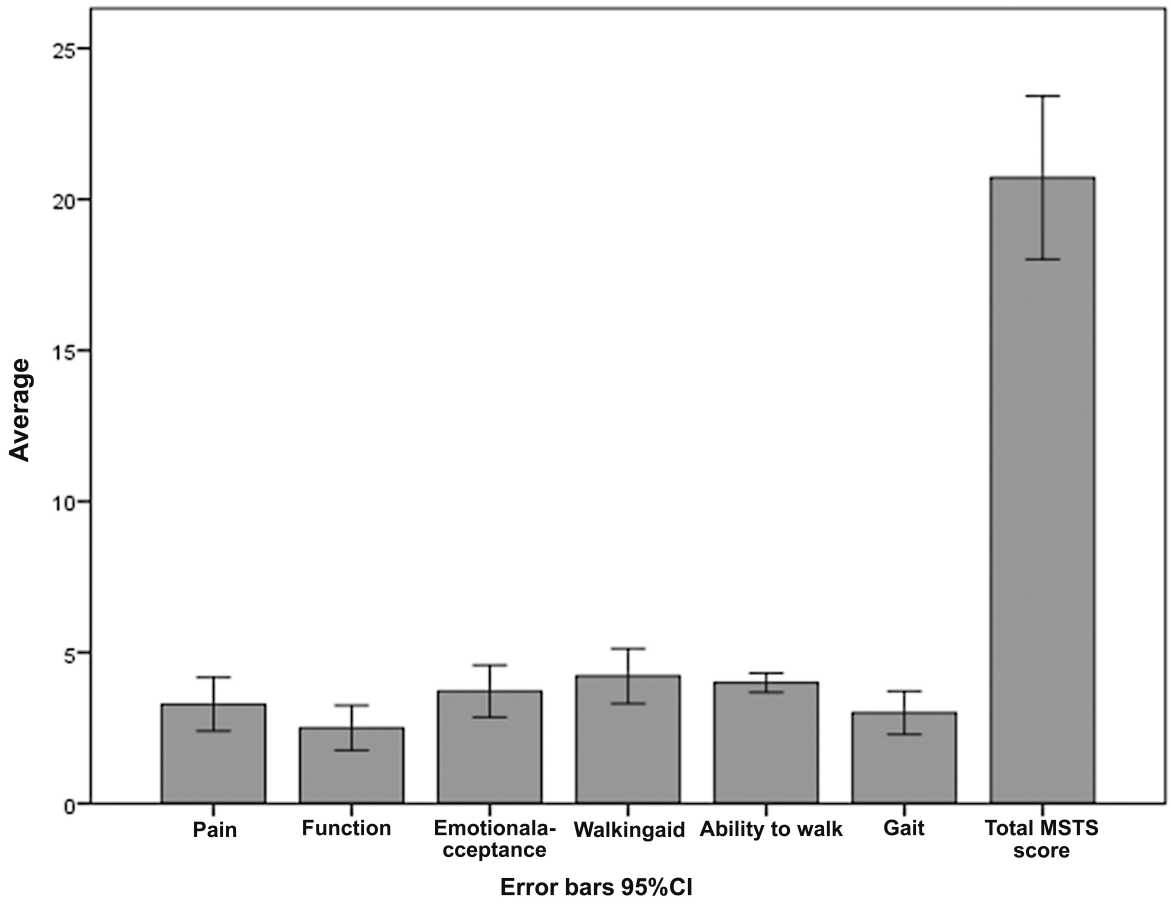

Fig. 3 Functional evaluation using the functional classification system of the Musculoskeletal Tumor Society (MSTS) of bone sarcomas of the lower extremity, Brazilian version (MSTS-BR).

were 30 cases (58.8% of the failures) that occured later when compared to the failures due to local recurrence (the earliest, and worse prognosis), soft-tissue failure, and infection. Mechanical failure also did not seem to compromise limb salvage, and was not the cause of any amputation; regarding patients who evolved with infection and local recurrence, amputation was indicated.

Pala et al.,[18] analyzing reconstruction of the distal femur with modular endoprosthesis, found a failure rate of 27% and a survival rate at 10 years of 70%; and Bergin et al.[19] found a rate of failure of 73.3%. Haijie et al. [10], in a systematic review article of 40 studies, found a rate of 78.5% of aseptic loosening and infection, the main causes of failure. Kinkel et al.[3] reported a probability of limb salvage after endoprosthesis failure of 92%, and the causes of amputation were local recurrence and infection. In the present study, the same rate was of 92.4%, and the causes were also the same. Kinkel et al.[3] reported a survival rate of primary implants of 57% at 5 years, and we found a rate of 63.6% in the same period.

Our series had an estimated 10-year survival of 43.5%, which is lower than that of some published series, and this may have occurred because we included only patients with primary tumors, who are mostly growing, which may lead to more cases of loosening. Our mean follow-up was also longer compared to that of some publications and, obviously, the higher the follow-up, the greater the probability of identifying implant failure.

Age presented statistical significance in terms of implant survival: endoprostheses in patients aged $\leq$ 26 years had a lower survival when compared to older patients. Therefore, age $>$ 26 years showed to be a protective factor against the occurrence of endoprosthesis failure (hazard ratio [HR] $=0.392$; confidence interval [CI] $=0.176$–0.871; $p=0.022$). The result can be justified by patient growth and higher demand (leisure activities, games etc.).

The statistical analysis also revealed a difference in survival according to the laterality of the endoprosthesis, showing that the risk of failure was higher on the right side, while the left side provides protection against failure (HR $=0.534$; CI $=0.297$–0.959; $p=0.036$). One hypothesis would be that, in most people, the dominant member is the right one, which would be subject to greater demand.

The functional analysis using the MSTS-BR revealed a high score in the questions about the need for gait aid (crutches, walking sticks), showing that most of the evaluated patients did not use such devices, as well as in the questions on ability to walk and emotional acceptance. The mean score was of 20.7 out of a maximum of 30 points (that is 69%), demonstrating a satisfactory functional result.

Conclusion

Aseptic loosening was the main cause of endoprosthesis failure in the present series. Mechanical failures – those related to the implant – do not seem to compromise limb salvage, and the need for revision of the endoprosthesis occurs later; as for local recurrence and infection, they can lead to amputation, and are causes of failure that occur earlier. Revision procedures are expected due to the increased survival of cancer patients. The limb-salvage rate after complication of the preserving surgery was high, and the rates of infection and local recurrence were low. The rates of failure and survival of the implant were in accordance with those found in the literature, and we conclude that the use of the endoprosthesis for the reconstruction of bone failure after resection of tumors of the distal femur is an appropriate method with satisfactory functional results, including in the long term.

Financial Support
The present study did not receive financial support from public, commercial, or non-profit sources.

Conflict of Interests
The authors have no conflict of interests to declare.

References

1 Hwang JS, Mehta AD, Yoon RS, Beebe KS. From amputation to limb salvage reconstruction: evolution and role of the endoprosthesis in musculoskeletal oncology. J Orthop Traumatol 2014;15(02): 81–86
2 Pala E, Henderson ER, Calabrò T, et al. Survival of current production tumor endoprostheses: complications, functional results, and a comparative statistical analysis. J Surg Oncol 2013;108(06):403–408
3 Kinkel S, Lehner B, Kleinhans JA, Jakubowitz E, Ewerbeck V, Heisel C. Medium to long-term results after reconstruction of bone defects at the knee with tumor endoprostheses. J Surg Oncol 2010;101(02):166–169
4 Cannon CP, Zeegen E, Eckardt JJ. Techniques in Endoprosthestic Reconstruction. Oper Tech Orthop 2005;14:225–235
5 Pugh LR, Clarkson PW, Phillips AE, Biau DJ, Masri BA. Tumor endoprosthesis revision rates increase with peri-operative chemotherapy but are reduced with the use of cemented implant fixation. J Arthroplasty 2014;29(07):1418–1422
6 Ottaviani G, Robert RS, Huh WW, Palla S, Jaffe N. Sociooccupational and physical outcomes more than 20 years after the diagnosis of osteosarcoma in children and adolescents: limb salvage versus amputation. Cancer 2013;119(20):3727–3736
7 Houdek MT, Wagner ER, Wilke BK, Wyles CC, Taunton MJ, Sim FH. Long term outcomes of cemented endoprosthetic reconstruction for periarticular tumors of the distal femur. Knee 2016;23(01): 167–172
8 Chan D, Carter SR, Grimer RJ, Sneath RS. Endoprosthetic replacement for bony metastases. Ann R Coll Surg Engl 1992;74(01): 13–18
9 Henderson ER, Groundland JS, Pala E, et al. Failure mode classification for tumor endoprostheses: retrospective review of five institutions and a literature review. J Bone Joint Surg Am 2011;93 (05):418–429
10 Haijie L, Dasen L, Tao J, Yi Y, Xiaodong T, Wei G. Implant Survival and Complication Profiles of Endoprostheses for Treating Tumor Around the Knee in Adults: A Systematic Review of the Literature Over the Past 30 Years. J Arthroplasty 2018;33(04):1275–1287.e3
11 Schwartz AJ, Kabo JM, Eilber FC, Eilber FR, Eckardt JJ. Cemented distal femoral endoprostheses for musculoskeletal tumor: improved survival of modular versus custom implants. Clin Orthop Relat Res 2010;468(08):2198–2210
12 Rebolledo DC, Vissoci JR, Pietrobon R, de Camargo OP, Baptista AM. Validation of the Brazilian version of the musculoskeletal tumor society rating scale for lower extremity bone sarcoma. Clin Orthop Relat Res 2013;471(12):4020–4026
13 Lausen B, Schumacher M. Maximally Selected Rank Statistics. Biometrics 1992;48:73–85
14 Cox DR. Regression models and life-tables (with discussion). J R Stat Soc B 1972;34(02):187–220
15 Schoenfeld D. Partial residuals for the proportional hazards regression model. Biometrika 1982;69:239–241
16 Grambsch PM, Therneau TM. Proportional hazards tests and diagnostics based on weighted residuals. Biometrika 1994; 81:515–526
17 Pala E, Trovarelli G, Calabrò T, Angelini A, Abati CN, Ruggieri P. Survival of modern knee tumor megaprostheses: failures, functional results, and a comparative statistical analysis. Clin Orthop Relat Res 2015;473(03):891–899
18 Pala E, Trovarelli G, Angelini A, Ruggieri P. Distal femur reconstruction with modular tumour prostheses: a single Institution analysis of implant survival comparing fixed versus rotating hinge knee prostheses. Int Orthop 2016;40(10):2171–2180
19 Bergin PF, Noveau JB, Jelinek JS, Henshaw RM. Aseptic loosening rates in distal femoral endoprostheses: does stem size matter? Clin Orthop Relat Res 2012;470(03):743–750