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Spanish Multicenter Megaprosthesis Study (MEGAPROT) on 816 Tumor Prostheses: Main Results

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Abstract: (1) Background: The use of tumor megaprostheses faces challenges, but the published series are typically small and offer limited solutions. Our aim was to compile a large series; describe patient profiles and surgical techniques; analyze prosthetic survival identifying factors affecting survival; and provide a basis for future subanalyses. (2) Methods: This is a retrospective observational multicenter study that included patients with a tumor megaprosthesis in any anatomical location. Demographic, etiologic, and surgical variables were analyzed. Data on complications and survival were also collected. (3) Results: Our series includes a total of 816 prostheses (585 primary, 181 revision, and 50 second revision). The patients' mean age was 44.2 ± 20.8 years. Primary surgeries were performed on the femur (n = 404; 69.1%), tibia (n = 79; 13.5%), humerus (n = 74; 12.6%), pelvis (n = 20; 3.4%), and scapula (n = 4; 0.7%). Survival following primary surgery was 73.3% at 10 years. No statistically significant differences were found with respect

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to survival from primary surgery between males and females (p = 0.194), between the different etiologies (p = 0.540), or between the lower and the upper limb (p = 0.618). In contrast, statistically significant survival differences were found when the type of fixation was analyzed ($p < 0.001$). (4) Conclusions: This study analyzed one of the largest series of patients treated with tumor megaprostheses, demonstrating their acceptable survival and validating them as a treatment option for bone tumors.

Keywords: megaprostheses; tumor; prostheses; survival; orthopedics; fixation; coating; neoplasm; osteosarcoma

1. Introduction

The term megaprosthesis usually refers to large-sized endoprosthetic systems, with a modular or custom design, used in the reconstruction of bone defects of various shapes and sizes. Although originally indicated for tumor surgery, megaprostheses can now be used for virtually any kind of skeletal reconstruction, including revision arthroplasties with severe bone loss and for the management of fractures where traditional osteosynthesis is not an option [1–4].

Although the emergence of megaprostheses dates back to the 1970s, their use only became widespread in the 1980s and 1990s concomitantly to the improvement of adjuvant treatments [1,5,6]. From then on, prosthetic reconstruction became possible in cases where the only option would have been amputation [1]. Current modular designs boast a wide variety of interchangeable components adapted to specific bone defects, with different types of coatings and fixation systems. Some systems even allow the manufacturing of custom components created based on medical imaging data.

Megaprostheses present unique challenges, particularly due to their large size and complex biomechanical demands. Common complications include mechanical failures, such as loosening and periprosthetic fractures. Advances in implant design, such as modular systems, biocompatible materials, and modern fixation techniques, have significantly reduced mechanical complications [4]. But, even if functional results are often satisfactory, providing patients with improved quality of life [1], these reconstructions still face the challenge of reducing the incidence of certain non-mechanical complications such as wound dehiscence, necrosis, soft tissue loss, deep infection, and local tumor recurrence [1,7].

The interest aroused by this kind of treatment has resulted in a growing number of publications analyzing the performance of megaprostheses in their various indications. However, the heterogeneity of indications, anatomical locations, implant models, and patients makes comparisons across series a real challenge. Moreover, only few large series have been published [8–11].

The Musculoskeletal Tumor Research Group (LINVESTAL) of the Spanish Society of Orthopedic and Trauma Surgeons conducted the so-called MegaProt multicenter study with a view to analyzing one of the largest series of tumor prostheses ever brought together. The purpose of the present study was to present a detailed description of the cases collected in the MegaProt study as well as its main results which, being aware of the heterogeneity of this series, could serve as a basis for future subanalyses.

2. Materials and Methods

2.1. Overview

The MegaProt study on megaprostheses was a retrospective observational multicenter study conducted on the initiative of the LINVESTAL research group. The trial was approved

by the Ethics Committee of the Ramon y Cajal University Hospital on 9 September 2019 (Authorization nr. 371). All subjects gave their informed consent before being included in the trial. The data were collected in a central online database that complied with the data protection legislation. Cases were anonymized using an alphanumeric code.

2.2. Inclusion and Exclusion: Study Variables

The study included all patients undergoing joint replacement with a megaprosthesis for tumor-related indications at any skeletal location. Eligible patients had either a primary procedure following tumor resection or a revision procedure for failure of a prior reconstruction. Revisions were only included if the corresponding primary surgery was already part of the study cohort, ensuring continuity of data. No restrictions were placed on the start date to maximize the dataset's size and capture long-term outcomes.

Exclusion criteria encompassed patients receiving megaprostheses for non-tumor indications, such as severe trauma or congenital conditions, and revisions where the original surgery was not included. Additionally, cases with incomplete records on surgical details, complications, or follow-up data were excluded to ensure the reliability and consistency of the dataset.

The variables analyzed were demographic (patients age, sex, height, and weight), etiologic (underlying condition, anatomical region, stage of the disease, and presence of metastasis), and surgical (extent of the resection, implant model, type of fixation, and coating used). Data on complications (following the classification by Henderson [11–13]) and survival of the implants were also collected. All the data were recorded with respect to the primary procedure and any subsequent revisions.

2.3. Statistical Analysis

A descriptive analysis of the data was carried out, describing measures of central tendency and dispersion. For comparisons between groups, parametric and nonparametric mean difference tests were applied depending on the normality of the samples (as determined by the Kolmogorov–Smirnov test). Qualitative variables were analyzed by means of Pearson's chi-squared test or the Fisher's exact test, depending on the magnitude of the expected values. Kaplan–Meier survival curves were generated only for patients operated from the year 2000—to avoid bias due to loss to follow-up—and using prosthetic failure for any cause as an endpoint (the death of the patient was not regarded as failure of the prosthesis). Differences in survival were evaluated using the log-rank test. Statistical significance was set at a p value of 0.05 in all cases. The analysis of data was performed using R software (R Development Core Team), v. 4.1.3. [14].

3. Results

3.1. Sample Size, Participating Sites, and Time Distribution

Our historical series includes a total of 585 patients (307 male and 278 female) with tissue defects of different etiologies treated with megaprostheses between 1981 and 2021 (Figure 1). Patients were treated at 12 different hospitals (Table 1). A total of 181 patients (97 male/84 female) underwent revision surgery of varying complexity, and 50 of these patients (28 male/22 female) required a third procedure. This third operation failed in 12 cases (7 male/5 female) (Figure 2). Thus, the total number of surgeries was 816.

3.2. Demographic and Etiologic Data

The mean age of patients at the time of the primary surgery was 44.2 ± 20.8 years, with a range from 3 to 100 years. For the first revision surgery, the mean age was

44.2 ± 19.0 years, ranging from 15 to 92 years. In the case of the second revision surgery, the mean age was 47.1 ± 19.9 years, with ages ranging from 17 to 92 years.

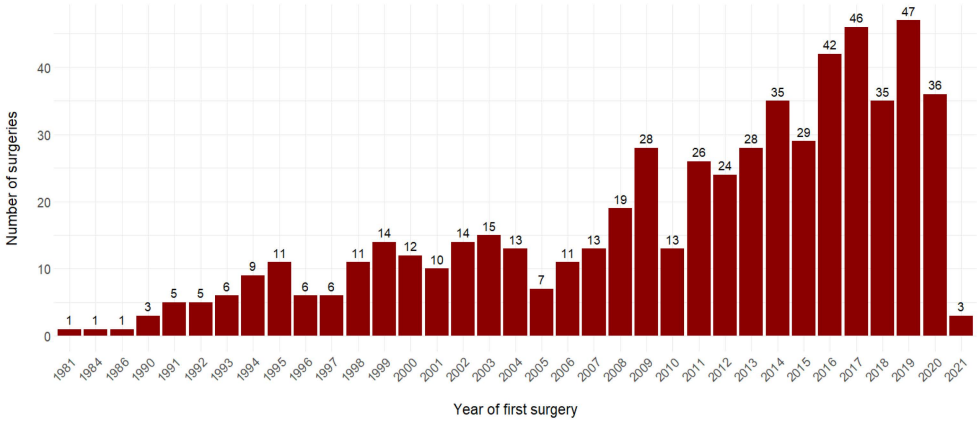

Figure 1. Historical distribution of the cases analyzed in the MegaProt study.

Table 1. Case distribution by hospital.

Hospital	Primary Surgery	Second Surgery	Third Surgery	Total (N)	Total (%)
Santa Creu i Sant Pau Hospital	166	76	18	260	31.9%
Ramon y Cajal University Hospital	139	41	14	194	23.8%
Cruces Hospital	57	23	9	89	10.9%
Valencia University General Hospital	49	12	2	63	7.7%
La Fe University Polyclinic Hospital	45	11	5	61	7.5%
Virgen de la Arrixaca Clinical University Hospital	38	10	0	48	5.9%
Virgen de las Nieves Hospital	32	4	0	36	4.4%
Donostia University Hospital	31	0	0	31	3.8%
Nuestra Senora de la Candelaria University Hospital	12	0	0	12	1.5%
San Carlos Clinical Hospital	10	0	0	10	1.2%
Bellvitge Hospital	4	4	2	10	1.2%
Marques de Valdecilla University Hospital	2	0	0	2	0.2%
TOTAL	585	181	50	816	100.0%

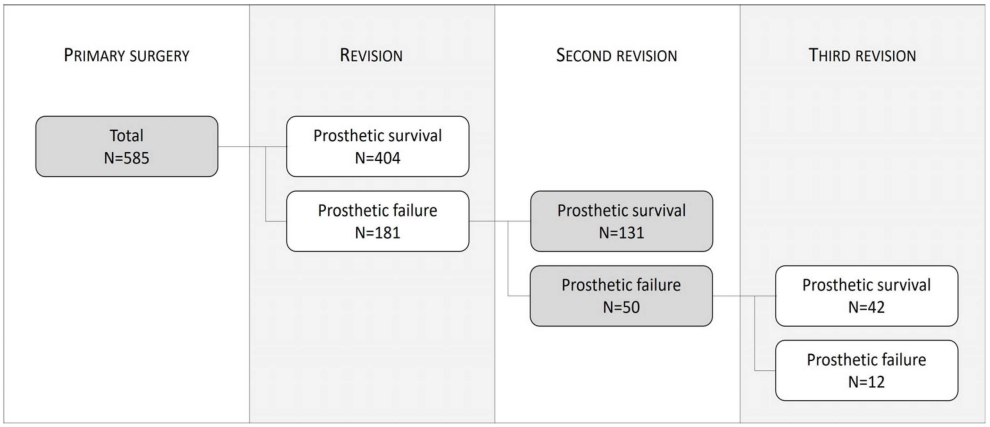

Figure 2. Distribution of the cases, including primary procedures and any subsequent revisions.

Most primary surgeries were performed for osteosarcoma (N = 200; 34.2%), bone metastasis not originating from a sarcoma (N = 115; 19.7%), and chondrosarcoma (N = 106; 18.1%), other etiologies accounting for only a small proportion of cases (Table 2).

Table 2. Etiology across the different procedures.

Etiology	Primary Surgery		Second Surgery		Third Surgery		Failure of Third Surgery	
	N	%	N	%	N	%	N	%
Osteosarcoma	200	34.2%	78	43.1%	24	48.0%	8	66.7%
Bone metastasis not originating from a sarcoma	115	19.7%	18	9.9%	4	8.0%	0	0.0%
Chondrosarcoma	106	18.1%	30	16.6%	10	20.0%	1	8.3%
Ewing sarcoma	39	6.7%	10	5.5%	3	6.0%	2	16.7%
Giant Cell Tumor	37	6.3%	16	8.8%	3	6.0%	1	8.3%
Tumors of unknown histological origin	35	6.0%	11	6.1%	1	2.0%	0	0.0%
Low-incidence bone sarcomas	30	5.1%	14	7.7%	3	6.0%	0	0.0%
Multiple myeloma	13	2.2%	3	1.7%	1	2.0%	0	0.0%
Soft-tissue sarcomas with secondary bone involvement	10	1.7%	1	0.6%	1	2.0%	0	0.0%
TOTAL	585	100.0%	181	100.0%	50	100.0%	12	100.0%

As regards the revision rate, low-incidence bone sarcomas were those with the highest rates (46.7% of cases), followed by giant cell tumors (GCTs) (43.2%), osteosarcomas (39.0%), tumors of unknown histological origin (31.4%), chondrosarcomas (28.3%), Ewing sarcomas (25.6%), multiple myelomas (23.1%), bone metastases not originating from a sarcoma (15.7%), and soft-tissue sarcomas with secondary bone involvement (10.0%).

As regards the anatomical compartment involved, the majority of primary surgeries were performed on the femur (n = 404; 69.1%), followed by the tibia (n = 79; 13.5%), the humerus (n = 74; 12.6%), the pelvis (n = 20; 3.4%), and the scapula (n = 4; 0.7%) (Table 3). More specifically, the most commonly affected anatomical region was the distal femur (35.7%), followed by the proximal femur (29.1%), the proximal tibia (13.3%), and the proximal humerus (11.6%).

Table 3. Anatomical location of primary surgeries.

Anatomical Location	N	%	Bone	N	%
Proximal femur	170	29.1%	Femur	404	69.1%
Distal femur	209	35.7%			
Intercalary femur	12	2.1%			
Total femur	13	2.2%			
Proximal tibia	78	13.3%	Tibia	79	13.5%
Distal tibia	1	0.2%			
Intercalary tibia	0	0.0%			
Total tibia	0	0.0%			
Proximal humerus	68	11.6%	Humerus	74	12.6%
Distal humerus	6	1.0%			
Intercalary humerus	0	0.0%			
Total humerus	0	0.0%			
Scapula	4	0.7%	Scapula	4	0.7%
Pelvis	20	3.4%	Pelvis	20	3.4%
Other	4	0.7%	Other	4	0.7%
TOTAL	585	100.0%	TOTAL	585	100.0%

Sarcomas were evaluated following the Musculoskeletal Tumor Society (MSTS) staging system [15]. Of the 398 primary sarcomas examined, 63.6% (n = 253) were type IIB. Type IIA sarcomas were the second most frequent (n = 71; 17.8%), followed by type IB (n = 45; 11.3%), type IA (n = 27; 6.8%), and type III (n = 2; 0.5%) sarcomas.

Considering all tumor types, 161 (27.5%) of all the cases treated in primary surgery were cases of metastasis.

3.3. Surgical Data

On average, the most extensive bone resections were performed on the total femur (38.5 ± 14 cm) and the scapula (20 ± 3.4 cm). Additionally, the mean sizes of primary resections in various anatomical regions were as follows: distal femur (16.2 ± 5.5 cm), intercalary femur (15.1 ± 6.4 cm), distal tibia (15.0 ± 0 cm), proximal femur (14.8 ± 5.2 cm), pelvis (14.0 ± 6.2 cm), proximal tibia (13.7 ± 3.8 cm), proximal humerus (12.0 ± 3.8 cm), and distal humerus (10.8 ± 4.9 cm).

In 471 (86.3%) of primary surgeries, a tumor resection with negative margins (R0) was achieved. In 69 (12.6%) patients an R1 was performed, with only 6 (1.1%) of the patients evaluated exhibiting an incomplete resection with macroscopic involvement (R2).

With 108 (18.5%) cases, LINK was the most commonly used prosthetic system for primary procedures, followed by METS (n = 90; 15.4%), composite systems (n = 70; 12.0%), OSS (n = 66; 11.3%), MUTARS (n = 44; 7.5%), HMRS-GMRS (n = 42; 7.2%), OSS Compress (n = 42; 7.2%), PSO (n = 33; 5.6%), and KOTZ (n = 20; 3.4%); none of the other systems employed was implanted in more than seven patients. Surgeons using allograft–prosthesis composite reconstructions did not specify the manufacturer of the assembly. In revision procedures, amputations played a significant role, accounting for 17.7% (n = 31) of cases. The full data are shown in Table 4.

Table 4. Reconstruction systems used in primary surgeries.

System	N	%
LINK	108	18.5%
METS	90	15.4%
Composite	70	12.0%
OSS	66	11.3%
MUTARS	44	7.5%
HMRS-GMRS	42	7.2%
OSS Compress	42	7.2%
PSO	33	5.6%
Other	40	6.8%
Kotz	20	3.4%
Comprehensive-Mosaic	7	1.2%
Growing prostheses	7	1.2%
LPS	7	1.2%
A2C	5	0.9%
Stanmore	4	0.7%
TOTAL	585	100%

Most surgeons in our series applied a cemented fixation, either in isolation (N = 240; 41.0%) or combined with a hydroxyapatite collar (N = 87; 14.9%). The second most common fixation technique was uncemented fixation with hydroxyapatite-coated components (N = 182; 31.1%), followed at a certain distance by axial compression (N = 35; 6.0%), metal-coated components (N = 20; 3.4%), and custom fixations (N = 16; 2.7%). Silver-coated implants were used in 13 cases (2.2%).

As mentioned above, 181 prostheses failed following the primary surgery; 50 failed after the first revision, and another 12 failed after the second revision. The causes of such failures were classified according to Henderson's classification [11]. Structural failures were the most frequent cause of failure after the primary surgery (n = 44; 23.2%), infections being the most frequent cause after the revision surgery (n = 16; 30.8% following the first revision and n = 5; 41.7% after the second). The full data are provided in Tables 5 and 6.

Table 5. Classification of surgical failures (Henderson classification). The percentage is calculated with respect to the total number of prosthetic failures.

Type of Failure	Primary Surgery		Second Surgery		Third Surgery	
	N	%	N	%	N	%
I: Soft tissue failure	24	12.6%	2	3.8%	1	8.3%
II: Aseptic loosening	40	21.1%	14	26.9%	2	16.7%
III: Structural failure	44	23.2%	10	19.2%	3	25.0%
IV: Infection	31	16.3%	16	30.8%	5	41.7%
V: Recurrence or progression of the tumor	37	19.5%	6	11.5%	1	8.3%
Unknown	14	7.4%	4	7.7%	0	0.0%

Table 6. Classification of primary surgery failures (Henderson classification) by anatomical site. The percentage is calculated with respect to the total number of prosthetic failures by anatomical site.

Type of Failure	Femur		Humerus		Pelvis		Tibia	
	N	%			N	%	N	%
I: Soft tissue failure	10	7.9%	4	18.2%	0	0.0%	10	28.6%
II: Aseptic loosening	27	21.3%	5	22.7%	0	0.0%	8	22.9%
III: Structural failure	31	24.4%	5	22.7%	1	20%	7	20%
IV: Infection	19	15%	3	13.6%	3	60%	6	17.1%
V: Recurrence or progression of the tumor	29	22.8%	3	13.6%	1	20%	4	11.4%
Unknown	11	8.7%	2	9.1%	0	0.0%	0	0.0%

The type of failures also evolved over time, as shown in Figure 3, with structural failures giving way to a more balanced pattern of complications.

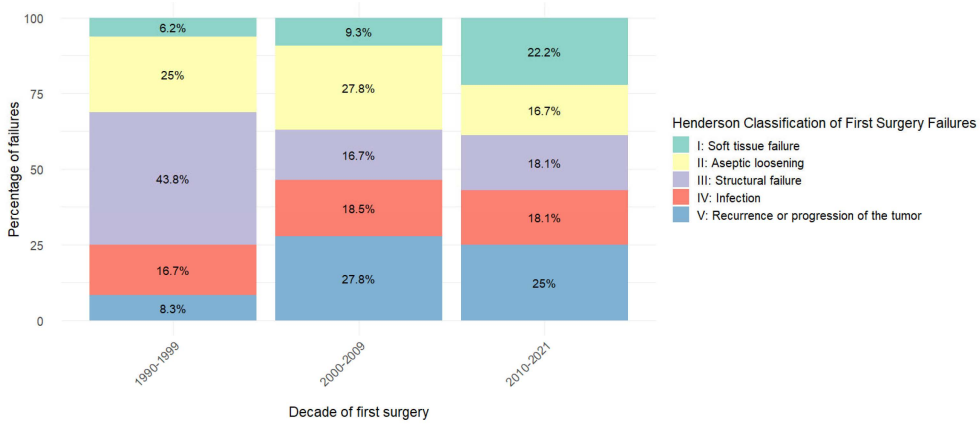

Figure 3. Evolution of the causes of failure over time.

3.4. Status at the End of Follow-Up

At the time of their last follow-up visit, patients had undergone a mean of 1.62 (±1.1) procedures (range: 1–12). At the end of follow-up, most patients in the sample exhibited no evidence of disease (N = 276; 47.2%). A total of 146 patients (25.0%) had died from the disease, and another 14 (2.4%) because of other reasons. Seventy-nine patients (13.5%) were alive despite having the disease. The status of the subjects at the end of the study is presented in Table 7.

3.5. Prosthesis Survival

The survival rate following primary surgery using prosthetic failure for any cause as an endpoint and considering only patients operated in the year 2000 or later was 73.3% at 10 years, patients surviving for a mean of 91.2 ± 68.3 months. No statistically significant differences were found ($p = 0.298$) between survival following primary surgery and survival

following first or second revisions (Figure 4) nor were any statistically significant differences found with respect to survival from primary surgery between males and females ($p = 0.194$), between the different etiologies ($p = 0.540$), or between the lower and the upper limb ($p = 0.618$). In contrast, statistically significant differences were found with respect to the type of prosthetic fixation ($p < 0.001$).

Table 7. Final status of the patients.

Type of Failure	Metastasis		No Metastasis		Total	
	N	%	N	%	N	%
No evidence of disease (NED)	20	12.4%	253	60.8%	3	37.5%
Died of disease (DOD)	68	42.2%	78	18.8%	0	0.0%
Unknown	18	11.2%	49	11.8%	3	37.5%
Alive with disease at a distance (AWD distance)	38	23.6%	27	6.5%	2	25.0%
Died of some other cause (DOC)	8	5.0%	6	1.4%	0	0.0%
Alive with disease (AWD)	9	5.6%	3	0.7%	0	0.0%
Alive with local disease (AWD local)	161	100.0%	416	100.0%	8	100.0%
TOTAL	20	12.4%	253	60.8%	3	37.5%

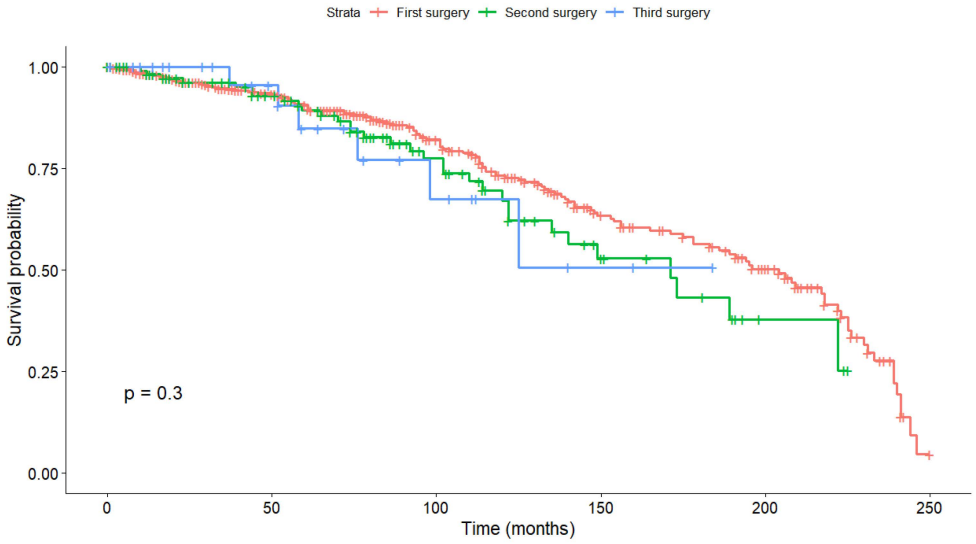

Figure 4. Kaplan–Meier estimate of survival of primary and subsequent revision surgeries (log-rank test p-value = 0.298).

4. Discussion

Tumor megaprostheses allow restoration of anatomical continuity following resection of a bone tumor or a soft tissue tumor with bone involvement. They are also a valid alternative in the context of failed reconstructions of any type. This study, based on the collaborative effort of the members of the LINVESTAL group, analyzed one of the largest series of patients treated with a tumor megaprostheses ever brought together in the history of medical literature [8–11], including 585 primary cases, 181 first revisions, and 50 second revisions. One of its main contributions is that it provides a realistic overview of the type of patient treated with these implants and facilitates a statistical analysis of the data, which should result in the extraction of practical conclusions that improve current treatments. Although the indications of megaprostheses are not limited to tumors [1–3], all the procedures included here were prompted by a tumor-related condition.

There is a certain amount of controversy around the use of megaprostheses in the context of metastatic tumors. Although these implants have traditionally been used palliatively in metastatic patients, in an attempt to control pain and prevent or treat pathological

fractures, megaprostheses are currently used even in oligometastatic patients (with up to five metastases according to some authors). In addition, the survival of these patients has significantly improved thanks to new targeted therapies, hormone therapy, and immunotherapy. Megaprostheses have indeed been shown to provide consistent results for as long as patients remain alive. Instead of attempting to achieve bone healing, they replace the affected bone tissue, with most systems allowing immediate weight-bearing. Even for patients with an unfavorable prognosis, this is a compelling argument in favor of the use of these systems, which can make a definite contribution to improving patients' quality of life [1,16]. In 161 (27.5%) of cases in this study, the indication for treatment with a megaprosthesis was a metastatic tumor. This indication was replicated in up to 12 of the hospitals participating in the study, which demonstrates a high degree of unanimity and consistency among practitioners, who consider it a valid treatment option. However, the use of a megaprosthesis in metastatic patients should be based on a careful assessment by the hospital's tumor board of the baseline etiology, the patient's clinical status (Karnofsky scale), the anatomical location, the degree of involvement, and the available local and systemic treatments.

Prosthetic failure was classified using the system first proposed by Wirganowicz [12] and subsequently systematized by Henderson [11]. Palumbo et al. [13] applied this classification to their series and found that 12% of all their failures were type I; 19% were type II; 17% were type III; 34% were type IV, and 17% were type V. In our series, those percentages were—in the case of primary procedures—12.6%, 21.1%, 23.2%, 16.3%, and 19.5%, respectively. With the exception of the infection rate, which was higher in Palumbo's analysis, our figures are very similar to the abovementioned authors'.

The rate of mechanical complications in the literature stands between 5% and 48%, with aseptic loosening identified as the most common cause of failure [1,2,9,12]. The incidence of mechanical failure (types I, II, and III) following primary surgery in our series was 56.9%, with structural failure (type III) being the most common mechanism of failure (23.2% following primary surgery). Our data are not at variance with that of authors who claim that the rate of mechanical complications has gradually decreased with the advent of new prosthetic designs and new materials [1]. In our analysis, the rate of mechanical failure following primary procedures went down from 75.0% in the 1990s to 53.8% in the first decade of the 2000s. Nonetheless, the rate increased slightly (to 57%) over the period 2011–2020.

Unwin et al. [17] found a correlation between aseptic loosening rates and the extent of resections. Such a correlation was also observed in the present study ($p = 0.005$). We also found that the mean age of patients experiencing aseptic loosening was significantly lower than reported in the literature (36.7 years vs. 47.8 years; $p = 0.003$), possibly due to their higher activity levels [13,17].

The fixation technique used may also have an impact on the rate of mechanical failure. It has been observed that cemented implants are associated with high aseptic loosening rates and that up to one-third of reconstructions around the knee are associated with such loosening [1]. Although the failure rate in our historical series was fortunately not as high as that, aseptic loosening was observed in 6.9% (14 out of 188) of cemented implants. The best results as far as aseptic loosening is concerned appear to have been obtained by prostheses secured by axial compression (0%, 0 out of 35) or made of trabecular metal (0%, 0 out of 20). Nevertheless, it must be said that these fixation modalities are much less frequent than, for example, the use of hydroxyapatite-coated uncemented implants (5.4% aseptic loosening, 8 out of 139) or cemented implants with a hydroxyapatite collar (5.7% aseptic loosening, 5 out of 82).

Turning now to structural failure (type III), other authors [13] found that the mean age of patients experiencing such failure is significantly lower, also possibly due to their higher activity levels. In our study, we observed a clear trend in the same direction, although we did not establish statistical significance (37.5 years vs. 46.7 years; $p = 0.06$).

The most usual non-mechanical complications were infection and tumor recurrence. Failures due to infection in our series fell within the ranges reported in the literature, i.e., between 2% and 17% [1,7]. Indeed, 5.3% of the primary procedures in our study failed as a result of infection. Nonetheless, the infection rate increased in the subsequent revision surgeries, with 8.8% following the first revision and 10.0% following the second. Some authors have correlated the size of implants with the incidence of infections or complications [4]. However, our data did not show a statistically significant relationship between the amount of bone resected and the presence of infection ($p = 0.275$) nor did we find a correlation between the patients' age and the presence of infection ($p = 0.964$). Like Meijer et al. [18], we found no statistically significant differences between the presence of metastasis and infection ($p = 0.639$).

The advent of silver-coated implants has been hailed as a breakthrough with the potential of reducing infection rates [1,19,20]. In our series, however, silver-coated implants used in primary surgery were associated with higher infection rates (23.1%) ($p = 0.018$) than uncoated ones (4.9%). It must nonetheless be said that the number of silver-coated implants was low in our series (13 out of 585). It is therefore possible that such implants were used precisely in cases at higher risk of infection (revision surgeries for infection, complex anatomical locations, or complex sarcomas where operating room time is typically longer and a wider exposure is required). Only three silver-coated implants were used for revision surgery. Taking into consideration that ours is a historical series that includes all kinds of implants used in a wide range of situations and that only a low number of silver-coated implants were employed, the results obtained cannot really be used to draw any hard-and-fast conclusions.

The terms limb survival and implant survival are used interchangeably in various reports and defined according to a variety of outcomes such as amputation, aseptic loosening, or operations or reoperations for any cause requiring resection of the prosthesis following the last follow-up visit [1]. To facilitate comparisons with the literature, we followed the same criterion. Shehadeh reported an implant survival rate of 84% at 5 years and of 72% at 10 years taking prosthetic failure for any cause as an endpoint [9]. Gosheger et al. found a 5-year limb survival of 71.2%, although minor revisions were excluded from their analysis [10]. Mittermayer described an overall implant survival rate of 79% at 5 years and of 71% at 10 years [8]. Overall survival following primary surgery in our series, considering only patients operated in 2000 and later, and using prosthetic failure for any cause as an endpoint, was 73.3% at 10 years, with a mean survival time of 91.2 months. This is an outstanding result considering that our series comprised cases of very different etiologies, anatomical locations and prosthetic models, and from a variety of centers. Some authors have reported that upper-limb prostheses are associated with significantly higher survival rates than lower-limb ones, particularly those implanted around the knee. In our case, the 10-year survival rate was 73.8% for lower-limb implants (excluding the pelvis) and 66.0% for upper-limb ones. However, no statistically significant differences were found in our study between the upper and lower limb survival curves ($p = 0.358$) nor were any survival differences found regarding the prostheses implanted around the knee (distal femur, proximal tibia, and their combinations) ($p = 0.304$). Shehadel et al. [9] reported a 10-year survival rate of 100% for scapula implants and of 78% for proximal humerus implants. In our case, even if all scapula implants survived until completion of the study,

the mean follow-up was shorter (7.4 years). As regards the proximal humerus, our 10-year survival rate was lower (65.0%) than the one reported by those authors.

This study is not without limitations. Given its historical and retrospective nature, it combines highly heterogeneous conditions, technologies and patients, which hinders the interpretation of data and the extraction of meaningful conclusions. In addition, the fact that many of the patients were treated before the era of digitalization makes it difficult to obtain certain data that are crucial for a comprehensive analysis. Also, the study presents limited data on functional outcomes and quality of life, primarily due to the inherent challenges posed by the wide range of anatomical locations involved. Given this variability, it would be difficult to identify a common functional assessment scale applicable across all cases. Regarding quality of life, as this is a retrospective study with no restrictions on the inclusion timeline, baseline data necessary for meaningful comparisons are unavailable. Nonetheless, the primary objective of the study was to analyze implant survival rather than function or quality of life, aligning with its core purpose. Finally, the comparison of survival between primary and revision surgeries may be biased because, although we do not consider patient death as prosthetic failure, as patients age, they are more likely to become censored cases, which could affect the results of the analysis. Having said this, the multicenter nature of the analysis, together with the specialization of participating hospitals and the large size of the sample provide an accurate picture of the profile of the patients treated and of the techniques used to manage their condition. Lastly, the structure of the report provides a useful platform that could be used in the future to carry out segmented analyses that provide a clear idea of the results for each specific entity.

In summary, this study resumes data from a large-scale investigation involving numerous patients, providing valuable insights for clinical practice. Future research will involve segmented studies to further explore specific patterns and refine strategies to improve patient outcomes.

5. Conclusions

Overall survival following primary surgery, using prosthetic failure for any cause as an endpoint, was 73.3% at 10 years in our series, with no statistically significant differences between males and females, between the different etiologies, or between the upper and the lower limb. Significant differences were, however, observed with respect to the type of prosthetic fixation used. The most common causes of failure were structural failure, aseptic loosening, and tumor progression. These were followed at a considerable distance by infection and soft tissue complications.

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