What was the survival of megaprostheses in lower Limb reconstructions after tumor resections?

Rodolfo Capanna, Guido Scoccianti, Filippo Frenos, Antonio Vilardi, Giovanni Beltrami & Domenico Andrea Campanacci

Abstract

Background

Prosthetic replacement is the most commonly used option for reconstruction of osteoarticular bone loss resulting from bone neoplasm resection or prosthetic failure. Starting in late 2001, we began exclusively using a single system for large-segment osteoarticular reconstruction after tumor resection; to our knowledge, there are no published series from one center evaluating the use of this implant.

Questions / Purposes

We investigated the following issues: 1) What is the overall survival, excluding local tumor recurrence, for these endoprostheses used for tumor reconstructions of the lower extremities (knee and hip)? 2) What types of failure were observed in these reconstructions? 3) Do the survival and complications vary according to site of implant?

Methods

Between September 2001 and March 2012, we exclusively used this implant for tumor reconstructions. During that time, 278 patients underwent tumor reconstructions of the hip or knee, of whom 200 (72%) were available at a minimum 2 years followup. Seventy-eight patients were excluded from the study for insufficient followup as a result of early death (42) or loss at followup (36). The reconstruction types were the following: proximal femur (69 cases), distal femur (87), proximal tibia (32), and total knee (12). Failures were classified according to the Henderson classification. Nine patients among those with followup shorter than 2 years had presented one or more failures and they were included in our analysis but separately evaluated.

Results

Overall survival (no further surgical procedures of any type after primary surgery), excluding Type 5 failure (tumor recurrence), was 75.9% at 5 years and 66.2% at 10

years. Seventy-one failures occurred in 58 implants (29%). Mechanical failures accounted for 59.2% and nonmechanical failures for 40.8%. The first causes of failure of the implants were the result of soft tissue failure in 6%, aseptic loosening in 3%, structural failure in 7%, infection in 8.5%, and tumor recurrence in 4.5% of the whole series. Nine implants sustained two or more failures. Overall incidence of infection was 9.5%. No statistically significant differences were observed according to anatomical site.

Conclusions

Like in the case with many such complex oncologic reconstructions, the failure rate at short- to midterm in this group was over 20%. Comparative trials are called for to ascertain whether one implant is superior to another. Infection and structural failure were the most frequent modes of failure in our experience.

Introduction

Prosthetic replacement with modular implants has become the most common reconstructive technique of bone loss of the lower limb after tumor resection [1, 16, 17, 25, 26, 31, 33, 34]. The same modular systems may be used to restore osteoarticular defects of the hip and knee in prosthetic revision surgery and posttraumatic situations [6, 14, 32]. The major advantages of endoprostheses are the relatively simple and quick intraoperative assembly and immediate mechanical stability, allowing early weightbearing and functional recovery. Biologic tendinous reattachment to the metallic prosthesis is not possible and usually results in loss of strength of hip abductors and the extensor mechanism of the knee. For this reason, allograft-prosthesis composites have been introduced with the aim of combining the advantages of endoprostheses with the functional improvement resulting from biologic tendinous reattachment of the hip abductors and patellar tendon [2, 7, 8, 15, 38].

When compared with conventional prostheses used in total joint arthroplasty for arthritis, a consistently higher rate of complications has been reported with modular megaprostheses, particularly resulting from infection, wear or breakage of prosthetic components, and stem loosening [1, 3, 11, 12, 17, 19, 27, 28, 34–38]. The higher infection rate is believed to be the result of prolonged surgical times and large soft tissue exposure in oncologic resections and to a higher risk of contamination in revision and posttraumatic cases. A higher rate of mechanical complication in megaprostheses is explained by the high mechanical stresses on prosthetic components and stems as a result of the loss of muscular insertions and the long lever arm. In 2011, Henderson et al. [22] proposed a classification of failures of tumor megaprostheses, considering soft tissue failure as Type 1, stem loosening as Type 2, component breakage and periprosthetic fracture as Type 3, infection as Type 4, and

local recurrence as Type 5. This classification was adopted by the International Society of Limb Salvage to introduce a common language for the evaluation of the results of limb salvage procedures.

In 2001, a new modular prosthetic reconstruction system for the lower limb was introduced. The system allows assembling as a conventional megaprosthesis or as an allograft-prosthesis composite (APC), therefore allowing the surgeon to make intraoperative decisions depending on the clinical situation. Starting in September 2001, we began exclusively using this system for large-segment osteoarticular reconstruction after tumor resection of the lower limb; to our knowledge, there are no published series from one center evaluating the use of this implant.

We therefore sought to analyze the revision-free survival of implants. Specifically, we sought to ascertain the following:
1) What is the overall survival, excluding local tumor recurrence, for these endoprostheses used for tumor reconstructions of the lower extremities (knee and hip)?
2) What types of failure were observed in these reconstructions?
3) Do the survival and complications vary by site of implant?

Patients and methods

Study design and settings

We retrospectively reviewed our institution's database of patients who underwent a surgical procedure of bone resection and reconstruction with a Megasystem C® megaprosthesis (Waldemar Link, Hamburg, Germany) of the lower limb from January 2001 to March 2012. Three hundred fifty-eight implants were identified. Seven implants were excluded because they were implanted in the first period, when we were not yet using this system exclusively. Among the 351 implants left, 55 implants were excluded because they had been implanted in nononcologic conditions, leaving 296 implants for evaluation. To obtain a more homogeneous series, we decided to limit our evaluation to hip and knee mobile single-joint reconstructions after resection and therefore arthrodesis, total femur, and intercalary prostheses (18 implants) were removed from the series, leaving 278 implants. Only patients with a followup of 2 years or more were included in the study. Therefore, another 78 implants were excluded because of insufficient followup (42 implants in 41 patients as a result of early death; 36 implants in 36 patients because they had been lost at followup). Two hundred implants were included in the study (Fig. 1).
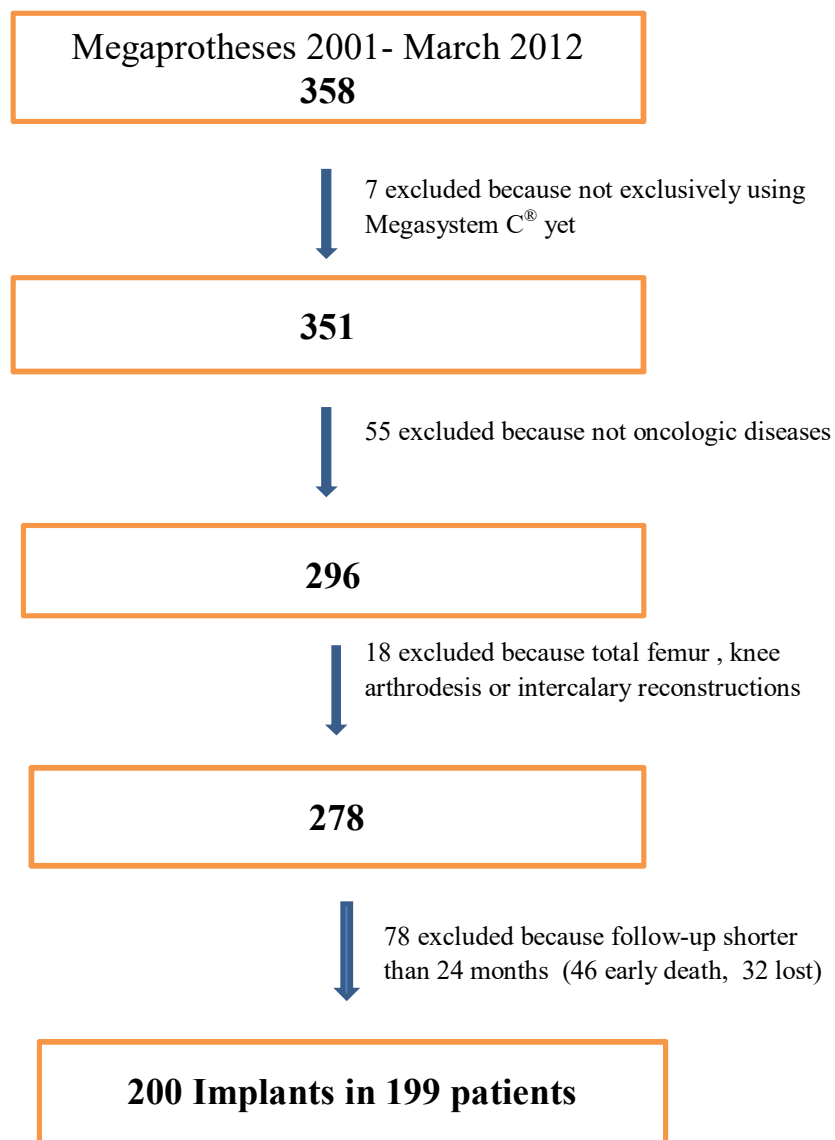
Fig. 1 The flow diagram shows our whole series of megaprostheses and how we selected the cases examined in the present study.

Participants / Study subjects

Between September 2001 and March 2012, we exclusively used this implant for tumor reconstructions. During that time, 278 patients underwent tumor reconstructions of the hip or knee; of these, 200 (72%) were available at a minimum of 2 years followup. Among these 200 patients, 131 were still under observation at the date of the current study, 45 had died (at an average time from surgery of 46 months; range, 25–131 months) and 23 (with 24 implants) had been lost at followup (at an average time from surgery of 54 months; range, 25–136 months).

There were 103 males (with 104 implants) and 96 females. Age at surgery ranged from 12 to 90 years (mean, 43 years).

Primary sarcomas accounted for 62% of the procedures (124 of 200), metastatic disease for 24.5% (49 cases), hematologic malignancies for 1% (two cases), and benign bone tumors and other bone diseases for 12.5% (25 cases) (Table 1).

Table 1 - Incidence of different histotypes in our series (200 implants)

Histotypes	Number	Percentage
Osteosarcoma	58	29
Ewing's sarcoma	17	8.5
Chondrosarcoma	26	13
Other sarcomas	23	11.5
Metastases from carcinomas	49	24.5
Hematological malignancies	2	1
Giant cell tumor	20	10
Other bone diseases (1 fibrous dysplasia, 1 chondroblastoma, 1 desmoplastic fibroma, 1 Gorham's disease, 1 pigmented villonodular synovitis)	5	2.5

Description of Experiment, Treatment, or Surgery

A prosthetic reconstruction was performed at the proximal femur in 69 cases, distal femur in 87, and proximal tibia in 32; in 12 patients, an extraarticular resection and TKA were performed using a proximal tibia allograft including the whole extensor apparatus (patellar tendon, patella, quadriceps tendon) according to a technique we specifically described in a previous paper [5]. The criteria for choosing an APC reconstruction versus a total metal prosthesis were the following: a young patient with high functional demands, absence of extraosseous extension of the tumor (thus

permitting salvage of soft tissues and all the tendon structures necessary to allow functional reconstruction), and diagnosis of primary bone tumor not requiring radiation therapy (benign tumor or malignant primary tumor with no indication for radiotherapy). We were more likely to use an APC in the proximal tibia to provide for extensor apparatus reconstruction. APCs were occasionally used for the proximal femur and never for the distal femur.

An APC was used in 33 patients, in eight cases at the proximal femur and in 25 cases at the proximal tibia, including in this latter group the patients who underwent TKA after extraarticular resection (12 cases).

For prosthetic replacements of the knee, a rotating hinge mechanism was used. Resurfacing of the patella was not performed.

The implant system we used provides either cemented or cementless stems. Cemented fixation of the stem was used in our series in 55% of cases. Cemented stems were preferred in metastatic lesions, in irradiated bone, or when postoperative radiotherapy was required; in old patients with osteoporotic bone; and when the shape of the medullary canal did not allow an adequate press-fit fixation. Cementless stems were used in primary tumors, in young and active patients, when radiotherapy was not expected and when an adequate press-fit was achievable.

During the 10-year study period, some technical modifications were introduced in the system. Specifically, the EndoModel® (Waldemar Link) rotating hinge was used until 2006, when the new SL® (Waldemar Link) rotating hinge design was introduced; in the series examined in this study, the new SL® rotating hinge accounted for 75 implants (57%), whereas the previous EndoModel® hinge had been used in 56 implants (43%). A new taper for modular unit connection was introduced in 2007, converting the previous taper with a hole for screw fixation (used in 84 implants in our series) to a taper without holes to enhance mechanical resistance and decrease the risk of stress and fatigue failure. This new type of taper was used in 57 implants. Afterward, in 2009, another modification of the taper was introduced by modifying the congruence between the two components of the taper junction to make the distribution of forces more homogeneous. This latest generation taper was used in 59 implants in our series.

In proximal femur procedures, reconstruction of the abductor mechanism was accomplished by suturing the vastus lateralis and gluteus medius on the body of the prostheses, which provides holes on its proximal part. The hip articulation was a bipolar hip unless acetabular involvement required a THA.

Aftercare

Intravenous antibiotics were administered to the patients before surgical incision and for 5 days thereafter. We usually use vancomycin and tobramycin. This regimen was modified in specific cases as a result of renal insufficiency or allergy. Antithrombotic prophylaxis was performed using low-molecular-weight heparin until restoration of adequate walking ability. The postoperative rehabilitation regimen varied according to site of surgery, reconstruction of the extensor mechanism in procedures involving the proximal tibia, and cementless or cemented fixation. In proximal femur reconstructions, a brace is used for 2 months after surgery with hip ROM of 0° to 60° for the first month and 0° to 90° for the second month. With the exception of procedures involving reconstruction of the extensor apparatus, full weightbearing was allowed in cemented implants and progressive weightbearing was allowed in cementless implants with partial weightbearing progressing to full after 1 month. No weightbearing and immobilization of the knee in extension for 1 month was our schedule for procedures at the knee involving reconstruction of the extensor mechanism.

Description of Followup Routine

Variables, Outcome Measures, Data Sources, and Bias

Followup of the patients ranged from 24 to 149 months (mean, 67 months).

Initial and followup data were extracted from our medical records relating to followup evaluations. Patients with insufficient data in our database were specifically recalled and evaluated.

Evaluation of the patients was accomplished by clinical and radiological examination. Local and systemic disease status was recorded. All reconstruction failures during the period from surgery to latest followup were recorded. Failures were defined, according to Henderson et al. [22], as those complications requiring complete revision of the endoprosthesis, unplanned revision of a failed portion of the endoprosthesis, fixation of a periprosthetic fracture, soft tissue reconstruction to restore joint stability, endoprosthetic removal without revision, and amputation.

Survival was analyzed considering any subsequent surgical procedure (either partial or total revision of the prosthesis or soft tissue procedures) as the endpoint. Minor complications included all the other unplanned events not leading to further surgical procedures such as delay in wound healing, soft tissue problems not requiring

surgery, transient nerve palsies, and thrombophlebitis; minor complications were recorded as well but were not included in the analysis of this study, because our aim was to evaluate major complications leading to implant failure. According to the classification system proposed by Henderson et al. [22], failures were categorized as mechanical or nonmechanical. Mechanical failures include those attributable to loss of normal function of the endoprosthesis and/or relationships between the endoprosthetic components and adjacent bone and soft tissue attachments. Nonmechanical failures include conditions that necessitate endoprosthesis removal or revision that do not compromise the function of the endoprosthesis and its surrounding connective tissues. Mechanical complications are further divided into three types: soft tissue failure, including instability, tendon rupture, or aseptic wound dehiscence (Type 1); aseptic loosening with clinical and radiographic evidence of loosening (Type 2); and structural failure, including periprosthetic or prosthetic fracture or deficient osseous supporting structure (Type 3). Nonmechanical complications are divided into two types: infection about the endoprosthesis requiring removal of the device (Type 4) and tumor progression with recurrence or progression of tumor and contamination of the endoprosthesis (Type 5).

As a result of the differences in etiology and treatment of the soft tissue modes of failure included in Type 1, we decided to further divide Type 1 failures into three subgroups: dislocation (Type 1A), tendon rupture (Type 1B), and aseptic wound dehiscence (Type 1C).

Statistical Analysis and Study Size

The incidence of major complications was calculated for the entire series and then by individual cohorts according to anatomical location or other characteristics of the patients and implants.

Statistical evaluation in comparing differences among cohorts was performed using the chi square test with Yates correction. Time of survival of the reconstruction was calculated from date of initial surgery to date of failure or last followup.

To assess the durability of the implants, we decided to separately evaluate survival according to complication Types 1 to 4 and complication Type 5, because failures resulting from tumor recurrence (Type 5) are not implant-related.

Survival was determined according to the method of Kaplan-Meier. Evaluation of factors affecting survival was accomplished using a log-rank test to compare different Kaplan-Meier curves. Statistical analysis was performed using Medcalc® Version 12.2.1.0 (Medcalc Software, Ostend, Belgium).

Results

Seventy-one failures occurred in 58 implants (29%). Overall limb salvage was 95.5% with nine amputations resulting from infection in one case and tumor recurrence in eight. Type 5 failure is related to recurrence of oncological disease. Considering local tumor recurrences leading to failure of the implant, 10 Type 5 failures occurred, in eight cases after resection for a primary malignant bone or soft tissue sarcoma and in two cases after a metastatic lesion. Because Type 5 failure is a complication unrelated to the implant, but rather to the resection or aggressiveness of the tumor, we decided to evaluate survival of the implants excluding Type 5 complications as a mode of failure. Overall survival, excluding Type 5, was 75.9% at 5 years and 66.2% at 10 years (Fig. 2). Twenty-four implants presented a followup of 10 years or more. Five-year survival for specific reconstructions types was 80.4% for the proximal femur, 70.4% for the distal femur, 84% for the proximal tibia, and 66.7% for extraarticular knee reconstructions (Fig. 3). If we include also Type 5 failures, overall survival was 72% at 5 years and 58.9% at 10 years.
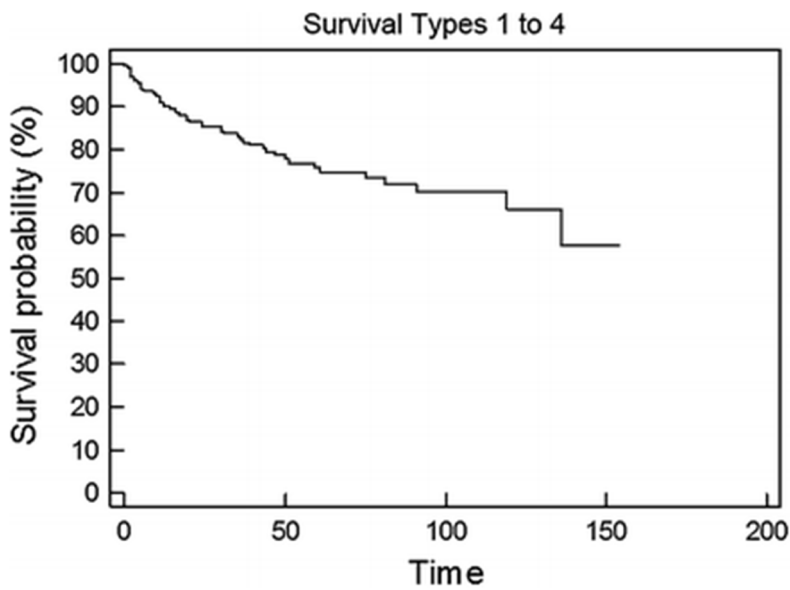
Fig. 2 - Overall survival (no further surgical procedures of any type after primary surgery) in Type 1 to 4 failures (excluding Type 5, tumor recurrence) was 75.9% at 5 years and 66.2% at 10 years in our series.
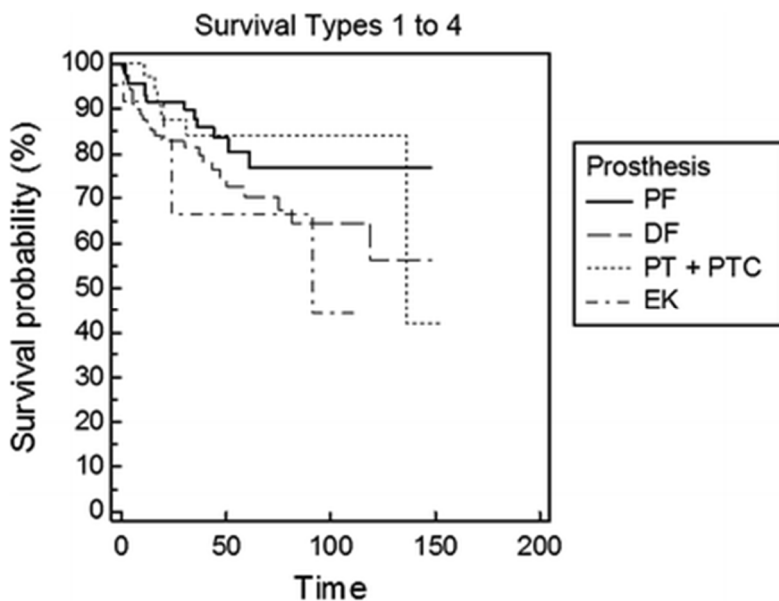

Fig. 3 - Five-year survival for a specific reconstruction type was 80.4% for the proximal femur, 70.4% for the distal femur, 84% for the proximal tibia, and 66.7% for extraarticular knee reconstructions. PF = proximal femur; DF = distal femur; PT + PTC = proximal tibia prostheses and APC; EK = extraarticular knee reconstructions.

Mechanical failures accounted for 59% of all failures and nonmechanical failures for the remaining 41% (Table 2). Average time of occurrence of failures varied according to the different types. Type 1 presented at an average time of 26 months (range, 0–136 months) after surgery; Type 2, 35 months (range, 12–61 months); Type 3, 50 months (range, 4–119 months); Type 4, 16 months (range, 2–51 months); and Type 5, 46 months (range, 9–78 months).

Table 2 - Incidence of different types of failures in the whole series and according to site of the procedure

Type	Number as first failure %	Number of total failures (number of failures/number of implants [percent of failures])	Proximal femur (n = 69) (number of failures/number of implants [percent of implants])	Distal femur (n = 87) (number of failures/number of implants [percent of implants])	Extraarticular knee (n = 12) (number of failures/ number of implants [percent of implants])	Proximal tibia (n = 32) (number of failures/number of implants [percent of implants])
1A	3 (1.5)	3/3 (1.5)	3/3 (4.3)	0/0 (0)	0/0 (0)	0/0 (0)
1B	3 (1.5)	5/5 (2.5)	0 (0)	2/2 (2.3)	1/1 (8.3)	2/2 (6.2)
1C	6 (3.0)	6/6 (3.0)	2/2 (2.9)	2/2 (2.3)	1/1 (8.3)	1/1 (3.1)
2	6 (3.0)	6/6 (3.0)	3/3 (4.3)	3/3 (3.4)	0/0 (0)	0/0 (0)
3	14 (7.0)	22/16 (11.0)	2/2 (2.9)	18/12 (13.8)	2/2 (16.7)	0/0 (0)
4	17 (8.5)	19/19 (9.5)	2/2 (2.9)	12/12 (13.8)	2/2 (16.7)	3/3 (9.3)
5	9 (4.5)	10/10 (5.0)	3/3 (4.3)	4/4 (4.6)	1/1 (8.3)	2/2 (6.2)
Total	58 (29.0)	71/58*	15/15 (26.0)	41/28 (32.2)	7/7 (58.3)	8 /8 (25.0)
Total without type 5	49 (24.5)	61/49†	12/12 (17.4)	37/25 (28.7)	6/6 (50.0)	6/6 (18.7)

* Fifty-eight implants with 71 failures (six times recurring the same type of failure in the same patient plus seven times occurring different types of failure in the same patient);

†49 implants with 61 failures (six times recurring the same type of failure in the same patient plus six times occurring different types of failure in the same patient).

Taking into consideration Type 1 subtypes, Type 1C failures (aseptic wound dehiscence) presented earlier at an average time of occurrence 6 months with a median of 2 months. Types 1A (dislocations, all occurring in hips) and 1B (tendon rupture) occurred, respectively, at an average of 18 months with a median of 11 months and at an average of 58 months with a median of 46 months.

Infection was a leading cause of revision. In our series, infection occurred in 9.5% of cases (19 implants in 19 patients). Revision of the prosthesis was accomplished in 17 patients; amputation was performed in two cases. Average time of occurrence of a septic complication was 16 months (range, 2–51 months). Forty-seven percent (nine cases) of septic complications occurred after 1 year from surgery. Two implants (superficial infections) were salvaged only with surgical débridement and medical therapy without revision of the implant. Another patient underwent débridement and afterward an amputation. Nine implants were revised with a two-stage procedure and seven implants with a one-stage procedure. Among these patients, at latest followup, after one or more surgical procedures, 17 patients were without signs of infection and two patients with recurrent infection who were unresponsive to any treatment (including multiple surgical procedures) had undergone an amputation. Among the infections healed with limb salvage, in four cases, a knee arthrodesis prosthesis was the final procedure. The incidence of infection was 16.7% in extraarticular total knee reconstructions with two of 12 implants, 13.8% in the distal femur with 12 of 87 implants, 9.3% in proximal tibia replacements with three of 32, and 1.9% in proximal femur resections with only two of 69 cases. Dislocation of the prosthesis (Type 1A) occurred in three patients, in all cases at the hip. All these patients underwent a revision procedure. One of them sustained three subsequent dislocations, treated twice with closed reduction and once with open surgery. Sixty patients had bipolar hips and three dislocated; nine patients had a THA and none dislocated. According to the Henderson classification [22], only the dislocations that required surgical revision of the prosthesis were classified as implant failures.

The low number of APCs of the proximal femur (eight cases) did not allow a significant comparison in stability between megaprostheses and APCs. Dislocation occurred in 4.3% of proximal femur reconstructions.

Types 1B and 1C complications involve periarticular or superficial soft tissues, rarely requiring partial or complete revision of the implant. A specific definition of failure in this subset of patients is not addressed in the Henderson classification [22]; the need for further surgical treatment, even if not modifying the implanted prosthesis, was considered a failure. Type 1B failures (tendon rupture) occurred in five patients, always involving the extensor apparatus at the knee. In four more patients, we observed mobilization of the plate used to fix the patellar tendon, but function of the extensor apparatus was not compromised and treatment was simply removal of the plate or repositioning of the screws; we considered this type of event a minor complication and not a failure. Six patients presented a Type 1C complication

(aseptic wound dehiscence or skin necrosis) requiring surgical débridement, combined in two cases with a plastic surgery procedure.

Aseptic loosening (Type 2 failure) was detected in six implants. In all these cases, the femur was the site of loosening (proximal femur in three; distal femur in three). No difference in incidence of loosening was found between cemented (three stems) and cementless stems (three stems) ($p = 0.94$). Twenty-two Type 3 failures (structural failures) occurred in 16 patients. Mode of structural failure was prosthesis breakage in 16 cases (in 13 patients), a periprosthetic fracture (including fractures of the patella in reconstructions around the knee) in four cases (in two patients), and an articular hinge or polyethylene liner failure in two cases. Prosthetic failure occurred in all cases at the Morse taper (Waldemar Link) joining the different moduli. This led to a modification of the design; first in 2007 a taper without a hole for screw fixation was introduced and then in 2009 the taper was further strengthened by increasing its diameter. In 57 implants with the first modification, the breakage rate dropped to 1.7% (one failure). So far, no breakage has been detected in the implants (59) with the latest generation of Morse tapers.

No differences (log-rank evaluation of Kaplan-Meier curves, $p < 0.05$) among different surgical sites were detected in survival both for all types of failures and for each single type of failure with the numbers available (Figs. 4, 5). At a standard log-rank comparison of the Kaplan-Meier curves, Type 3 failure presented a p value of 0.04 for differences among different reconstructions with distal femur and extra-articular knee reconstructions faring worse, but significance of this finding was not confirmed in analysis with Bonferroni correction [36].

Fig. 4 No statistically significant differences were found in survival for Type 4 failure according to anatomical site. PF = proximal femur; DF = distal femur; PT = proximal tibia prostheses; EK = extra-articular knee reconstructions; PTC = proximal tibia APC.

Fig. 4 - No statistically significant differences were found in survival for Type 4 failure according to anatomical site. PF = proximal femur; DF = distal femur; PT = proximal tibia prostheses; EK = extra-articular knee reconstructions; PTC = proximal tibia APC.

Fig. 5 No statistically significant differences were found in survival for Type 3 failure according to anatomical site. PF = proximal femur; DF = distal femur; PT = proximal tibia prostheses; EK = extra-articular knee reconstructions; PTC = proximal tibia APC.
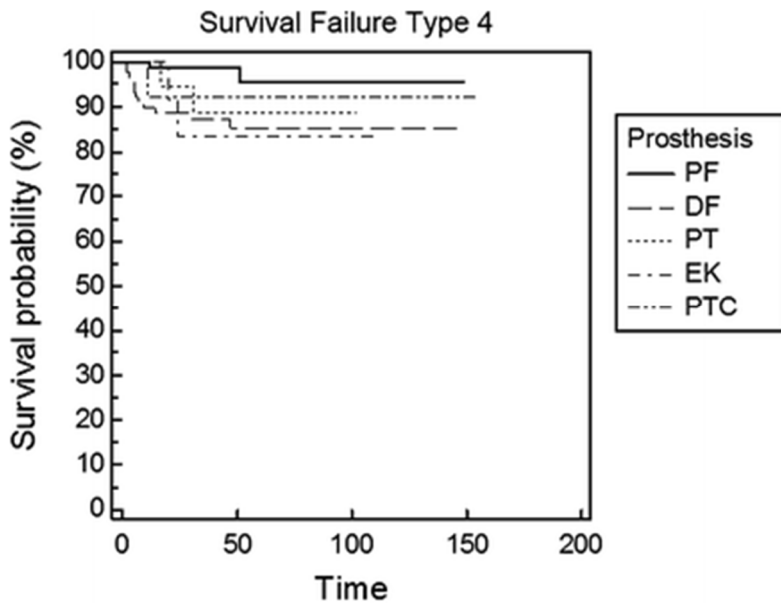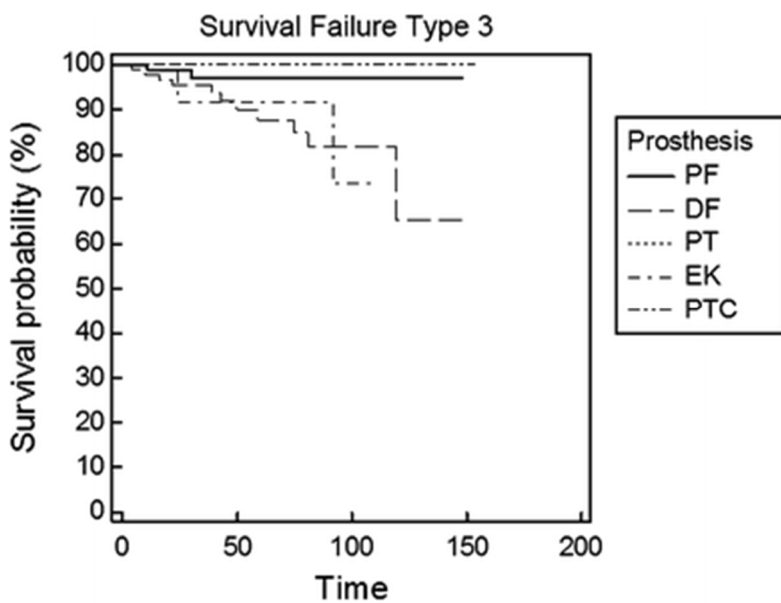
Looking at the whole group of 278 reconstructions of the hip or knee performed from September 2001 to March 2012, we observed also 11 failures in nine patients among the ones excluded from the study as a result of followup shorter than 24 months. Seven patients had presented a short followup because of early death and two because they were lost at followup during the first 2 years after surgery. In these nine patients, we observed three Type 4, two Type 1A, two Type 2, two Type 3, and two Type 5 failures.

Discussion

Endoprostheses are widely used for reconstruction of osteoarticular defects of the lower limb. Custom-made prosthetic implants were used until the beginning of the 1980 s when the first modular prosthetic systems were introduced [5, 23]. Modular systems can be used after oncologic resections and in posttraumatic or revision bone loss, allowing individual assembly based on intraoperative requirements [6]. Prosthetic replacement allows early weightbearing and functional recovery, but several complications have been reported with concerns about long-term implant survival (Table 3). In 2001, a new modular system (Megasystem C®) was introduced for lower limb reconstruction. With the present study, the midterm results of a single-center series of 200 reconstructions with this implant are reported with the analysis of failure rate and implant survival.

Table 3 – Survival and failures after reconstructions with megaprostheses: data from previous reports

Author	Year	Number of cases	Average followup months, range)	Anatomical site	Prosthesis type	Cement	Survival at 5 years	Survival at 10 years	Infection failure	Prosthesis breakage	Loosening failure
Ahlmann et al. [1]	2006	211	37.3 (1–204)	Lower limb	MSRS™ (Stryker, Mahwah, NJ, USA)	Cemented	78%	60%	5.2%	4.3%	2.4%
Gosheger et al. [16]	2006	250	45	Mixed	MUTARS® Implantcast, Buxtehude, Germany)	Uncemented	89.7% upper limb, 68.5% lower limb	60.4% overall	12%	1.6%	8%
Biau et al. [4]	2006	91	62 (0.5–343)	Distal femur, proximal tibia	GUEPAR® (Paris, France)	Cemented	85% femur, 72% tibia	55% femur, 43% tibia	11.0%	7.7%	15.4%
Myers et al. [29]	2007	335	144 (60–360)	Distal femur	STANMORE (Stanmore, UK)	Mixed	83%	67%	9.6%	2%	-
Jeys et al. [25]	2008	661	60 (120–420)	Mixed	STANMORE	Cemented	-	58%	11.3%	6.1%	11.3%
Guo et al. [19]	2008	104	47 (12–118)	Distal femur, proximal tibia	Custom-made	Cemented	70.5%	-	6.7%	6.7%	2.9%
Shehadeh et al. [34]	2010	232	120 (60–324)	Mixed	MSRS™ (Stryker)	Cemented	84%	72%	10.8%	4.3%	7.4%
Schwartz et al. [33]	2010	186	96 (1–336)	Distal femur	Modular r-h custom-made (Stryker/Howmedica, Mahwah, NJ, USA; Techmedica, Camarillo, CA, USA; Dow-Corning Wright, Arlington, TN, USA)	Cemented	88%	77% (20-year 58%)	3.2%	5.4%	11.8%
Healey et al. [21]	2013	82	43 (6–131)	Distal femur	COMPRESS® (Biomet, Warsaw, IN, USA)	Uncemented	85%	80%	6.1%	6.1%	3.7%
Pala et al. [31]	2013	295	50 (24–96)	Mixed	GMRS™ (Stryker)	Uncemented	68%	58%	9.5%	0%	5.1%
Our series	2013	200	67 (24–149)	Lower limb	Megasystem C® (Waldemar Link, Hamburg, Germany)	Mixed	75.9%	66.2%	9.5%	8% whole series 0.8% of 116 patients with modified cone	3.0%

This study is a retrospective evaluation of a series of cases treated at a single institution, representing the first report of the results of a new modular system. In evaluating prosthetic implants, long-term followup is needed, because it is easy to underestimate failure rates. To reduce this risk, we excluded all the patients with a followup shorter than 24 months. Nonetheless, the average followup in our study (67 months) is still inadequate for a definitive evaluation of the outcomes of an implant. Another important limitation of retrospective studies is the risk of selection biases. To limit this, we included all the implants performed in a 10-year period for oncologic reconstructions at the hip and knee. Nonetheless, we had to exclude from the definitive analysis 78 implants out of 278 because of followup shorter than 24 months. This may cause the persistence of a selection bias, but it is worth considering that more than half of these patients (46) had this short followup as a result of early death, whereas only 32 were lost at followup for undefined reasons; this should reduce the power of the bias. To try to limit the possible underestimation of failures, we recorded and separately examined in this article also those failures that we observed in the patients who had been excluded for a followup shorter than 24 months. Another limitation of our study is that we do not have a control group to ascertain whether one implant is superior to any other.

Survival of the implants in our series was similar to previously reported experience. An implant survival at 10 years ranging from 58% to 77% for cemented megaprostheses [1, 25, 33, 34] and from 58% to 70% for cementless megaprostheses was reported [16, 17, 31]. Eighty percent survival at 10 years was reported by Healey et al. [21] in a study including only distal femur replacements. We used both cemented (55%) and cementless stems (45%) with an overall survival rate of 75.9% at 5 years and 66.2% at 10 years. With the number of patients we had in this study, no difference between cemented and cementless prostheses was detectable for overall survival and specifically for Type 2 failures (aseptic loosening) or Type 4 failures (infection). The implant we have used can be assembled as a full metallic implant or as an APC with the functional advantages offered by biologic reattachment of tendons on the graft [2, 7, 8, 15, 38]. In the presented series, APCs were used also after extraarticular resections of the knee using a proximal tibial allograft with its entire extensor apparatus in 12 cases. The original technique was described by the authors in a previous report [5]. Hardes et al. [20] described 59 cases of prosthetic reconstructions after extraarticular resection of the knee preserving the extensor apparatus (patellar-split technique), reporting an implant survival rate of 48% at 2 years and 25% at 5 years; the most frequent complication was deep infection, observed in 37% of cases. Ten patients (16.9%) lost their limb as a result of complications. In our series, a better outcome was observed with an infection rate of

16.7%, a limb salvage rate of 91.7%, and an implant survival rate (failures Types 1 to 5) of 53.3% at 5 years.

Aseptic loosening (Type 2 failure) in megaprostheses was reported in the literature with a rate ranging from 2.4% to 15.4% for cemented stems [1, 4, 19, 25, 34] and from 0% to 8% for cementless implants [10, 16, 21, 26, 31] with evolving designs of the prosthesis allowing improvements in the last decades, like the introduction of a rotating hinge system at the knee [12, 18, 29]. Our series confirmed a low incidence of this type of failure, which occurred in six stems (3%) involving the distal femur in three patients and the proximal femur in three. Structural failure (Type 3 failure) was observed in 8% of patients in our series (16 patients reporting 22 failures). The most frequent structural failure was prosthetic breakage, which occurred in 16 cases (in 13 patients). In the literature, the average incidence of prosthetic component breakage was 4.5%, ranging between 0% and 7.7% [1, 16, 17, 19, 21, 25, 31, 33, 34]. In our experience, Morse taper failure occurred mostly in the first-generation design, where a hole used for screw fixation acted as a stress raiser. In 2007, a full Morse taper (without the hole) was introduced and in 2009, it was further strengthened by modifying the congruence between the two components of the taper junction to make the distribution of forces more homogeneous. Only one breakage was observed in the group of 57 patients with the first modification of the cones and no structural failures have been observed so far in the 59 implants of our series after the introduction of the latest design. Type 4 failure (deep infection) was observed in 9.5% of cases in our series. These data are comparable with infection rates described in the recent literature with a reported range from 5.2% to 12% [1, 16, 17, 19, 25, 31, 34] with the exception of Zeegen et al. [37], reporting only 2.8% of failures (prosthesis revision) for infection out of a 7.1% overall infection rate and Schwartz et al. [33] reporting 3.2% of infections.

No difference comparing anatomical sites and prosthetic reconstructions was detectable for overall survival. Looking at specific types of failures, no differences were detectable comparing different anatomical sites. An unexpected finding was observed for infection. Whereas a lower incidence of infection in proximal femur reconstructions is what we expected on the basis of most previous experience [9, 13, 28, 30], a less predictable result was an equivalent (even slightly higher) incidence of infections both in the distal femur and proximal tibia reconstructions. The proximal tibia in fact is usually considered at highest risk for septic complications [18, 24, 27, 29].

Dislocation in our series was confirmed to be a major issue in proximal femur reconstructions. Accurate reconstruction of the soft tissues around the prosthesis and adequate and careful aftercare treatment are mandatory.

Conclusion

The retrospective analysis of our series confirmed the high incidence of failures requiring revision surgical procedures in complex oncological lower limb reconstructions already outlined by previous studies with different prosthetic systems. Infection and structural failure were the most frequent modes of failure. Survival (no need of any subsequent surgical procedures) of 76% at 5 years and 66% at 10 years was observed, which is a promising result in such complex surgical procedures. Outcomes need to be further monitored with longer followup to verify long-term results and to try to outline any possible structural or surgical enhancement to promote better results. The evolution in the design of Morse tapers and the consequent improvement of results in our experience confirm the importance of permanent monitoring of outcomes and complications and of a prompt response with technical improvements for any prosthetic system. Comparative trials are called for to ascertain whether one implant is superior to any other.

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