Late Complications and Survival of Endoprosthetic Reconstruction after Resection of Bone Tumors

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Abstract

Background While complications following massive endoprosthetic reconstruction have been previously described, the incidence and effects of these complications over extended periods of time have not been well characterized in large series.

Questions/purposes We therefore determined: (1) incidence and types of complications; (2) relative risk of complications; (3) likelihood of secondary complications; (4) whether modularity altered such complications;

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Each author certifies that his or her institution either has waived or does not require approval for the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

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(5) implant failure and limb salvage rates and (6) implant survival over extended followup.

Methods We retrospectively reviewed 232 patients (241 implants: 50 custom, 191 modular) who underwent endoprosthetic reconstruction for malignant and aggressive bone tumors between 1980 and 2002. Complications were classified as infection, mechanical, superficial soft tissue, deep soft tissue, or dislocation. Survival was determined by Kaplan-Meier analysis. Minimum followup was 5 years (mean: 10 years; range: 5–27 years).

Results One hundred thirty-seven of 232 patients (59%) underwent a single reconstruction. Ninety-five patients had 242 additional procedures. Forty-four revised patients retained their original prosthesis. Limb salvage rate was 90%; implant failure (removal of the cemented part) was seen in 29% (70/241) with a median survival of 190 months. Twenty-five of 50 custom implants failed (8 then failed again) while 30/180 modular implants failed (7 then failed again). Of 70 instances of implant failure, 38/70 were mechanical, 27/70 infectious. Risk of infection increased 30% after a second procedure; 16 of 24 amputations were performed because of infection.

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Conclusions Mechanical complications were the most common cause of implant failure. Infection was the leading cause of both complication and amputation; risk of infection increased substantially with revision surgery. Modular implants had fewer mechanical complications, thus leading to fewer revisions and subsequent infections.

Level of Evidence Level III, therapeutic study. See the guidelines for authors for a complete description of levels of evidence.

Introduction

Segmental endoprosthetic implants (sometimes referred to as megaprotheses) are commonly used to reconstruct the skeleton after resection of primary bone tumors, soft tissue tumors secondarily invading bone and other selected cases of segmental defects. Limb-sparing reconstructions should fulfill several requirements; most importantly, the patient should not be at increased risk of local recurrence as compared with amputation. The reconstruction should be durable with few complications, especially those that could interfere with postoperative adjuvant therapy. Finally, the reconstruction should routinely produce a good functional result such that the limb is at least as functional as an external prosthesis following amputation.

With advances in adjuvant therapy for osseous malignancies, the 5-year long-term survival rate has improved from 20% to 70% [20]. Although endoprosthetic reconstruction is now widely used, the reported complication rate remains five to ten times higher than rates seen in routine total joint arthroplasties [1, 4–8, 13, 16, 19–24, 27]. This disparity may in part be due to differences in functional demand between young patients with primary bone sarcomas compared to elderly patients undergoing joint arthroplasty for osteoarthritis. Additionally, as more patients enjoy longer survival rates of their underlying disease, they may outlive the functional life of an endoprosthetic arthroplasty, leading to additional complications over time. Because of these factors, an increasing number of patients requiring revision surgery can be expected in the future.

Complications following endoprosthetic reconstruction include mechanical (eg, breakage/fracture of the implant, instability due to wear) and biologic (eg, infection, aseptic loosening, wound/soft tissue breakdowns) problems that require additional treatment beyond that needed for the original limb salvage. While others have reported specifically on these complications and potential methods of salvage following complications of endoprosthetic reconstruction [6, 12, 13, 20, 21, 23, 24], little has been published regarding the incidence of complications seen with extended followup or how patients fared longitudinally after

undergoing salvage of a complication. Some of these studies concentrated only on infection [6, 12, 13] while others reviewed the major types of complications without discussing their time frame, concentrating on survivor analysis rather on complications analysis [1, 8, 11, 14, 21, 23, 24]. We previously reported early results of a cohort of 82 patients who underwent segmental endoprosthetic replacement for sarcoma of bone, which showed a prosthetic survival rate of 83% at 5 years and 67% at 10 years [17]. This current study, which includes these early patients who have been continuously followed over time, was designed to determine what complications occurred over time, how they affected implant survival, and how they were managed.

We therefore determined: (1) the incidences of all complications, mechanical complications, and biologic complications; (2) the incidence of primary and secondary infections; (3) the likelihood of additional complications following treatment of an initial complication; (4) whether the introduction of modular implants altered the rate or type of complications; (5) the overall implant failure rate and ultimate limb salvage rate over time, and (6) limb and implant survival over time.

Patients and Methods

We retrospectively reviewed an institutional computerized database to identify 329 patients who underwent endoprosthetic reconstruction for neoplastic disease between 1980 and 2002. Of the 329 patients, 97 (20%) were excluded: 64 who underwent traditional hip hemiarthroplasty or received saddle prostheses, 19 whose records were incomplete, and 14 who received unusual custom endoprostheses or expandable implants. We reviewed the records of the remaining 232 patients with 241 endoprosthetic implants—seven patients had their original custom implant exchanged for a new modular implant, at which point the survival and tracking of complications for the new implant began and two patients had more than one site of reconstruction. There were 137 males and 95 females ranging in age from 8 to 99 years (mean: 34; median: 30 years). Ninety-four percent (227/241) of the surgeries performed were for tumors, including 179 primary bone sarcomas (117 osteosarcomas, 25 chondrosarcomas, 14 Ewings, 23 others), 33 metastatic or hematologic malignancies, and 15 benign/aggressive tumors of bone (Table 1). The distal femur was by far the most common location, accounting for 42% (101/241) of all implants, followed by the proximal tibia and the proximal humerus (Table 2). Patients included in this review had a minimum followup of 5 years (mean: 10 years; range: 5–26.8 years); 29 patients were lost to followup after the minimum 5-year

period. No patients were recalled specifically for this study; all data was obtained from the medical records.

From 1980 to 1988, implants were manufactured by Howmedica (Rutherford, NJ) on a customized case-by-case basis. Between 1988 and 2002, we used the Modular (Segmental) Reconstruction System (MSRS/MRS, (Stryker Howmedica, Mahwah, NJ, USA) for all patients (Fig. 1). Following resection of the bone tumor (or removal of a failed implant), skeletal reconstruction with a cemented implant was performed. Polymethylmethacrylate bone cement (Simplex, Howmedica) was used to fix all intramedullary stems using modern cementation techniques including vacuum mixing, pulsatile lavage, and pressurized injection. For prostheses involving the knee, a rotating hinge mechanism (Kinematic R; Howmedica) was used without resurfacing of the patella; standard bipolar cups were used preferentially at the hip. We then performed a soft tissue reconstruction appropriate for each case to achieve muscular coverage of the implants and to restore function, when possible, to the articulating joints.

Table 1. Preoperative diagnosis for all 241 patients treated with a segmental endoprosthetic replacement

Preoperative diagnosis	# patients
Osteosarcoma	117
Chondrosarcoma	25
Ewings sarcoma	14
MFH	7
Sarcoma N.O.S.	5
Hemangiopericytoma /hemangioendothelioma	4
Fibrosarcoma	3
Leiomyosarcoma	2
Synovial cell sarcoma	1
Paget's sarcoma	1
Lymphoma/carcinoma	24
Melanoma	5
Multiple myeloma	4
Giant cell tumor of bone	11
Other benign tumors	4
Prosthetic revision	11
Trauma	2
Osteoarthritis	1

Extensive details of surgical techniques for tumor resection and skeletal reconstruction utilizing cemented endoprostheses as well as the detailed soft tissue reconstructions routinely performed by the authors have been previously reported [2, 3, 9, 10, 17, 18, 25, 26]. For distal femur replacement, an anteromedial transadductor approach was performed to preserve the quadriceps muscles. Fasciocutaneous flaps were utilized to minimize potential skin loss, a rotating hinge knee mechanism was used to restore knee kinematics, and a modular endoprosthetic system was used to ensure proper restoration of limb length. For proximal tibia replacement, compound reconstruction of the extensor mechanism was performed using bone graft, woven Dacron tape, and rotational medial gastrocnemius muscle flap coverage. Preservation of the tibialis anterior and peroneal function was performed whenever possible. For proximal femur replacement, reconstruction of the abductor mechanism was performed using Dacron tape sutures and a cable grip system (Dahl-MilesTM; Stryker Howmedica, Mahwah, NJ) to attach the remaining abductor mechanism directly to the prosthesis. For proximal humerus replacement, dynamic and static suspension of the implanted prosthesis to the clavicular stump and scapula was performed to obtain shoulder stability after extraarticular resection of the proximal humerus, while capsular reconstruction was augmented with a Gortex vascular graft placed over the head of the prosthesis following intraarticular resection

Fig. 1A–B (A) Custom-made distal femur endoprostheses (Howmedica, now Stryker Howmedica) were used between 1980 until 1988. (B) Modular implants, the MSRS/MRS system (Stryker Howmedica), were used after their introduction in 1988.

Table 2. Anatomic locations of 241 endoprosthetic reconstructions after segmental resection of bone tumors

Prosthesis type	Distal femur	Proximal femur	Proximal humerus	Proximal tibia	Total femur	Scapular	Total
Custom	20	4	10	10	6	0	50
Modular (MSRS)	81	24	35	35	5	0	180
Scapular	0	0	0	0	0	11	11
Total	104	28	46	48	11	11	241

of the proximal humerus as well as for total scapular replacements.

Intravenous antibiotics were administered preoperatively and continued until the surgical drains were removed. Mechanical, intermittent compression stockings were used for deep vein thrombosis prophylaxis in lieu of anticoagulants; three patients were considered at high risk for deep vein thrombosis and received an inferior vena cava filter preoperatively.

Postoperatively, upper extremity patients were placed into off the shelf slings, as were patients with surgery around the knee. Patients with surgery around the hip and requiring reconstruction of the abductor mechanism were placed initially into a hip abduction pillow and then converted to custom fitted hip abduction braces applied on postoperative day 3 or 4.

The initial postoperative dressings were removed on the third day, while closed suction drains (large Hemovac or small chest tubes) were removed after drainage had slowed to less than 30 cc per shift. Following discharge, typically 4 to 7 days after surgery, patients were seen in clinic for wound checks and removal of sutures/staples once adequate skin healing had occurred. Patients with wound problems were aggressively treated with débridement and secondary closure or skin grafting. All patients underwent plain roentgenograms to ensure proper positioning and integrity of their implant. Additionally, all patients were seen at 6 weeks and 12 weeks postoperatively to evaluate their functional progression.

Physical therapy, individualized per anatomic site, was initiated in the immediate postoperative period. Immediate weight bearing of the lower extremity was permitted due to the stability of the cemented implants. For reconstructions around the knee, a knee immobilizer was used to facilitate wound healing; flexion was begun at 2 weeks for distal femoral replacements and after 6 weeks for proximal tibial replacements to protect the extensor mechanism reconstruction. Hip abduction braces were used for 6 weeks after proximal femur replacements to protect the abductor reconstruction, while routine total hip precautions were followed for 3 months. After upper extremity reconstructions, a simple sling was used to support the arm, with gentle Codman exercises started after the first week.

Endoprosthesis failure was defined as the need for complete revision of the cemented components, conversion to a different prosthesis, or amputation. Failure due to locally recurrent disease (seven patients) was not included in the implant survivorship analysis as these were unrelated to the durability of the actual endoprosthesis. Removal and replacement of modular bodies (eg, for infection) and replacement of mechanically worn polyethylene parts (eg, bushings,) were counted as complications but were not classified as implant failures unless the cemented stem was

Fig. 2A–B An example of mechanical failure following proximal tibial replacement is shown. **(A)** Radiograph of knee demonstrating fracture of the metallic tibial bearing component within the rotating hinge mechanism (arrow). This patient presented with sudden onset of instability and a large knee effusion. **(B)** Photo of the retrieved polyethylene insert containing the broken tibial bearing component stem (left) adjacent to new components. Revision surgery was limited to a simple exchange of the broken components, leaving the cemented implants in place.

also removed. For patients with multiple complications, all were tallied in the analysis; however, we attributed revisions and/or failures to the complication they directly followed. Loosening secondary to sepsis was classified as failure resulting from infection. Complications were divided into five categories: (1) mechanical complications, eg, stem fractures, aseptic loosening, polyethylene bushing wear requiring replacement (Fig. 2); (2) infection including wound and periprosthetic infections; (3) superficial soft tissue complications, eg, skin or flap necrosis or wound breakdown requiring surgery; (4) deep soft tissue complications, eg, extensor mechanism failure, pseudomeniscus formation, and deep complications not specified elsewhere (Fig. 3); and (5) dislocation: dissociation of an articulating joint.

Revision procedures were categorized as follows: (1) prosthetic component exchange/repair or revision including exchange of polyethylene components and replacement of part or all of the prosthesis; (2) amputation; (3) superficial soft tissue procedures including irrigation and débridement, skin grafting, and muscle flap creation or revision; (4) deep soft tissue repairs: revisions including synovectomy, arthrotomy, removal of pseudomeniscus (eg, internal scar tissue impinging within the mechanical joint), repair of extensor mechanism; and (5) incision and débridement (I&D): removal of all infected material including radical synovectomies and capsulectomies.

The incidence of complications, the primary and secondary rate of infection, and limb salvage rates were calculated for the entire series and then by individual cohorts (determined by implant type and anatomic location). Differences in the incidence of complications was

compared using the chi-squared (χ^2) test with Yates correction. Limb survival was calculated from date of original surgery to date of amputation (if applicable), or date of censoring (failure or date of last clinical followup). Implant survival over time was calculated using Kaplan-Meier analysis [15] starting from the date of the original surgery with prosthesis failure as the end point. Patients whose prostheses were removed as a result of locally recurrent disease were censored at that time. Those without prosthetic failure were censored either at patient death or date of last followup. Survival of custom versus modular implants was compared using log rank analysis of the KM curves. All statistical analysis was performed using a

Fig. 3 Intraoperative photo of pseudomeniscus formation (hypertrophic scarring within the hinge mechanism) between the two articular surfaces of the distal femoral prosthesis is shown. Impingement of this tissue during activities led to clinical symptoms of pain and instability sufficient to require revision surgery. These clinical symptoms are very similar to that seen following bushing failure.

commercially available program (JMP 8, SAS Institute Inc, Cary, NC).

Results

Complications occurred in 41% (95/232 patients, 103/241 implants), resulting in 242 revisions. Fifty-nine percent (137/232) of patients had no complications; seven underwent surgery for recurrent disease. The average number of procedures for all patients was two (original reconstruction and one revision) while patients with complications underwent on average three (original and two revisions). The incidence of mechanical complications was 21% (49 of 241 implants), the average time of occurrence was 70 months after the initial surgery, accounting for 29% (71/242 procedures) of revision procedures. Twenty of 49 patients experienced other complications as well (Table 3). The failures in 30 of 52 patients (58%) leading to reconstruction were mechanical (Table 4). Dislocations (five proximal tibias, four proximal humeri, one distal femur) occurred in 4% (10/232 patients) making it the least common complication. The incidence of biologic complications (excluding infection) was 25% (61/241 implants); these 32 superficial and 29 deep soft tissue complications led to 17% (40/242) of secondary procedures. The average time of occurrence for superficial complications was 3.6 months after the initial surgery; they were the first complication for 30 patients and, for 10 of these 30, their only complication. Seven patients with an initial superficial complication later experienced implant failure due to infection. The deep soft tissue complications occurred an average of 24 months after surgery. Twenty patients with

Table 3. Incidence of complications, other than infection, by implant type

Complication	Custom (n = 62)	Modular (n = 101)	Total (n = 163)
Mechanical			
Aseptic loosening	6 (9.6%)	6 (5.9%)	12 (7.4%)
Polyethylene loosening	3 (4.8%)	4 (4%)	7 (4.3%)
Tibial bearing	8 (12.9%)	7 (6.9%)	15 (9.2%)
Knee mechanism	2 (3.2%)	1 (1%)	3 (1.8%)
Hip mechanism	0 (0%)	5 (5%)	5 (3%)
Poly broken, unspecified	1 (1.6%)	1 (1%)	2 (1.2%)
Trauma fx:no fx	3:1 (4.8%:1.6%)	4 (4%)	8 (4.9%)
Broken or bent stem NOT due to trauma	3 (4.8%)	4 (4%)	7 (4.3%)
Bushing failure	5 (8%)	3 (3%)	8 (4.9%)
other	2 (3.2%)	3 (3%)	5 (3%)
Soft tissue			
Superficial	13 (20.9%)	27 (26.7%)	40 (25%)
Deep	12 (19.4%)	29 (28.7%)	41 (25.2%)
Dislocation	3 (4.8%)	7 (6.9%)	10 (6.1%)

Table 4. Overall incidence of patients with infection versus mechanical complications, number of procedures and risk of prosthetic failure

Complication type	Number of patients with complication*	Incidence of complication (232 patients)	Average number of procedures upon failure**	Number of patients with failure***	Risk of prosthetic failure
Infection	31	13.3%	3.54	22	70.9%
Mechanical	48	20.6%	1.75	31	64.5%

* Number of patients with one or more instances of the complication; those with both mechanical and infection complications are included in both groups; ** Number of procedures completed, including the one qualifying as failure; *** Many patients had multiple failures; patients here are only in one group, defined by their last recorded cause of failure; Risk of failure = # patient failures/# patient complications (eg: $22/31 = 70.9\%$ for infection, $31/48 = 64.5\%$ for mechanical).

Table 5. Number of infection complications and increase per surgical procedure*

# Procedures completed	# Patients with ____ Px completed	# Complications due to infection	% Procedures followed by infection	% change
1 (1° recon)	232	16	6.8%	
2	108	22	20.3%	+66.5%
3	59	16	27%	+25%
4	33	11	33%	+18.1%
5	4	23	17.4%	-42%
6	4	10	40%	+43.5%
7	2	7	28.6%	-28.5%
8	2	3	66.6%	+57%
9	1	2	50%	-25%

* Inventory of number of complications due to infection following a procedure; each instance of infection complication is counted, patients only drop out of the pool if they do not have any further revisions.

Table 6. Length of time to onset of infection and rate of failure

Time of onset (months postoperatively)	Number of patients (out of 232)	Mean number of procedures before infection	Percent of group whose procedure failed
Early (0–3 months)	10	1.2	70%
Intermediate (4–12 months)	3	1.3	0%
Late (13+ months)	18	2.2	88%

deep complications experienced other complications; nine implants (nine patients) failed secondary to infection or mechanical complications. Four implants (four patients) failed directly due to deep soft tissue complications.

The incidence of infection was 13% (31/241 implants), accounting for 33% (80/242 procedures) of revisions (Table 4). Risk of infection after original reconstruction was 7% (16/241 implants); this risk was 30% higher after revision (each instance of infection complication is counted, and patients only drop out of the pool if they do not have any further revisions) (Table 5). Five of 31 infected patients were salvaged without implant removal; 16 required amputation. Average time to infection was 53.5 months; over half occurred more than 1 year after the original reconstruction (Table 6). Failure from infection

after secondary procedures occurred in seven patients with an initial soft tissue complication, four with an initial mechanical failure, and two with an initial deep complication. Patients whose last recorded implant failure was infection had on average 3.5 complications, whereas patients whose last recorded failure was mechanical had on average 1.8 complications. The risk and percentage of infections substantially increased as patients underwent additional procedures (Table 5).

More ($p < 0.001$) custom implants had mechanical complications than modular implants: 38% (19/50 patients) versus 15% (27/180 patients), respectively. Likewise, the infection rate was higher ($p = 0.043$) among custom implants than modular: 18% (9/50) versus 7% (13/180), respectively. In addition, more ($p < 0.001$) custom

Table 7. Instances and rates of failure due in custom and MSRS implants

Complication type*	CUSTOM number of complications (% of 50 implants)	MSRS number of complications (% of 180 implants)	Failures among CUSTOM prostheses**	Failures among MSRS prostheses***
Infection	24 (28%)	56 (36%)	9 (18%)	13 (7.2%)
Mechanical	34 (40%)	37 (24%)	14 (28%)	16 (8.9%)
Other	28 (32%)	63 (40%)	2 (4%)	1 (.5%)
Total	83	152	25 (50%)	30 (16.8%)

* Last recorded cause of failure; ** The custom prosthesis failure rate was calculated from the ratio of the number of custom prosthetic failures to the total number of custom implants (50); *** The MSRS prosthesis failure rate was calculated from the ratio of the number of MSRS prosthetic failures to the total number of MSRS implants (180).

Fig. 4 The Kaplan-Meier analysis survival of all limbs for all patients over time is shown. The graph demonstrates 92% (95% CI 0.88–0.96) survival at 5 years, 90% (95% CI 0.86–0.95) survival at 10 years, and 90% (95% CI 0.86–0.95) survival at 20 years after surgery.

Table 8. Amputations and their causes

Reason for amputation	# of amputations	% of series (#/241)
Recurrence*	7	3%
Mechanical**	1	0.4%
Infection	16	7%
Superficial soft tissue	0	0%
Deep soft tissue	0	0%
Dislocation	0	0%

* Not counted as implant failures, censored in survival; ** This patient elected to have an amputation instead of further attempts at reconstruction.

implants failed than modular implants: 50% (25 of 50) versus 17% (30 of 180) (Table 7).

Failure rate for all endoprostheses was 29% (70/241 implants); failures experienced by patients was 22% (52/232 patients). Limb survival was 92% at 5 years and 90% at 10 and 20 years (Fig. 4); overall limb salvage was 90% (208 of 232 patients). There were 24 amputations, 16 for infection, seven for recurrent disease, and one for persistent

Fig. 5 The Kaplan-Meier survival analysis of all 241 endoprosthetic implants is shown. Implant survival was 84% (95% CI 0.79–0.90) at 5 years, 72% (95% CI 0.64–0.79) at 10 years and 37% (95% CI 0.20–0.53) at 20 years; the median survival was 189.9 months.

Fig. 6 The Kaplan-Meier survival analysis of all endoprosthetic implants stratified by implant design as a function of time; proximal femur and scapular implants showed a 100% survival rate. These data are further detailed in Table 9.

pain (Table 8). Implant survival was 84% at 5 years, 72% at 10 years and 37% at 20 years, with median survival of 189.9 months (Fig. 5). Implant survival varied by type (custom versus modular, Fig. 6) and by anatomic location (Fig. 7) (Table 9). Of 95 patients requiring revision surgery, 82% (78/95) were salvaged.

Discussion

Endoprosthetic reconstruction is now widely accepted in the reconstruction of skeletal defects following resection of bone tumors. Although early complications associated with such implants have been reported, the long term incidence and types of complications has not been characterized in large series; a detailed analysis of these complications and their time frame of occurrence is still needed. Furthermore the impact of introduction of modular system in alteration of these complications was not investigated in these series (Table 10). We therefore attempted to determine: (1) the incidence and time of occurrence of all complications; (2) the incidence of infections; (3) the risk of secondary complications following treatment of an initial complication; (4) whether modular implants altered the rate or type of complications; (5) the overall implant failure rate and ultimate limb salvage rate over time; and (6) limb and implant survival by observing our patient population over an extended period of time.

Fig. 7 This Kaplan-Meier survival analysis of modular (*solid line*) versus custom (*dotted line*) implants shows 5-year survival rates of 85% and 79% and 10-year survival rates of 79% and 55%, respectively. Survival was greater ($p < 0.04$) for the modular implants.

We recognize limitations in this study. First, it is a retrospective, observational analysis of patients treated over a long period of time, with patients lost to followup or to death from their underlying malignancy. Second, there is no appropriate control group to permit direct comparisons; the two groups compared (custom versus modular implants) were from consecutive time periods during which surgical and perioperative skills and procedures undoubtedly changed. Third, tumors of bone requiring segmental resection and reconstruction are very rare, limiting the overall number of procedures performed at any single location. Fourth, each tumor procedure is relatively unique in the amount of exposure and soft tissue resection that is required for a proper tumor margin, potentially affecting the durability and function of each reconstruction even in patients with identical diagnoses and anatomic locations. Additionally, there are wide variations in patients' height, weight, age, not to mention types and dosing of chemotherapy, all potentially affecting implant survival. However, many variables were minimized by the fact that all implants were made by a single manufacturer and all surgery was performed using the same surgical techniques at a single institution. Additionally, surviving patients have been followed extensively for long periods of time, with detailed records of complications and serial radiographs of the implants recorded at yearly visits.

The overall incidence of complications seen in our series is not inconsequential, with 41% of all patients experiencing a complication requiring further treatment. However, biologic complications (eg, wound problems) are likely related to the tumor resection and therefore independent of the choice of skeletal reconstruction. Mechanical complications, which occurred in 21% of patients, were the single most common cause of implant failure and are likely related to the implant itself. This rate is comparable to that reported in the literature, ranging from 5 to 48% (Table 10). Notably, the observed rate of aseptic loosening in this study (5%, 12/241 implants) was

Table 9. Survival of endoprostheses by location and type in our series

Prosthesis type	# of implants	# of failures	Median followup (months)	Median survival (months)	5 year survival	10 year survival	15 year survival
All DF	101	30	126	177	81%	70%	47%
All PF	28	0	99	nr	100%	100%	100%
All PH	45	6	108	nr	87%	78%	78%
All PT	45	16	140	199	79%	63%	63%
All scapula	11	0	89	nr	100%	100%	nr
All TF	11	3	106	104	91%	45%	nr
All MRS	180	30	98	199	85%	79%	63%
All custom	50	25	208	177	79%	56%	48%

DF = distal femur; PF = proximal femur; PH = proximal humerus; PT = proximal tibia; TF = total femur; nr = not reached.

Table 10. Literature review of endoprosthetic reconstruction and associated complications

Author [reference]	No. of patients in the series	Period of followup	Secondary amputation %	Periprosthetic infection		Mechanical complications		Dislocation complications		Soft tissue complications	
				%	Amputation required	%	Amputation required	%	Anatomical location	%	Type
Jeys et al. [13]	1264	Mean 5.9 yr	8.9%	11%	37%	–	–	–	–	–	–
Wirganowicz et al. [24]	278	Minimal 2 yr	6%	4%	31%	17% (1/3 AL)	9%	–	–	–	–
Gosheger et al. [8]	250	Mean 45 mo	13%	12%	NA	9.6% (4/5 AL)	None	2%	2 PH 3 PF	–	–
Shin et al. [20]	208	Minimal 10 yr	6%	5%	40%	19% (1/2 AL)	None	1%	2 PF	–	–
Ahlmann et al. [1]	211	Mean 37.3 mo	2.4%	5.2%	NA	4.3%	None	1.4%	3 PF	–	–
Zeegen et al. [27]	141	Mean 18 mo	6%	7%	20%	8% (All AL)	None	5%	5 PF 1 DF 1 patella	0.5%	Extensor mechanism failure
Gitelis et al. (PT & DF series) [7]	80	Mean is 5.3 yr	6.2%	2.5%	None	22.5% (AL 2/3)	None	0%	–	–	–
Kabukcuoglu et al. (PF series) [14]	54	Mean 9 yr	13%	1.8%	100%	11%	None	11%	PF	–	–
Sim et al. (DF&PT series) [21]	50	Median 24.5 mo	6%	12%	33%	6% (1/3 AL)	None	0%	–	–	–
Kawai et al. (DF series) [16]	40	Median 8 yr	12.5%	10%	25%	48% (4/5 AL)	None	–	–	30%	Superficial skin necrosis
Shehadeh et al. [current study]	232	Mean 10 yr	10%	13%	51%	Custom 38% Modular 15% (1/7AL)	2%	4.3%	4 PH 5PT 1DF	2.5% 13% 12%	contracture Deep superficial

PH = proximal humerus; PT = proximal tibia; PF = proximal femur; DF = distal femur; – = data not mentioned; AL = aseptic loosening.

substantially lower than reported in other series with mean followup of greater than 2 years (30–80%) (Table 10). While the cause of this difference is uncertain, a reasonable postulate is the difference is related to implant design, surgical or cementation techniques, or a combination thereof. This finding is worth further study as aseptic loosening has been reported as the most common complication in other studies. Clinical and radiographic surveillance of all surviving patients is ongoing in an attempt to determine the ultimate outcome of these cemented implants.

Infection was the most common complication seen in this series and was the most common cause of loss of limb; 51% of infections resulted in eventual amputation. The observed 7% risk of infection following the primary reconstruction increased 30% in patients requiring revision for other causes, emphasizing the need to avoid secondary procedures when possible. The risk of primary infection is comparable to that reported in the literature, of which many focused only on distal femoral replacements, with reported rates ranging from 2 to 12% (Table 10). Many of the patients in this series had major risk factors for infection including myelosuppression and relative cachexia related to their cancer and chemotherapy treatments, as well as long term indwelling catheters used to administer chemotherapy. However, the risk of infection following secondary procedures is clearly unrelated to these factors, as these typically occurred in those patients who had survived their original disease.

In addition to the risk of secondary infection, the risk of all complications was higher than that observed after the primary reconstruction. These secondary complications occurred over time, and while revision surgery can be successful in many, some patients experienced further complications and implant failure, an observation noted by others [4, 6, 13, 20, 21, 24]. Clearly, further efforts in understanding the causes of complications and strategies to prevent them could lead to substantial improvements in implant survival.

One factor leading to improved survival was the introduction of modular implants, an observation supported by our data showing that modular implants were much less likely to fail than custom implants (Table 3). This appears to be due to fewer mechanical complications in the modular group. Recognition of the problems associated with custom implants led to major design and manufacturing changes which were incorporated into the modular implant system specifically to reduce the incidence of mechanical complications [2, 9, 10, 25]. Other modifications, including circumferential porous coating for extracortical fixation (the “pursestring” effect) [9, 24] and routine use of gastrocnemius flaps for improved soft tissue coverage around the knee following proximal tibial replacement [9, 18, 25]

further reduced the risk of complications. Changes in implant design, incorporation of cross-linked polyethylene components, strict attention to the administration of pre-operative antibiotics, and use of new surgical prep solutions may lead to additional reductions in the risk of postoperative complications.

The overall implant failure rate observed in our series was 29% as compared to rates ranging from 20 to 35% reported in the literature (Table 10). The limb salvage rate for all patients in this study was 90%, demonstrating that many complications were successfully managed, particularly in the absence of infection. This result leads us to conclude that endoprosthetic reconstruction is warranted in a tumor population, a conclusion shared by others [1, 5, 7, 8, 11, 14, 16, 19, 24, 27]. Whether the limb salvage rate will change as patients enter their third and fourth decades following their index procedure can only be answered through further observation over time.

The survival curve for all implants over time shows a fairly constant decline in survival over time (Fig. 5). However, certain anatomic locations, notably the scapula, proximal humerus, and proximal femur, show few if any failures over time (Fig. 6, Table 9). While all of these implants share similar components and have cemented stems, local anatomy and biomechanical forces experienced by the implants around the knees clearly present major challenges to implant survival. Comparing custom and modular implant survival over time, the early (< 10 year) improved survival of the modular implants narrows after 15 years (Fig. 7, Table 9). Given the higher incidence of mechanical failures in the custom group, this suggests that biologic factors become the dominant factor with longer term followup. Further observation of implant survival may help to clarify this apparent correlation.

Endoprosthetic reconstruction for segmental skeletal defects following resection of bone tumors can be very successful with reliable long-term implant survival achieved in most patients, many after a single operation. Improved implant survival was seen after the introduction of a modular system, due in part to decreased mechanical complications and fewer secondary infections, as these patients were less likely to require revision surgery. While mechanical complications still occurred, modularity has the advantage of permitting revision of only those specific components that failed without removal of the entire prosthesis. This may influence the risk of infection as smaller exposures and shorter operative times are typically needed for limited revisions. When complications occur, the majority of patients can be salvaged with a functional limb; this is of increasing importance as more patients ultimately survive their underlying disease. The results presented in this study imply that efforts to improve endoprosthetic reconstruction should focus on the prevention

of postoperative complications. Reducing infection, improving mechanical durability, and better techniques for revision surgery could all reduce the risk of further complications in patients who suffer an initial complication. Further study of patient satisfaction, function, and long-term cost-effectiveness of endoprosthetic reconstruction is warranted.

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