Cemented Endoprosthetic Reconstruction of the Proximal Tibia

How Long Do They Last?

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Abstract

Background The few available studies documenting the long-term survival of cemented proximal tibial endoprostheses for musculoskeletal tumors do not differentiate between stem designs or patient diagnosis. There is wide variation in survival rates reported, possibly a result of this heterogeneity in patient population and implant design.

Questions/purposes We therefore asked: (1) How long do proximal tibial endoprostheses last? (2) What is the typical long-term functional result after proximal tibial replacement? And (3) what are the short- and long-term complications associated with endoprosthetic reconstruction of the proximal tibia, particularly with respect to the soft tissue reconstruction?

Patients and Methods We retrospectively reviewed 52 patients with 52 proximal tibial endoprosthetic reconstructions for a tumor-related diagnosis. Kaplan-Meier survivorship analysis was performed using revision of the stemmed components for any reason as an endpoint for implants, and death due to disease progression for patients. Function was assessed using the MSTS scoring system. The minimum followup was 1 month (mean, 96 months; range, 1–284 months; median, 69 months).

Results Using revision of the stemmed components for any reason as an end point, overall prosthesis survival at 5, 10, 15, and 20 years was 94%, 86%, 66%, and 37%, respectively. The 29 modular implants demonstrated a trend toward improved survival compared to the 23 custom-designed components, with a 15-year survivorship of 88% versus 63%. The mean postoperative Musculoskeletal Tumor Society score at most recent followup was 82% of normal function (mean raw score, 24.6; range, 4–29).

Conclusions Cemented endoprosthetic reconstruction of the proximal tibia provides a reliable method of reconstruction following tumor resection.

Level of Evidence Level IV, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

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Introduction

Amputation was the standard method for achieving local control of tumors of the proximal tibia prior to the early 1970s. Since the advent of effective chemotherapeutic regimens, limb sparing surgery provides improved patient

function and acceptance when compared to amputation [41, 43, 46]. The first limb salvage efforts in this anatomic location consisted largely of resection arthroplasty [2, 5, 17, 29]. Alternative methods of reconstruction for tumors involving this anatomic location include Van Ness rotationplasty [17, 22, 29], resection arthrodesis [2, 5], allograft [4, 6, 15, 53], allograft-prosthetic composite reconstruction [7, 21, 25], and endoprosthetic reconstruction. Acceptable long-term implant survival may be obtained with allograft-prosthetic composite techniques [7, 21, 25], which provide a substrate for soft tissue and extensor mechanism attachment. Allograft-prosthetic composites offer the best alternative to endoprosthetic reconstruction of the proximal tibia as biologic fixation can be achieved through direct attachment of the patellar tendon to the allograft bone [7, 21, 25].

Early attempts at endoprosthetic proximal tibial reconstruction were fraught with wound-related complications, patellar tendon attachment problems, and high rates of repeat surgery, largely a result of an insufficient soft tissue envelope to surround the proximal tibia [20]. In 1983, at the second International Symposium on Limb Salvage (ISOLS) meeting in Vienna, Austria, Jean Dubousset of France first reported his results using a medial gastrocnemius rotation flap as a means of obtaining soft tissue coverage over a proximal tibial endoprosthesis [8]. The clinical success of this technique in terms of extensor mechanism function and soft tissue healing permitted the routine use of endoprostheses for reconstruction after tumor resection of the proximal tibia [9, 10, 38].

Cemented proximal tibial endoprostheses are widely used today [3, 14, 16, 19, 23, 26, 33, 36, 37, 51]. A few reports available document the long-term survival of these devices for musculoskeletal tumors [26, 36, 51]. These studies document a wide range of implant survival from 22% to 86% [3, 14, 18, 19, 23, 26, 33, 36, 37, 44, 51]. Additionally, these studies make no attempt to account for changes in implant design or differences among patient diagnoses.

We therefore sought to address the following questions: (1) How long do proximal tibial endoprostheses last? (2) What is the typical long-term functional result following proximal tibial replacement? And (3) what are the short- and long-term complications associated with endoprosthetic reconstruction of the proximal tibia, particularly with respect to the soft tissue reconstruction?

Patients and Methods

We retrospectively reviewed the charts of all 57 patients who underwent cemented endoprosthetic tibial reconstruction between December 1985 and December 2008. Three skeletally immature patients underwent reconstruction with an expandable prosthesis, with the intent of performing

Table 1. Patient demographics

Variable	Number of patients
Total	52
Male	25 (48.1%)
Female	27 (51.9%)
Age (years)*	24.2 (13–71)
Diagnosis	
High-grade osteosarcoma	38 (73.1%)
Giant cell tumor	4 (7.7%)
Ewing's sarcoma	3 (5.8%)
Chondrosarcoma	2 (3.8%)
Soft tissue sarcoma	2 (3.8%)
Parosteal osteosarcoma	1 (1.9%)
Fibrosarcoma	1 (1.9%)
Undifferentiated spindle cell sarcoma	1 (1.9%)
Group 1: Low grade or benign	9 (17.3%)
Group 2: High grade localized	43 (82.7%)

* Value is expressed as mean, with range in parentheses.

multiple expansions and component exchanges during growth and were not included in the present analysis. An additional two reconstructions were performed for a diagnosis other than musculoskeletal tumor and were also excluded from the study cohort. This left 52 proximal tibial endoprosthetic reconstructions in 52 patients with a tumor-related diagnosis available for study (Table 1). The study cohort of 52 reconstructions was divided into two groups, according to the staging system described by Enneking et al. [12]: Group 1 (n = 9) included those with low-grade malignancy (Stage IA or IB) or benign conditions, and Group 2 (n = 43) consisted of those with high-grade localized disease (Stage IIA or IIB). There were no patients with Stage III primary sarcomas or metastatic disease in this cohort. Minimum followup for all patients was 1 month (mean, 96.0 months; range, 1.0–283.6 months; median, 69.2 months). At the time of most recent followup, 13 of 52 patients (25%) had died, 11 due to progression of disease, one due to sepsis related to a perirectal abscess, and another due to age-related causes. Thirty-nine patients (75%) remained alive; 38 patients were disease-free, and one patient with giant cell tumor and stable pulmonary nodules was alive at 148.4 months. No patients were seen specifically for this chart review. Eleven of the 52 patients were followed for less than 2 years. Four died at 4, 5, 15, and 18 months and four were recent procedures that have short-term followup. Three were lost to followup at 5, 6 and 7 months, but were well at the time of last evaluation. We had prior approval from our institution's Office for Protection of Research Subjects (UCLA IRB #G08-10-100-01).

Implants were manufactured by two companies: Howmedica/Stryker (Mahwah, NJ) and Techmedica Inc

(Camarillo, CA). Between 1985 and 1989, these implants were custom-designed, one-piece casted implants. A rotating-hinge was utilized in all cases. A one-piece custom tibial endoprosthesis was implanted in 23 cases (44%), while a modular endoprosthesis was utilized in 29 (56%). The 51 implants (98%) manufactured by Stryker/Howmedica used the Kinematic® rotating-hinge mechanism. The one implant (2%) manufactured by Techmedica used the Noiles® rotating-hinge mechanism. Porous extramedullary coating was applied to the body of the first 10 proximal tibial endoprostheses. The subsequent 10 endoprostheses were manufactured without this surface but demonstrated an alarming incidence of osteolysis and radiolucent lines. We have previously reported this subset of patients [48]. This coating was then reapplied to the prosthetic body over a limited distance (2–3 cm) for the remaining 32 implants in the series. In the initial custom design, the tibial polyethylene component was secured by three metal tabs to the proximal tibial implant. The subsequent design in the early 1990s used a press-fit capture mechanism.

The surgical technique for tumor resection included a wide surgical margin; tourniquets were never utilized [9]. All resections performed in this series were intraarticular and intracompartmental. The surgical approach utilized a longitudinal medial incision over the distal thigh extending medially toward the ankle and following the juncture of the anterior compartment with the tibia. Once the tibia was completely exposed, the level of resection was marked on the tibia distally with an osteotome. A more distal mark on the tibia and a mark on the distal femur were made and this distance measured and recorded. The posterior tibial and peroneal arteries were identified in the popliteal space. The anterior tibial artery and vein were identified in the proximal calf and the anterior compartment. This vessel was occasionally sacrificed for large, laterally based tumors. If this was required, a Doppler probe was used to confirm the presence of blood flow distally with manual compression on the artery before ligation. The ligamentous structures were dissected free from their femoral origins and the posterior capsule was transected. The distal marrow was sent for frozen-section analysis to ensure a negative marrow margin. With the knee flexed, the distal femoral cuts were performed freehand using a sagittal saw. Once the frozen section of the distal marrow was reported as negative, the tibia was reamed over a guidewire to maximize fit and fill of the distal canal with the prosthetic stem. The trial endoprosthesis was reduced, and restoration of the preresection extremity length was verified using the marks on the proximal tibia and femur. The neurovascular bundle was palpated to ensure there was not excessive tension on the vessels, and a Doppler probe at the ankle confirmed the presence of the posterior tibial and dorsalis pedis pulses. Before cementation, all patients received 100 mg

Solu-Cortef® (Pfizer, New York, NY) to help protect against the inflammatory effects of fat emboli. The medial gastrocnemius muscle was dissected free before cementing the endoprosthetic components and was rotated over the tibial component. To reconstruct the extensor mechanism, the joint capsule and patellar tendon were sutured to the leading edge of the transposed gastrocnemius muscle. A split-thickness skin graft was then applied to the muscle flap in all cases.

Postoperatively patients were immobilized either with a long posterior splint or a cast for 4 weeks and were then allowed to begin gentle ROM exercises. Warfarin was administered for 3 weeks (goal international normalized ratio of 2.0–3.0). On the third postoperative day, patients were made weightbearing as tolerated with ambulatory supports, which were used for 6 to 8 weeks. At 4 weeks, the cast was removed and ROM and motor strengthening exercises were begun. Intravenous antistaphylococcal antibiotics were administered until the drains were removed, generally 6 to 8 days after surgery.

Patients were followed every 2 to 3 weeks for the first 2 months after surgery. They were then followed quarterly for 2 years, semiannually for an additional 2 years, and then annually. Radiographs of the affected limb were obtained at each postoperative visit, along with quarterly chest radiographs and semiannual chest CT. Postoperative function was evaluated for each patient with the use of the MSTS function score [13].

Data retrieved from the charts included the index diagnosis and disease stage at the time of presentation (according to the system described by Enneking [12]), length of followup, postoperative Musculoskeletal Tumor Society (MSTS) function scores at the time of most recent followup [13], and any major postoperative events (complications, repeat surgery for any reason, revision of stemmed components, infection), and local recurrence. Complications and implant survival data were included for all patients, including those with short-term followup and the three patients lost to followup (at time end-points of 5, 6, and 7 months).

Patient, prosthesis, and limb survival rates were determined using the Kaplan-Meier product-limit method [27]. Prosthesis survivorship was evaluated using revision of the stemmed components for any reason (including mechanical failure, infection, or local recurrence) as an end point. Mechanical failure included aseptic loosening or fatigue fracture of the stemmed tibial or femoral components. Bushing, axle, and polyethylene failures were analyzed separately, as they were successfully managed without the need for revision of major stemmed components. Statistical analysis was performed using a commercially available statistics package (SPSS® Version 11.0; SPSS Inc, Chicago, IL).

Results

Using revision of the stemmed components for any reason as an end point, overall prosthesis survival at 5, 10, 15, and 20 years was 93.8%, 86.4%, 65.8%, and 37.0%, respectively (Fig. 1; Table 2). Ten cemented stemmed components (19.2%) were revised: nine due to mechanical failure and one due to late hematogenous infection. Among the nine stemmed components revised for mechanical failure, six were due to aseptic loosening of the tibial stem at a mean 11.8 years postoperatively (range, 3.8–19.6
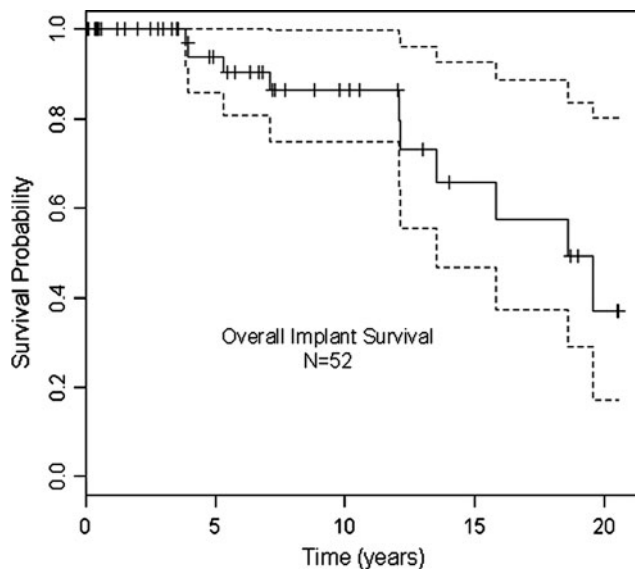
Fig. 1 Kaplan-Meier survivorship analysis shows overall prosthesis survival (n = 52). Using revision of the stemmed components for any reason as an end point, overall prosthesis survival at 5, 10, 15, and 20 years was 93.8%, 86.4%, 65.8%, and 37.0%, respectively. Dashed lines represent 95% confidence intervals.

years). Three of the six cemented stems revised for aseptic loosening had an extramedullary porous surface and three did not. The remaining mechanical stem failures included single instances of aseptic loosening of the femoral component at 7.1 years, fatigue fracture of the femoral condyle at 13.5 years, and periprosthetic tibial fracture at 18.6 years postoperatively. A second revision procedure was required in four of these nine cases of mechanical failure. One patient required a third revision procedure due to acute infection. None of the casted (n = 23) or modular forged stems (n = 29) have experienced fatigue fracture. Failure of the rotating-hinge mechanism necessitating replacement of the bushings, axle, tibial bearing, or polyethylene without revision of the stemmed components occurred in 12 cases (23.1%) at a mean of 8.9 years postoperatively (range, 2.5–17.1 years). Of the 12, failure of the tibial polyethylene capture mechanism occurred in eight (all of which utilized the original tabbed capture mechanism), standard bushing failures in two, and single instances of the fatigue fracture of the axle and tibial bearing component. All nine patients initially diagnosed with low-grade or aggressive benign tumors have survived (Table 2). The 5-, 10-, 15-, and 20-year disease-specific survival rates for the 43 patients diagnosed with high-grade localized disease were 81.2%, 69.9%, 69.9%, and 69.9%, respectively. Survival of contemporary modular implants exceeded the 15-year patient survival among those with high-grade localized disease. The 29 modular implants demonstrated a trend toward improved (p = 0.13) survival compared to the 23 custom designed components, with a 15-year survivorship of 87.5% versus 62.9% (Fig. 2).

The mean postoperative MSTS score at the time of most recent followup was 82.0% of normal function (mean raw score, 24.6; range, 4–29). The postoperative ROM on most recent assessment for all patients revealed mean flexion of

Table 2. Implant and patient survival

Survival	5 years			10 years			15 years			20 years		
	%	95% CI		%	95% CI		%	95% CI		%	95% CI	
		Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper
Implant survival												
Low grade (n = 9)	100.0			75.0%	42.6%	100.0%	37.5%	8.4%	100.0%	37.5%	8.4%	100.0%
Stage IIA/IIB (n = 43)	93.0%	84.0%	100.0%	88.1%	76.1%	100.0%	71.2%	51.1%	99.1%	38.1%	17.0%	85.4%
Custom (n = 23)	89.5%	76.7%	100.0%	83.9%	68.7%	100.0%	62.9%	42.9%	92.2%	35.4%	16.0%	78.1%
Modular (n = 29)	87.5%	67.3%	100.0%	87.5%	67.3%	100.0%	87.5%	67.3%	100.0%	NA		
Overall (n = 52)	93.8%	85.9%	100.0%	86.4%	74.7%	99.9%	65.8%	46.7%	92.7%	37.0%	17.1%	80.2%
Patient survival by diagnosis												
Low grade (n = 9)	100.0			100.0			100.0			100.0		
Stage IIA/IIB (n = 43)	81.2%	69.6%	94.8%	69.9%	55.4%	88.1%	69.9%	55.4%	88.1%	69.9%	55.4%	88.1%

95% CI = 95% confidence interval; NA = not applicable.
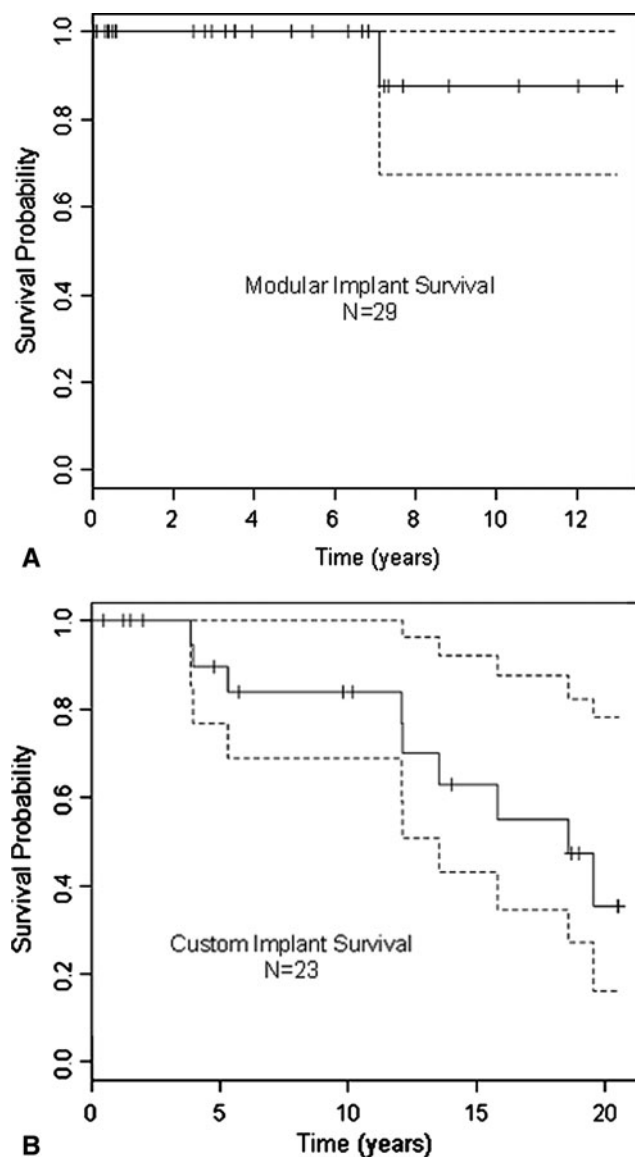
Fig. 2A–B Kaplan-Meier survivorship analysis shows (A) modular (n = 29) versus (B) custom (n = 23) implant survival. Although not statistically significant, the 29 modular implants demonstrated a trend toward improved survival compared to the 23 custom-designed components, with a 15-year survivorship of 87.5% versus 62.9% (p = 0.13). Dashed lines represent 95% confidence intervals.

110.0° (range, 30°–135°), mean passive extension to 1.4° (range, 0°–50°), and mean active extension lag of 17.9° (range, 0°–100°). Forty-two patients achieved full active extension, while nine patients demonstrated a residual active extensor lag (range, 5°–100°).

Seven of 52 patients (13.5%) experienced delayed wound healing or minor postoperative wound dehiscence, three of which were treated nonoperatively. Among the four treated surgically, two underwent simple wound excision and primary closure, one required a split-thickness skin graft, and one necessitated coverage with a rectus abdominus free muscle flap. Deep infection occurred in three of the 52 patients (5.8%). One patient developed a deep bacterial infection immediately after the index procedure and was successfully treated surgically with irrigation and débridement with retention of the components. A second patient with a modular prosthesis presented with an acute hematogenous infection 2 years after the index operation. The cemented stems were retained, along with an antibiotic spacer, and after 6 weeks of intravenous antibiotics, the modular components were replaced successfully. The third patient, who underwent his initial reconstruction in 1985, experienced a late infection with Staphylococcus epidermidis in 1990. After multiple episodes of repeat infection, he ultimately underwent two-stage reimplantation of a custom-designed endoprosthesis with crosspin fixation for antirotational control in both the femoral and tibial stems in 2008. He is currently pain free and ambulates without supports despite a 90° active extensor lag. Five of the 52 patients (9.6%) ultimately required amputation after either the index or revision procedure and were categorized as failed limb salvage efforts. The reason for amputation was local recurrence in three patients and single instances of regional metastasis and intractable pain. A total of 98 procedures were performed in 52 patients, including all index procedures and all procedures related to local complications or revisions.

Discussion

Endoprosthetic reconstruction of the proximal tibia is challenging due to a variety of factors. Problems include the frequently poor residual soft tissue envelope and the need for reconstruction of the extensor mechanism to either the prosthesis or allograft. At the 1983 ISOLS meeting in Vienna, Jean Debousset of France described the use of a gastrocnemius rotation flap used to cover the proximal tibial prosthetic implant. This provided excellent coverage over the prosthesis and an anchorage point for the joint capsule and patellar tendon attachments. As a result, prosthetic replacement of the tibia became feasible, since soft tissue coverage and extensor mechanism attachment were possible [8, 9, 40, 45]. While the use of this reconstructive method is now widespread, the available long-term data report a wide range of implant survival from 22% to 86% [3, 14, 19, 23, 26, 33, 36, 37, 39, 44, 51, 52, 54]. We therefore raised the following questions: (1) How long do proximal tibial endoprostheses last? (2) What is the typical long-term functional result after proximal tibial replacement? And (3) what are the complications associated with endoprosthetic reconstruction of the proximal tibia, particularly with respect to the soft tissue reconstruction?

Table 3. Review of the available literature on proximal tibial endoprosthetic reconstruction

Study	Number of implants	Mean followup (years)	Implant survivorship/revision rate[a,b]				MSTS score[b,c]	Amputation[b]	Infection[b]	Local recurrence[b]
			0–9 years	10–14 years	15–19 years	≥ 20 years				
Horowitz et al. [23] (1991)	16	5.3	31.3[d]				3E, 7G, 4F[e]	18.8%	37.5%	0.0%
Malawer and Chou [33] (1995)	13	3.5	46.2[d]				70.0%	23.1%	30.8%	0.0%
Grimer et al. [19] (1999)	151	6.7			66.0[d]		77%[f]	17.0%	28.0%	16.0%
Kawai et al. [28] (1999)	7	3.1	58[g]				90%	14.3%	12.5%[h]	0.0%
Ilyas et al. [24] (2000)	15	3.5	100[g]				61%	13.3%	13.3%	0.0%
Bickels et al. [3] (2001)	55	6.3	5.4[d]				48G/E, 6F, 1P	3.6%	3.6%	6.2%
Natarajan et al. [37] (2003)	133	5.0	84.5[g]				63E, 36G, F8, P21	2.3%	12.0%	3.0%
Flint et al. [14] (2006)	44[i]	5.0	73.0[g]				75%	15.9%	15.9%	4.5%
Myers et al. [36] (2007)	99	15.0			30.0[d]			25%[j]	19.5%	5.1%
Jeys et al. [26] (2008)	136[k]	9.0		62.5[g]		40.6[g]	NA	18.4%	21.0%	4.0%
Wu et al. [51] (2008)	44	7.1	44.4/81.4[g,l]	22.2/65.3[g,l]			84.6%	15.9%	15.9%	2.3%
Schwartz et al. [current study] (2010)	52	8.0	93.8[g]	86.4[g]	65.8[g]	37.0[g]	82.0%	9.6%	5.8%	5.8%

[a]Shown as percentage (number as reported in original article converted for ease of comparison); [b]numbers (as reported) converted to percentage of all cases for ease of comparison; [c]all but first two articles (Horowitz et al. [23] and Malawer et al. [33]) used the revised 1993 MSTS scoring system [13]; [d]reported percentage of implants revised; [e]E = excellent, G = Good, F = Fair, P = Poor, according to the 1987 MSTS scoring system [11] [f]50 of 100 analyzed; [g]Kaplan-Meier survivorship of implant; [h]reported as four wound complications of 32 total knee implants (comprising both proximal tibia and distal femur); [i]all treated with cementless Kotz Modular Femur and Tibia Resection System (Stryker, Rutherford, NJ); [j]number reported as calculated by survival analysis; [k]includes all tibial endoprostheses; [l]first number is survivorship of nine custom implants; second number is survivorship of 35 modular implants; MSTS = Musculoskeletal Tumor Society; NA = not available or not studied.
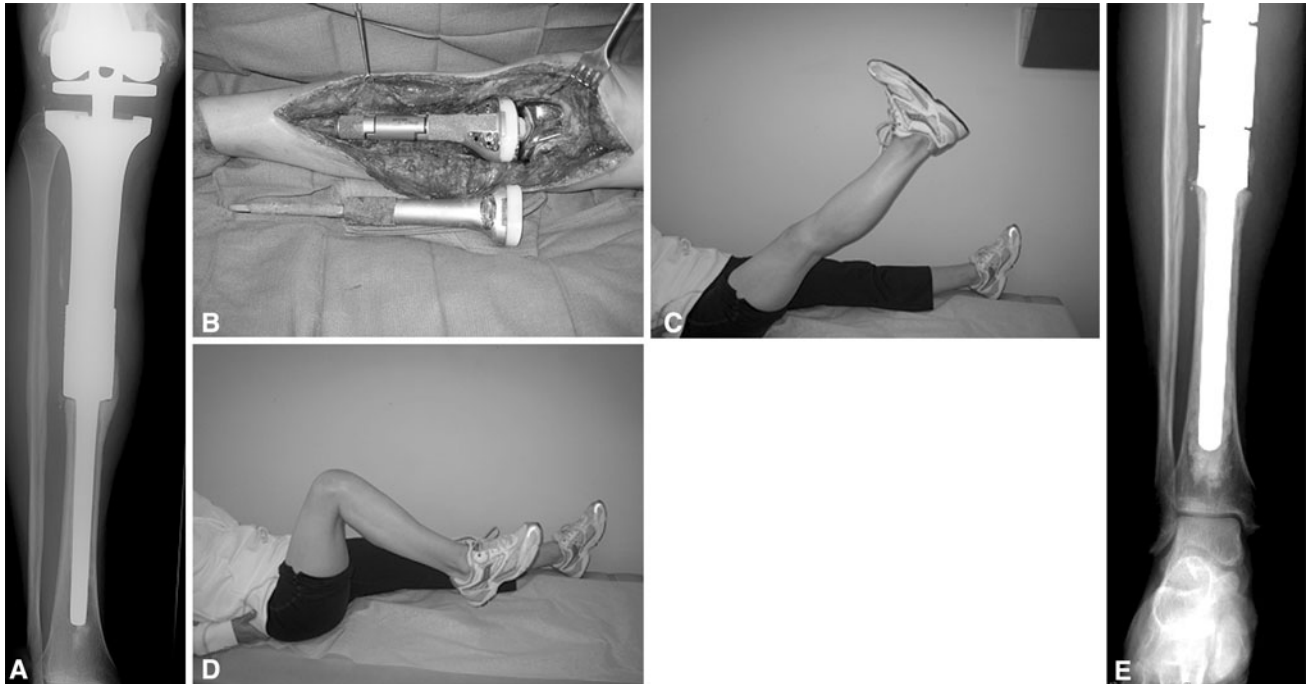

Fig. 3A–E Images illustrate the case of a patient experiencing aseptic loosening of a tibial stem 20 years after initial procedure. (**A**) A plain AP radiograph demonstrates the aseptic loosening of the tibial stem. (**B**) An intraoperative photograph shows revision of the stem. Clinical photographs show the patient's function at the time of most recent followup, illustrating active range of motion from (**C**) full extension to (**D**) 110 degrees of flexion. (**E**) A plain AP radiograph 2 years following revision showing a well-fixed tibial stem.

The limitations of this study include the small patient cohort, and the three patients lost to followup. First, regarding the relatively small cohort, musculoskeletal tumors of the proximal tibia are rare, making it exceedingly difficult to amass a large number of patients for prospective evaluation. While this series appears small, the available literature reports outcomes for cohorts ranging from seven to 136 patients over varied followup lengths, employing widely varied surgical techniques and implants. We report a relatively uniform cohort of 52 patients who underwent reconstruction by one surgeon, with one method of extensor mechanism and soft tissue reconstruction. We believe that the implant survival data of such a uniform cohort provides a major contribution to the available literature. The three patients lost to followup were included to capture all data related to perioperative complications and events. The lost-to-followup quotient (ratio of patients lost to followup to the number of failures reported) [35] was much less than 1, indicating a low likelihood that these three patients would substantially affect the data analysis.

Long-term survival of proximal tibial implants varies widely across studies, possibly due to dissimilarity in implant design and surgical technique (Table 3). Our findings are similar to previous reports that point to an improvement in prosthesis longevity among newer forged modular implants [33, 47]. Although not statistically significant, the use of modularity tended to improve 15-year survivorship to 87.5% from 15- and 20-year survivorship of 63% and 35% seen with the initial custom-cased components; the study may have been underpowered to show any real difference. Similar to other series of cemented endoprosthetic reconstruction, the major mode of stem failure seen was aseptic loosening (Fig. 3). The use of an extramedullary porous ingrowth surface (Fig. 4) was associated with a lower incidence of aseptic loosening, as we have previously reported [48]. Additionally, improvements in the polyethylene locking mechanism resulted in fewer cases of failure of the articulating surface.

Our immediate use of a continuous passive motion machine in the 1980s resulted in a large extensor lag, and after personal communication (JJE) with Jean Debousset (1987), this practice was discontinued in favor of immobilization for a period of 4 weeks. Due to wide variation in reporting methods and subjective evaluation criteria, it is difficult to compare ROM data, strength testing, and extensor mechanism function across study cohorts. Function after proximal tibial endoprosthetic reconstruction varies in the literature from 60% to 90% of normal function, according to MSTS scores (Table 3). We report an overall MSTS score of 82.0%, despite a mean active extension lag of 17.9°. Passively, almost all patients were able to achieve full extension (mean 1.4° short of full extension). These data support the notion that, even with an
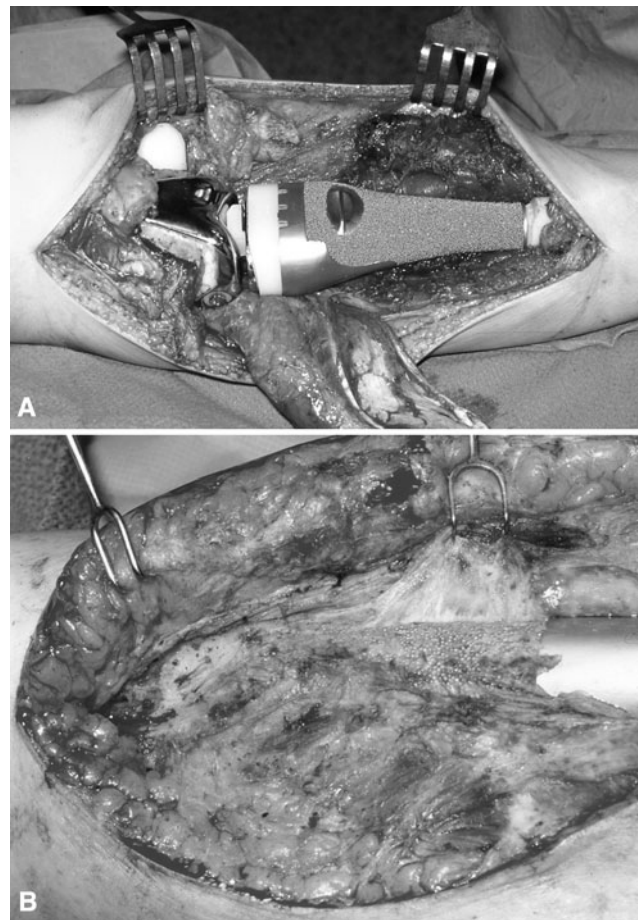
Fig. 4A–B (A) The initial implant design used for the first 10 cases in this series featured extensive extramedullary porous coating with the aim of encouraging bone ingrowth. The coating was removed after bone ingrowth did not occur. The subsequent 10 cases were manufactured without this surface and were noted to demonstrate increased radiographic radiolucent lines and osteolysis. Three of the 10 implants (30%) without this surface demonstrated aseptic loosening, while only three of 42 implants (7.1%) with extramedullary coating showed signs of loosening. (B) An intraoperative photograph at the time of implant revision demonstrates soft tissue ingrowth into the extramedullary porous surface. This ingrowth is thought to provide a barrier that functions to limit access of wear debris to the bone-cement interface.

active extensor lag after insertion of the residual patellar tendon into the rotated gastrocnemius flap, most patients remain able to achieve full extension during swing-through phase of gait. Recurvatum is avoided by engagement of the extensor stop on the femoral prosthesis, providing a stable platform for walking. Formal gait analysis to better define the mechanisms of ambulation in this complex patient population would certainly improve our understanding of the biomechanics involved and likely lead to enhancements in implant design.

Local complications typically reported after endoprosthetic reconstruction of the proximal tibia include mechanical failure, local recurrence, wound-related issues,
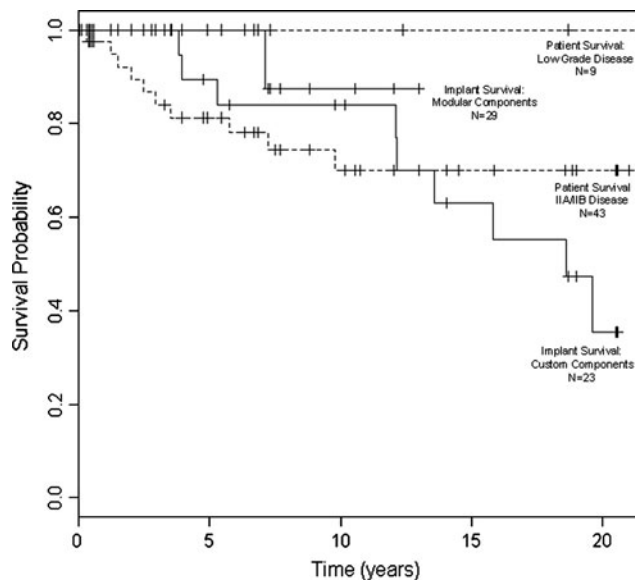
Fig. 5 A graph shows implant versus patient survival for the entire study cohort. Modular implants performed better than custom implants, with a 15-year survival of 93.7% versus 51.7%, respectively. Patients with low-grade or benign disease and long-term survivors with high-grade localized disease should expect to undergo at least one revision procedure in their lifetime.

and neurovascular compromise (Table 3). The most common complication encountered in this series was related to wound healing, although only three patients experienced a deep infection involving the prosthesis. The purpose of the soft tissue reconstructive method utilized in this series was to permit wide tumor resection while providing reliable rates of wound healing. Orthopaedic oncologists in the 1970s advocated for reconstructive methods that, if unsuccessful, could be converted to an amputation level no higher than would have been necessary to achieve local control initially. Amputation rates after limb salvage procedures of the proximal tibia vary from 2.3% to 23.1%, although the level of amputation is not regularly reported. Five of 52 patients (9.6%) treated at our institution ultimately required an amputation, none of which were performed for wound-related issues. The only amputation performed at a level higher than would be needed at the time of initial presentation was in the single patient with regional thigh metastasis who underwent a hip disarticulation. All of the mechanical failures and complications related to infections or wound healing in this series were successfully revised, and all maintain successful limb salvage.

Our data suggest for patients with low-grade or benign disease with a normal life expectancy, reoperation or revision is likely to be necessary. Survival of contemporary modular implants exceeds the 15-year patient survival among those with high-grade localized disease (Fig. 5). This further encourages our continued use of cemented

endoprostheses for this patient population, even as survival rates improve [1, 30–32, 34, 42, 49, 50]. The main challenge in the future is to develop an effective porous ingrowth substrate to enhance soft tissue attachment to the prosthesis at the level of the tibial tubercle to further improve extensor mechanism repair.

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