

# SURVIVAL OF TOTAL KNEE REPLACEMENT WITH A MEGAPROSTHESIS AFTER BONE TUMOR RESECTION

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**Background:** The use of a megaprosthesis has become the method of choice for reconstruction after bone tumor resection at the knee. However, the long-term survival of megaprotheses is poor. In this study, we sought to identify factors that were associated with implant failure and amenable to interventions designed to improve implant survival.

**Methods:** A retrospective review of the charts of ninety-one patients who had undergone resection of a tumor of the knee followed by reconstruction with a custom-made megaprosthesis was performed. The distal part of the femur was resected in fifty-six patients and the proximal part of the tibia, in thirty-five patients. The reconstruction was performed with an allograft-prosthesis composite in thirty-three patients and with metal or plastic sleeves in fifty-eight patients. Reconstruction of the extensor mechanism was necessary in all thirty-five patients with a tibial tumor.

**Results:** The median duration of follow-up was sixty-two months. The extensor mechanism was significantly less likely to rupture when partial continuity had been preserved at the time of the resection. Intra-axial laxity (an arc of motion of  $>5^\circ$  in the frontal plane) was significantly more common when the prosthesis had an antirotation pin than when it did not have an antirotation pin ( $p = 0.0023$ ). There was mechanical failure of ten allograft-prosthesis composites and ten sleeve reconstructions. Thirty-six patients had removal of at least one component of the prosthesis. When revision due to local tumor recurrence was excluded, the median duration of prosthetic survival was 130 months following the distal femoral resections and 117 months following the proximal tibial resections. The median duration of survival was 117 months for the allograft-prosthesis composites and 138 months for the sleeve reconstructions. Body weight and activity level were independent predictors of early revision.

**Conclusions:** The long-term survival of the knee megaprotheses in this study was poor. Mechanical failure was multifactorial and the leading cause of revision. Use of allograft-prosthesis composites and use of bushings or an antirotation pin appeared to have no mechanical benefits. We recommend that weight control programs and advice about adapting their activity level be offered to patients preoperatively.

**Level of Evidence:** Prognostic Level II. See Instructions to Authors for a complete description of levels of evidence.

Reconstructive options after bone tumor resection at the knee include implantation of a custom-made total knee prosthesis, osteoarticular allografting<sup>1,2</sup>, use of an allograft-prosthesis composite<sup>3,4</sup>, arthrodesis with intercalary bone-grafting<sup>5,6</sup>, and rotationplasty<sup>7,8</sup>. However, implantation of a megaprosthesis has become the method of choice to restore function, control the malignant disease, and optimize patient satisfaction<sup>9-12</sup>. Long-term survival rates for megaprotheses have failed to reach those for primary total knee replacements, and mechanical failure remains a major problem<sup>11-23</sup>. Aseptic loosening, implant-related complications, and rup-

ture of the extensor mechanism are common, and early revision is often needed.

We conducted a retrospective study of ninety-one patients who underwent total knee replacement with a fully constrained, fixed-hinge megaprosthesis after resection of a malignant knee tumor. Our purpose was to identify factors that are independently associated with implant survival.

## Materials and Methods

From May 1972 to April 1994, ninety-one patients underwent resection of a malignant knee tumor followed by re-

construction with a GUEPAR custom-made megaprosthesis (Stryker, Benoist Girard, Herouville Saint Clair, France). All patients who are managed at our institution are included in a health-care program and are followed accordingly. Data were retrieved retrospectively from hospital records. The ethics committee gave approval for the study.

There were fifty-three male patients and thirty-eight female patients with a median age of twenty-seven years (range, twelve to seventy-eight years), a median body weight of 62 kg (range, 37 to 95 kg), and a median height of 172 cm (range, 147 to 194 cm) at the time of the index arthroplasty. The right limb was affected in thirty-eight patients. Before the onset of symptoms, twelve patients had a low activity level (unemployed, retired, or housebound); fifty-four, a moderate level (work involving some physical activity); and twenty-five, a high level (regular participation in sports).

The distal part of the femur was resected in fifty-six patients and the proximal part of the tibia, in thirty-five patients. The tumor involved the joint in three patients. The diagnosis was osteosarcoma in fifty-four patients, fibrosarcoma or malignant fibrous histiocytoma in thirteen, chondrosarcoma in nine, benign giant-cell tumor in eleven, Ewing sarcoma in two, and metastatic bone disease in two. Adjuvant chemotherapy was used in fifty-six patients and preoperative radiation therapy, in ten. Metastases were detectable in ten patients at the time of surgery. Preoperative data are summarized in Table I.

A chromium-cobalt, GUEPAR fully constrained, fixed-hinge prosthesis was implanted. We used the GUEPAR-I model, with a 12-mm axis, from 1972 to 1977, and thereafter we used either the GUEPAR-II model, which is characterized by wider and longer stems, or the GUEPAR-I model, depending on the bone geometry. The GUEPAR-II prosthesis was implanted in seventy-four patients. In 1980, polyethylene bushings and an antirotation pin were added to the hinge mechanism in an effort to decrease the high rates of wear. Bushings are articulating cylindrical components that fit around the axis between the femoral and tibial parts of the hinge. Antirotation pins are small lugs protruding from the extremity of the axis that fit into a hole in order to lock rotation of the axis during flexion and extension of the knee. The polyethylene bushings were replaced by metal bushings in 1984, and from 1989 onward bushings were no longer used. The use of antirotation pins was discontinued in 1992. In all, forty-eight prostheses had no bushings or antirotation pin, twenty-nine had both, and fourteen had an antirotation pin only. All prostheses were custom-made by the manufacturer on the basis of the preoperative radiographs.

An anteromedial approach was used in sixty-eight patients; an anterolateral approach, in twenty-two; and a combined approach, in one. The surgical technique involved resection of the tumor and reconstruction of the joint. The biopsy site was included with a 2-cm margin. The neurovascular bundle was exposed from the Hunter canal proximally to the proximal part of the tibia distally. The medial gastrocnemius and the medial hamstrings were detached to allow a wide exposure of the popliteal vessels and the sciatic nerve. The tumor resection was then carried out according to oncological prin-

ciples. The medullary canal was reamed to a diameter that was 2 mm larger than the planned stem diameter. A trial was done with the implant to control kinematics, length, and rotation (the tibial component was positioned in line with the tibial tuberosity). The cementing technique involved lavage, use of a cement restrictor, and pressurization of the cement. For reconstructions with an allograft-prosthesis composite, the prosthesis was cemented into the allograft on a back table and a second trial was done after polymerization of the cement was complete; the composite was fitted into the medullary canal, and if necessary the cuts were adjusted to match and maximize the contact surface between the host bone and the allograft. Finally, the composite was cemented into the host bone and care was taken to ensure that no cement was caught between the allograft and the host bone. The complete technique has been described elsewhere<sup>24</sup>.

For distal femoral tumors, the median resection length was 16 cm (range, 9 to 30 cm), the median total length of the femoral stem was 34 cm (range, 17 to 45 cm), and the median length of the portion of the femoral stem that was cemented into the host bone was 16 cm (range, 8 to 21 cm). For proximal tibial tumors, the median resection length was 13 cm (range, 9 to 20 cm), the median total length of the tibial stem was 30 cm (range, 20 to 38 cm), and the median length of the portion of the tibial stem that was cemented into the host bone was 15 cm (range, 10 to 21 cm). Tumor involvement of the joint was suspected in three patients with a femoral tumor, who underwent extracapsular en bloc resection of the joint. Diaphyseal-metaphyseal reconstruction was achieved with one of three methods: use of a metal sleeve (fifty patients [forty-nine femora and one tibia]), use of a massive irradiated structural allograft (thirty-three patients [seven femora and twenty-six tibiae]), and use of a Delrin (Stryker) or polyethylene sleeve (eight patients with a tibial tumor). The patella was resurfaced in fifty-eight patients and removed in three (as part of an extracapsular en bloc resection in two and as a result of an intraoperative patellar fracture in one). Cement fixation was used in all patients. The anterior tibialis artery was excised in four patients and the common peroneal nerve, in five. Excision of the popliteal vessels with bypass surgery was required in one patient. Table I shows preoperative and operative data.

Reconstruction of the extensor mechanism was required in all thirty-five patients who had a tibial tumor. However, partial continuity of the extensor mechanism was preserved by periosteal elevation in ten of those patients. Autogenous reconstruction was performed in twenty-eight patients, with use of a medial gastrocnemius flap (thirteen patients), fascia or pes anserinus tendon (ten patients), or both (five patients). The seven remaining patients underwent nonautogenous reconstruction: the extensor mechanism was attached to the bone allograft in three patients, to the tendon allograft in two, and to the plastic sleeve in two. The extensor mechanism was also reconstructed, with the sartorius and biceps femoris tendons, in two patients with a femoral tumor who were treated with en bloc joint resection.

The study end point was revision for reasons unrelated

TABLE I Preoperative and Operative Data\*

	Femur (N = 56)	Tibia (N = 35)
<b>Demographic</b>		
Gender (male)	34	19
Age† (yr)	13-20, 29, 51-78	12-18, 25, 50-74
Weight† (kg)	40-53, 63, 73-95	37-51, 61, 72-95
Height† (cm)	147-161, 172, 175-192	149-164, 170, 178-194
<b>Diagnosis</b>		
Side (right)	22	16
Joint involved	3	0
Metastasis	4	6
Neoadjuvant chemotherapy	31	25
Preop. radiation therapy	4	6
<b>Tumor type</b>		
Osteosarcoma	31	23
Chondrosarcoma	4	5
Fibrosarcoma	6	2
Malignant fibrous histiocytoma	4	1
Giant-cell tumor	9	2
Ewing sarcoma	2	0
Metastasis	0	2
<b>Treatment</b>		
Approach (medial)	42	26
Resection length† (cm)	9-15, 16, 20-30	9-12, 13, 15-20
Extensor mechanism reconstruction	2	35
Patella resurfaced	44	14
Patellectomy	3	0
Reconstruction	56	35
Metal sleeve	49	1
Allograft-prosthesis composite	7	26
Polyethylene/Delrin sleeve	0	8
Nerve injury	0	5
Vessels sacrificed	0	5
<b>Prosthesis</b>		
Type (GUEPAR II)	43	31
Trochlea	54	17
Femoral stem length† (cm)	17-31, 34, 35-45	—
Tibial stem length† (cm)	—	20-30, 30, 30-38
Length of portion of femoral stem cemented† (cm)	8-15, 16, 17-21	—
Length of portion of tibial stem cemented† (cm)	—	10-14, 15, 18-21
Bushings	18	11
Antirotation pin	23	20

\*The values are given as the number of patients, except where otherwise indicated. †The continuous variables are given as the minimum-first quartile, median, and third quartile-maximum.

to the tumor except when otherwise specified. For quantitative variables (continuous variables), we report the median, range, and first and third quartile values. Categorical variables are reported as counts. Tertiles, separating the group into three equal subgroups, were used to convert age, body weight, and resection length into categorical variables. Intra-axial

laxity was measured clinically with the knee in full extension and was defined as positive when the arc of motion was  $>5^\circ$  in the frontal plane. The level of activity was determined at the one-year postoperative evaluation; when a patient had been followed for less than one year, the activity level was classified as low. Differences between groups were analyzed

with use of the Wilcoxon rank-sum test for quantitative variables and the chi-square test, or the Fisher exact test when appropriate, for qualitative variables. Prosthetic survival was calculated with the Kaplan-Meier method and was compared between groups with use of the log-rank test; all patients were included in the analysis. Median survival time was derived with the 95% confidence interval. The Cox proportional hazards regression model was used to assess the effect (hazard ratio) on prosthetic survival of age, preoperative body weight, preoperative radiation therapy, adjuvant chemotherapy, resection length, tumor location, type of prosthesis, use of bushings or an antirotation pin, and use of an allograft sleeve. The proportional hazards assumptions were checked with use of time-varying coefficients. A multivariable analysis with a backward stepwise variable selection procedure, based on Akaike's information criterion<sup>25</sup>, was used to identify the set of independent predictors of prosthetic survival. All analyses were performed with R 1.9.1 (version 1.9.1; The R Foundation for Statistical Computing) and S-Plus 2000 (Mathsoft, Seattle, Washington) software packages. All tests were two-sided, with a significance level of 0.05.

## Results

### Follow-up

The median duration of follow-up was sixty-two months (range, 0.5 to 343 months). At the time of the last follow-up, sixty-eight patients (75%) were alive and disease-free. Of the twenty-three deaths, twenty were due to local recurrence or metastatic disease and three, to other causes. Eleven patients were followed for less than one year: five of them were lost to follow-up because they returned to their home country and attempts to contact them failed, five died, and one required revision surgery. At one year postoperatively, fourteen patients (18%) had a low activity level; fifty-nine (74%), a moderate level; and seven (9%), a high level. At the last evaluation, thirty-two patients (40%) had a low activity level; forty-five (56%), a moderate level; and three (4%), a high level. Fifty-three patients (66%) had returned to their previous level of activity by the time of the one-year evaluation and forty-three (54%) had done so by the time of the last follow-up.

Nine patients (10%) had postoperative complications, which included transient palsy of the common peroneal nerve (four patients), permanent palsy of the common peroneal nerve (six patients), ischemic necrosis of the anterior tibialis muscle requiring surgical excision (two patients), and hematoma requiring surgical drainage (two patients). Thus, four of the nine patients required surgery for complications. No postoperative deaths were related to the procedure.

Of the thirty-five patients with a tibial tumor, nine (26%) had failure of the reconstructed extensor mechanism. All of these failures occurred in patients without partial preservation of the extensor mechanism ( $p = 0.036$ ). Of the nine failures, four occurred after a gastrocnemius flap reconstruction and five, after another type of reconstruction ( $p = 0.70$ ). Only four of the nine patients required revision surgery. Severe patellofemoral mal-

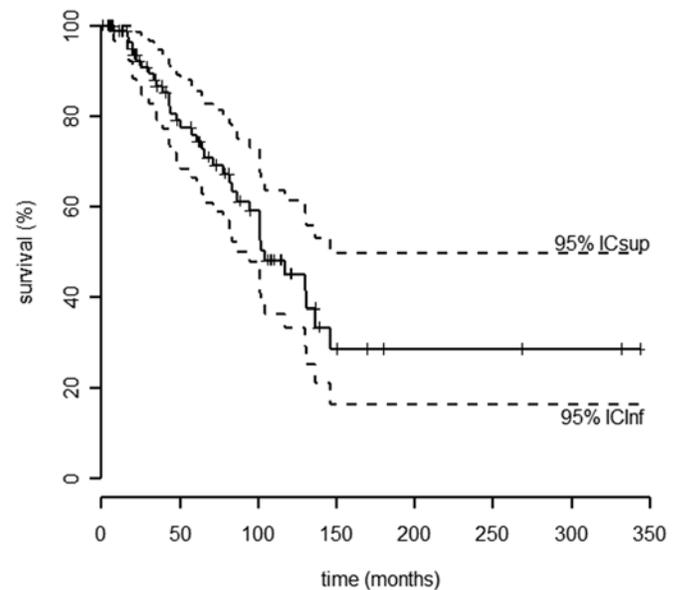


Fig. 1  
Overall prosthetic survival with revision for any reason as the end point. ICsup and ICInf = inferior and superior confidence limits.

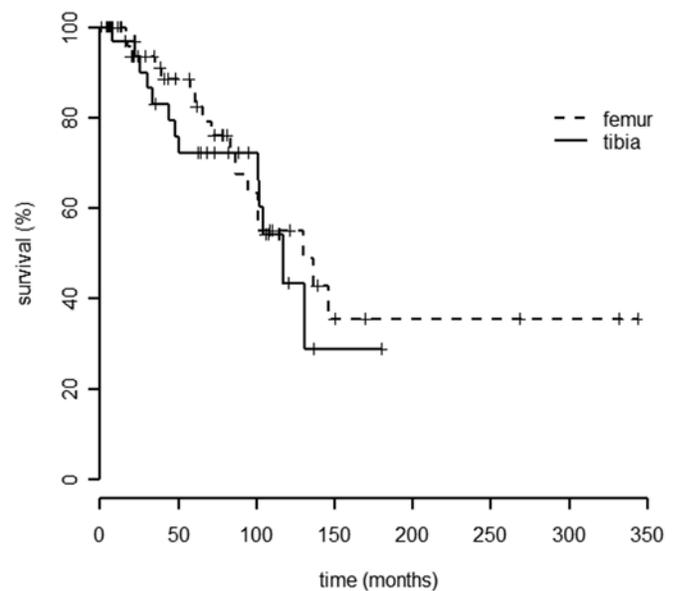


Fig. 2  
Survival of the femoral and tibial reconstructions, excluding revisions due to local tumor recurrence.

tracking requiring realignment occurred in two other patients.

Of the thirty-three allograft-prosthesis composites, ten (30%) failed. Nine of the failed composites were proximal tibial reconstructions, of which six required revision. Seven of the nine failures of a tibial reconstruction were due to fracture of the allograft, and two were due to resorption and aseptic loosening. One distal femoral reconstruction had signs of aseptic loosening without evidence of resorption, and revision was re-

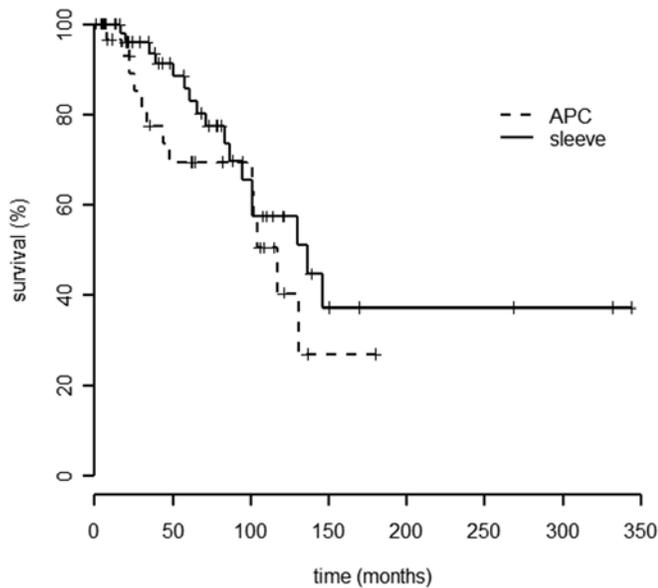


Fig. 3  
Survival of the allograft-prosthesis composites (APC) and the reconstructions with a metal or plastic sleeve, excluding revisions due to local tumor recurrence.

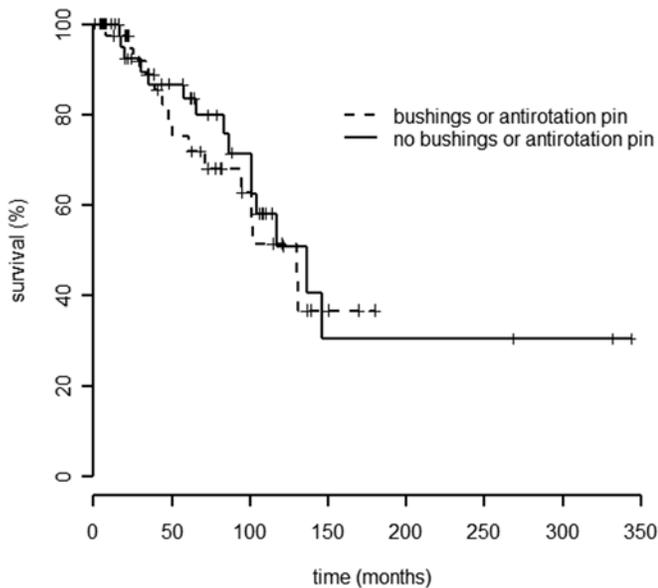


Fig. 4  
Survival of the prostheses with and without bushings and an antirotation pin, excluding revisions due to local tumor recurrence.

quired. Six allografts (three femoral and three tibial) had signs of partial resorption without evidence of mechanical failure. Six other patients (18%) required surgery because of infection, which resolved after repeated lavage (in two patients) or revision surgery (in four patients). Preservation of the allograft sleeve was not possible at the revision surgery. Twelve allografts (36%) showed radiographic evidence of incorporation into the recipient bone at the time of the last follow-up.

Of the fifty-eight reconstructions with a metal or plastic sleeve, ten (17%) showed evidence of aseptic loosening (including seven treated with revision) and seven (12%) required revision because of infection. Although mechanical failure was more common in the group treated with an allograft-prosthesis composite (ten of thirty-three) than in the group treated with the metal or plastic sleeve reconstruction (ten of fifty-eight), the difference was not significant with the number of patients analyzed ( $p = 0.19$ ).

Of the forty-eight patients treated without bushings or an antirotation pin, three had intra-axial laxity, eight had evidence of aseptic loosening at the time of the last follow-up, and six required revision surgery. Of the other forty-three patients, fourteen had intra-axial laxity, ten had evidence of aseptic loosening, and eight required revision surgery. Prostheses with an antirotation pin (with or without bushings) were significantly more likely to develop intra-axial laxity ( $p = 0.0023$ , odds ratio = 6.9). However, the use of bushings or an antirotation pin was not related to aseptic loosening, with the numbers available ( $p = 0.44$ ).

Eighteen prostheses (20%) had evidence of aseptic loosening at the time of the last follow-up. Of the fifty-six distal femoral reconstructions, ten failed: the femoral component was loose in eight patients, and the tibial component was loose in two. Of the thirty-five proximal tibial reconstructions, eight failed: the femoral component failed in one patient, and the tibial component failed in seven patients. The rate of aseptic loosening was not significantly different, with the numbers available, between the group treated with distal femoral reconstruction and that treated with proximal tibial reconstruction ( $p = 0.6$ ).

Four patients lost  $>5^\circ$  of passive extension, and thirteen patients had an extensor lag of  $>5^\circ$ . In two patients, the knee was fixed in extension at the time of the last follow-up for the purpose of this study: one of these patients had a chronic infection that subsequently required amputation, and the other had multiple tumor recurrences in the quadriceps muscle that required hip disarticulation. Two patients had an extensor lag of  $>30^\circ$ ; both had failure of the extensor mechanism reconstruction. One of these patients, who had a  $60^\circ$  extensor lag, had a recurrence of the tumor in the quadriceps muscle that subsequently required extensive excision; the other patient had a  $90^\circ$  extensor lag but refused additional surgery and used an orthosis to walk.

### Reoperations

In all, 104 repeat surgical procedures were performed in fifty-three (58%) of the ninety-one patients. Thirty-six patients had had at least one component removed at the time of the last follow-up (with implantation of a new component, arthrodesis, or amputation). Fifty-four repeat operations (54% of all of the repeat surgical procedures) in thirty-five patients were performed to treat mechanical complications. The components were left in place during thirty-one procedures, which included revision of the extensor mechanism (eight); arthrolysis or manual joint mobilization (nine); allograft re-

TABLE II Repeat Surgical Procedures

	Distal Femoral Tumors			Proximal Tibial Tumors			Total No. of Operations
	Operation*	Revision	Subtotal	Operation*	Revision	Subtotal	
Mechanical	11 (11)	15	26	20 (9)	8	28	54
Infectious	5 (4)	2	7	13 (6)	5	18	25
Tumoral	10 (6)	4	14	5 (3)	2	7	21
Total	26 (21)	21	47	38 (18)	15	53	100

\*The values are given as the number of procedures with the number of patients in parentheses.

placement (four); hinge axis replacement (six); and patellar realignment, diagnostic arthroscopy, curettage and packing of a periprosthetic cyst, and posterior tibialis tendon transfer for treatment of a common peroneal nerve palsy (one each).

One or both components of twenty-three prostheses (25%) were revised for mechanical reasons, which included aseptic loosening (eight femoral stems and six tibial stems), stem fracture (five femoral and one tibial), or axis-related complications (two with severe bushing wear and intra-axial laxity and one with a hinge fracture).

Twenty-five operations in thirteen patients were performed to treat infection. The rate of infection was not significantly different between patients who had received adjuvant treatment (irradiation or chemotherapy) and those who had not ( $p = 0.13$ ). Local tumor recurrence led to twenty-one operations in twelve patients. Amputation or disarticulation was required in six patients. Table II lists the repeat surgical procedures.

### Prosthetic Survival

With revision for any reason as the end point, the median duration of prosthetic survival was 105 months (95% confidence interval, 94.3 to 145.7 months) (Fig. 1). The life table for implant survival with the annual survival rates is presented in the Appendix. In the worst-case scenario, with all patients lost to follow-up classified as having had a failure, the median duration of prosthetic survival was 101 months (95% confidence interval, 83.6 to 145.7 months) in the series as a whole whereas it was 101 months (95% confidence interval, eighty-four months to infinity) following distal femoral resections and 105 months (95% confidence interval, eighty-two months to infinity) following proximal tibial resections (an insignificant difference,  $p = 0.74$ ). When we excluded the six patients who required revision because of local tumor recurrence, we found that the median duration of prosthetic survival was 130 months (95% confidence interval, 94.3 months to infinity) overall, whereas it was 130 months (95% confidence interval, 94.3 months to infinity) following distal femoral resections and 117 months (95% confidence interval, 101 months to infinity) following proximal tibial resections (an insignificant difference,  $p = 0.57$ ; Fig. 2). Overall, 80% and 52% of the prostheses were in place after five and ten years, respectively. After five years, the prosthetic survival rates were 85% following distal femoral resections and

72% following proximal tibial resections. The rates after ten years were 55% and 43%, respectively.

The median duration of prosthetic survival was 117 months (95% confidence interval, 101 months to infinity) following the allograft-prosthesis-composite reconstructions and 138 months (95% confidence interval, 101 months to infinity) following the reconstructions with a metal or polyethylene sleeve (an insignificant difference,  $p = 0.27$ ; Fig. 3). The median duration of survival of the prostheses with an antirotation pin (with or without bushings) was 130 months (95% confidence interval, 94.3 months to infinity) compared with 137 months (95% confidence interval, 101 months to infinity) for the other designs (Fig. 4). In the group with a proximal tibial resection, the median duration of prosthetic survival was 131 months (95% confidence interval, 101 months to infinity) following reconstructions with use of a gastrocnemius flap and 105 months (95% confidence interval, thirty-four months to infinity) following reconstructions with other methods.

Multivariate analysis identified only body weight ( $p = 0.028$ ; hazard ratio = 1.82; 95% confidence interval = 1.07 to 3.11) and level of activity ( $p = 0.042$ ; hazard ratio = 2.64; 95% confidence interval, 1.04 to 6.74) as independent predictors of early revision for mechanical reasons. Age ( $p = 0.77$ ), adjuvant chemotherapy ( $p = 0.97$ ), radiation therapy ( $p = 0.71$ ), resection length ( $p = 0.30$ ), prosthetic type (GUEPAR I or GUEPAR II,  $p = 0.94$ ), tumor location (distal femoral or proximal tibial,  $p = 0.23$ ), use of an allograft sleeve ( $p = 0.17$ ), and use of an antirotation pin or bushings ( $p = 0.72$ ) were not independent predictors of early revision for mechanical reasons and were excluded from the final model.

### Discussion

Improving prosthetic survival after resection of malignant tumors in the knee is a major goal of surgery. In earlier series ranging in size from thirty-two to 167 patients, prosthetic survival rates ranged from 57% to 93% after five years and from 50% to 88% after ten years<sup>11,13-22</sup>. Mechanical failure and infection were the main reasons for removal of the prosthesis.

We found that prosthetic survival was shorter (although not significantly so) after tibial reconstructions than it was after femoral reconstructions. Similar results have been reported by others. In a study of sixty-four megaprotheses, Wunder et al.<sup>13</sup> reported that the five-year prosthetic survival

rate was 90% after treatment of distal femoral tumors and 69% after treatment of proximal tibial tumors. Kawai et al.<sup>16</sup> found rates of 88% and 58% after twenty-five distal femoral and seven proximal tibial reconstructions, respectively. Reconstruction is technically more demanding after proximal tibial resection than it is after distal femoral resection. This may contribute to the shorter prosthetic survival time in patients treated for a proximal tibial tumor. Another factor may be the higher rate of infection: infection led to 33% of the revisions after the proximal tibial resections but only 10% of those after distal femoral resections in our study. These findings are consistent with those in previous studies ranging in size from thirty-two to sixty-four patients<sup>10,13,16</sup>.

Mechanical failure was the leading reason for revision in our series, with twenty-three (64%) of the thirty-six revisions performed for this reason. In earlier studies, ranging in size from thirteen to 135 patients, revision for mechanical reasons accounted for 42% to 89% of all revisions<sup>11,13,14,16-20,22,26-29</sup>. These variations may be due in part to differences in follow-up times and in reporting of rates. Increased implant loads, poor fixation into the host bone, and vulnerable prosthetic components (for example, hinges and bushings) influence the risk of mechanical failure as compared with that associated with unconstrained primary total knee replacement.

The rate of aseptic loosening was 20% (eighteen of ninety-one prostheses) in our patients and ranged from 2% to 22% in earlier studies ranging in size from thirteen to 133 patients<sup>11,13,14,16-19,26,28,30</sup>. Loosening has been ascribed to many factors, including poor-quality cement fixation in diaphyseal bone<sup>12,18,22</sup>, increased torque transmitted to the interfaces with fully constrained hinges<sup>15,17,19,21</sup>, increased torque associated with greater resection length<sup>12,19</sup>, abnormal peak stresses with loss of extension control<sup>9,16,18-20</sup>, poor shock absorption of weight-bearing axes<sup>11,16</sup>, and the greater physical activity of younger patients<sup>12,15</sup>. However, other investigators found that loosening had no relationship with cement fixation<sup>11,16,19</sup>, fully constrained hinges<sup>18</sup>, resection length<sup>15,16,18</sup>, or age<sup>10,16,18,19</sup>. These conflicting results may reflect the multifactorial nature of loosening and the limited statistical power of multivariate analyses of data from small populations. Therefore, suspected risk factors should receive attention with the goal of improving implant survival. Moreover, we found that body weight and the patient's level of activity predicted revision for mechanical reasons. The revision rate in patients who weighed >68 kg was 3.6 times higher than that in patients who weighed <57 kg. This finding indicates a need for weight control programs and patient education. A higher level of activity independently predicted early revision. Patients who engage in sports should receive information on the effects of high levels of activity and advice about adapting their activities in order to minimize loads through the knee.

Implant-related complications led to nine (39%) of the twenty-three revisions for mechanical problems. Stem fractures and hinge failures were seen with the first model of the prosthesis (GUEPAR I). However, improvements in design have addressed this issue successfully, and none of these complications

were seen with the GUEPAR-II prosthesis. The use of bushings or an antirotation pin was associated with intra-axial laxity but not with aseptic loosening. The bushings used in the GUEPAR models are smaller than those used with current megaprotheses, and this could explain their frequent deterioration.

A reconstruction of the extensor mechanism is one of the weak components of reconstruction following proximal tibial resection, and failure is common. The rates of secondary ruptures ranged from 4% to 15% in series ranging in size from nine to sixty-four patients<sup>13,15,16,18,27,31,32</sup>. There is general agreement that biologic reconstruction should be attempted<sup>127,32-35</sup> and that, when possible, the continuity of the extensor mechanism should be preserved by periosteal elevation, as this provides a reliable soft-tissue bed for reconstruction and decreases the risk of rupture.

Of the thirty-three patients who were treated with an allograft in our study, ten had mechanical failure and six had infection. Nine of the ten mechanical failures occurred in patients who had had a proximal tibial resection. Wunder et al.<sup>13</sup> reported a significantly higher failure rate with allograft-prosthesis composites than with megaprotheses (six of eleven compared with ten of sixty-four,  $p = 0.009$ ). However, a possible explanation for that higher rate is that separate intramedullary stems and plates were used to secure the graft to the host bone<sup>36</sup>. The use of cement, irradiated allografts, and chemotherapy has been reported to increase the failure rate<sup>36-40</sup>, and those factors may have played a role in our poor results. Restoration of bone stock in young patients is an attractive option, but preservation of grafts at revision is rarely feasible. We found no evidence of benefit from using tendon or bone allograft to reconstruct the extensor mechanism. Whether use of an allograft-prosthesis composite is superior to use of a metal or plastic sleeve for proximal tibial reconstruction is unclear. The number of early revisions for allograft failure may outweigh any possible long-term benefits. Controlled comparative studies of large numbers of patients with long durations of follow-up are needed to investigate this issue.

Infection remains a major concern after knee tumor surgery and is the second most common complication (after aseptic loosening), with reported rates ranging from 7% to 23% in series ranging in size from thirteen to 135 patients<sup>9,10,13,14,16-18,22,26,28,29,41</sup>. Plotz et al.<sup>11</sup> reported a fairly low infection rate (3%) but counted only deep infections in a series of sixty-four patients. Proximal tibial reconstruction is more likely to be followed by inadequate soft-tissue coverage and therefore is associated with a greater risk of infection than is distal femoral reconstruction<sup>10,14,18,28,41</sup>. Salvage of an infected joint is difficult, and amputation is often required<sup>9,10,14,16-18,28,29,41</sup>.

## Appendix

 A life table for implant survival with revision for any reason as the end point is available with the electronic versions of this article, on our web site at [jbjs.org](http://jbjs.org) (go to the article citation and click on "Supplementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ■

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