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Distal Femur Resection With Endoprosthetic Reconstruction

A Long-Term Followup Study

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The distal femur is a common site for primary and metastatic bone tumors and therefore, it is a frequent site in which limb-sparing surgery is done. Between 1980 and 1998, the authors treated 110 consecutive patients who had distal femur resection and endoprosthetic reconstruction. There were 61 males and 49 females who ranged in age from 10 to 80 years. Diagnoses included 99 malignant tumors of bone, nine benign-aggressive lesions, and two nonneoplastic conditions that had caused massive bone loss and articular surface destruction. Reconstruction was done with 73 modular prostheses, 27 custom-made prostheses, and 10 expandable prostheses. Twenty-six gastrocnemius flaps were used for soft tissue reconstruction. All patients were followed up for a minimum of 2 years. Function was estimated to be good or excellent in 94 patients (85.4%), moderate in nine patients (8.2%), and poor in seven patients (6.4%). Complications included six deep wound infections (5.4%), six aseptic loosenings (5.4%), six prosthetic polyethylene component failures (5.4%), and local recurrence in five of 93 patients (5.4%) who had a primary bone sarcoma. The limb salvage rate was 96%. Distal femur endoprosthetic reconstruction is a safe and reliable technique of functional limb sparing that provides good function and local tumor control in most patients.

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The distal femur is a common anatomic location for primary and metastatic bone tumors.[6,7] These tumors traditionally were treated with resection arthrodesis or amputation of the extremity, with unfavorable functional and psychologic outcomes.[9,27] Improved survival among patients with sarcomas made these drawbacks even more pronounced and stimulated the investigation of a less aggressive surgical approach. Simon et al[26] compared the results of limb-sparing resections with those of amputation in 227 patients who had an osteosarcoma of the distal femur. They concluded that doing a limb-sparing procedure in lieu of amputation did not shorten the disease-free interval or compromise the long-term survival of these patients.[26] Cosmesis and function, however, were much better, with preservation of knee motion and ability to ambulate.

The use of induction chemotherapy, coupled with advances in imaging and surgical techniques, now make it possible to do distal femur endoprosthetic reconstruction in 90% to 95% of patients with primary bone sarcoma of this site.[12,13,19,20,23,25,28] Grimer et al[11] showed that a limb-sparing resection with endoprosthetic reconstruction clearly is more cost-effective than amputation. The reason for this finding is that most patients with primary bone sarcoma are young and active. If treated by amputation, they probably will require a sophisticated artificial limb that has to be replaced at regular intervals, and may include the use of an artificial sport limb, swimming limb, and spare limb. In addition, most patients will have stump problems develop that will necessitate recasting of the socket.[11] Successful experience with distal femur endoprosthetic reconstruction led to its use in the treatment of metastatic bone tumors and nononcologic diagnoses.[1,18,29] Between 1980 and 1998, the authors did distal femur resection with endoprosthetic reconstructions in 110 consecutive patients. The current study was done at two oncology centers, using the same technique of resection and reconstruction. On the basis of this long-term experience, principles of distal femur resection with endoprosthetic reconstruction with emphasis on surgical anatomy, surgical technique, and functional and oncologic outcomes are presented.

MATERIALS AND METHODS

Between 1980 and 1998, 110 consecutive patients had distal femur resection with endoprosthetic reconstruction. Patients were treated at two institutions; all participating surgeons were trained together and used the same techniques of resection and reconstruction. There were 61 males and 49 females who ranged in age from 10 to 80 years (median, 21.5 years). Nineteen patients were younger than 12 years. Ninety-three patients had primary bone sarcomas, five patients had other primary malignant tumors of bone, and one patient had metastatic carcinoma to the distal femur. Nine patients had benign-aggressive lesions, and two patients had massive bone loss and destruction of the articular surface attributable to nonneoplastic diagnoses. Table 1 shows the histopathologic diagnoses and surgical classification of the patients in this series.[10]

Complete staging studies were done before surgery for all patients with primary bone sarcoma. Imaging studies included plain radiography, computed tomography (CT), and magnetic resonance imaging (MRI) of the entire thigh, knee, and leg. Particular attention was given to tumor extent through the distal femur, the anatomic location and extent of cortical breakthrough, and magnitude of soft tissue extension and its relation to the popliteal vessels. When posterior cortical breakthrough was present, angiography also was done to evaluate more accurately the patency of the popliteal vessels and their relation to the tumor.

Surgical Technique

Distal femur resection with endoprosthetic reconstruction has three steps: tumor resection, endoprosthetic reconstruction, and soft tissue reconstruction.[3,12,19] Each step is summarized.

Tumor Resection

The patient is placed in the supine position on the operating table, and a long medial incision is made. The incision begins in the midthigh, crosses the knee along the medial parapatellar area and distal to the tibial tubercle, and then slightly curves posterior to the pes muscles. The biopsy site is included, with a 2-cm margin in all directions. This incision enables wide exposure of the distal ½ of the femur, sartorial canal, knee, popliteal fossa, and proximal ½ of the tibia. Distal extension of the incision allows the use of a gastrocnemius flap, if necessary. The popliteal space is approached by detaching and retracting the medial hamstrings. This exposes the popliteal vessels and sciatic nerve.

The interval between the popliteal vessels and the posterior femur then is developed by ligation and transection of the geniculate vessels. The distal femur is approached via the interval between the rectus femoris and vastus medialis, leaving the intact vastus intermedius over the distal femur. A portion of the vastus medialis is left over the medial soft tissue extension of the tumor. Alternatively, a portion of the vastus lateralis is left over a lateral soft tissue extension. The joint capsule then is opened longitudinally along its anteromedial

TABLE 1. Histopathologic Diagnoses and Surgical Staging of 110 Patients Treated With Distal Femur Endoprosthetic Reconstruction

Histologic Diagnoses		Number of Patients	Enneking's Surgical Classification[10]				
			IA	*IB*	*IIA*	*IIB*	*IIB*
Primary bone sarcomas	Osteosarcoma	74	—	5	1	67	1
	Chondrosarcoma	5	—	1	—	4	—
	Malignant fibrous histiocytoma	5	—	—	2	3	—
	Ewing's sarcoma	4	—	—	—	4	—
	Pleomorphic sarcoma	2	—	—	—	2	—
	Primitive neuroectodermal tumor	1	—	—	—	1	—
	Synovial cell sarcoma	1	—	—	—	1	—
	Leiomyosarcoma of bone	1	—	—	—	1	—
Other primary malignant tumors of bone	Lymphoma of bone	4	NA	NA	NA	NA	NA
	Multiple myeloma	1	NA	NA	NA	NA	NA
Metastatic lesions	Malignant melanoma	1	NA	NA	NA	NA	NA
Benign-aggressive tumors	Giant-cell tumor	8	NA	NA	NA	NA	NA
	Synovial chondromatosis	1	NA	NA	NA	NA	NA
Nonneoplastic diagnoses	Osteoarthritis	1	NA	NA	NA	NA	NA
	Osteoporosis	1	NA	NA	NA	NA	NA
Total		110	—	6	3	83	—

NA = nonapplicable

border and ligaments and menisci are removed. Distal femur osteotomy is done at the appropriate location as determined by the preoperative imaging studies (Fig 1). In general, 3 to 4 cm beyond the point of proximal tumor extension is appropriate for primary sarcomas; 1 to 2 cm is sufficient for metastatic carcinomas. A tibial osteotomy then is done to allow the introduction of the prosthetic tibial component. It is done in the same manner as a standard knee arthroplasty; approximately 1 cm of bone is removed. The osteotomy is perpendicular to the long axis of the tibia.

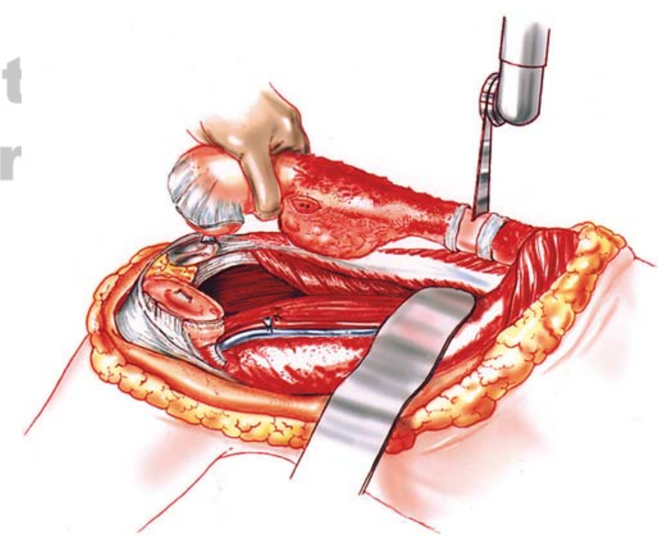

Fig 1. A distal femur osteotomy is shown. An intact layer of the vastus intermedius muscle is left over the specimen. Reprinted from Malawer M. Chapter 30 "Distal Femoral Resection with Endoprosthetic Reconstruction" In Malawer MM, Sugarbaker PH *Musculoskeletal Cancer Surgery: Treatment of Sarcomas and Allied Diseases.* Kluwer Academic Publishers Dordrecht 2001. Page 475

Endoprosthetic Reconstruction

Since their introduction in the mid1980s, modular prostheses were used preferably for reconstruction (Fig 2). Custom-made prostheses were used only in cases requiring unusual stem length or diameter. Expandable prostheses were used in patients younger than 12 years. The largest possible stem diameter was used. The canal was reamed 2 mm larger than the chosen stem diameter. Trial articulation initially was done; the device used for this step in the procedure includes a femoral stem, body, condyle components, axle and polyethylene bushings, and tibial bearing and plug components.

The definitive modular prosthesis then is assembled (Fig 3). Exact orientation of the prosthesis is essential. Based on the linea aspera and tibial tuberosity as the remaining anatomic guidelines, the femoral and tibial components are placed in line with both. The cementing technique involved pulsatile lavage, use of an intramedullary cement restrictor, reduction of the cement by centrifugation, use of cement gun, and pressurization of the cement. Patellar resurfacing is not done routinely because most patients who have this procedure are young and without significant degenerative changes in the patella.

Soft Tissue Reconstruction

Special attention is given to covering the prosthesis completely with muscle tissue. The remaining vastus medialis is sutured to the rectus femoris. The sarto-

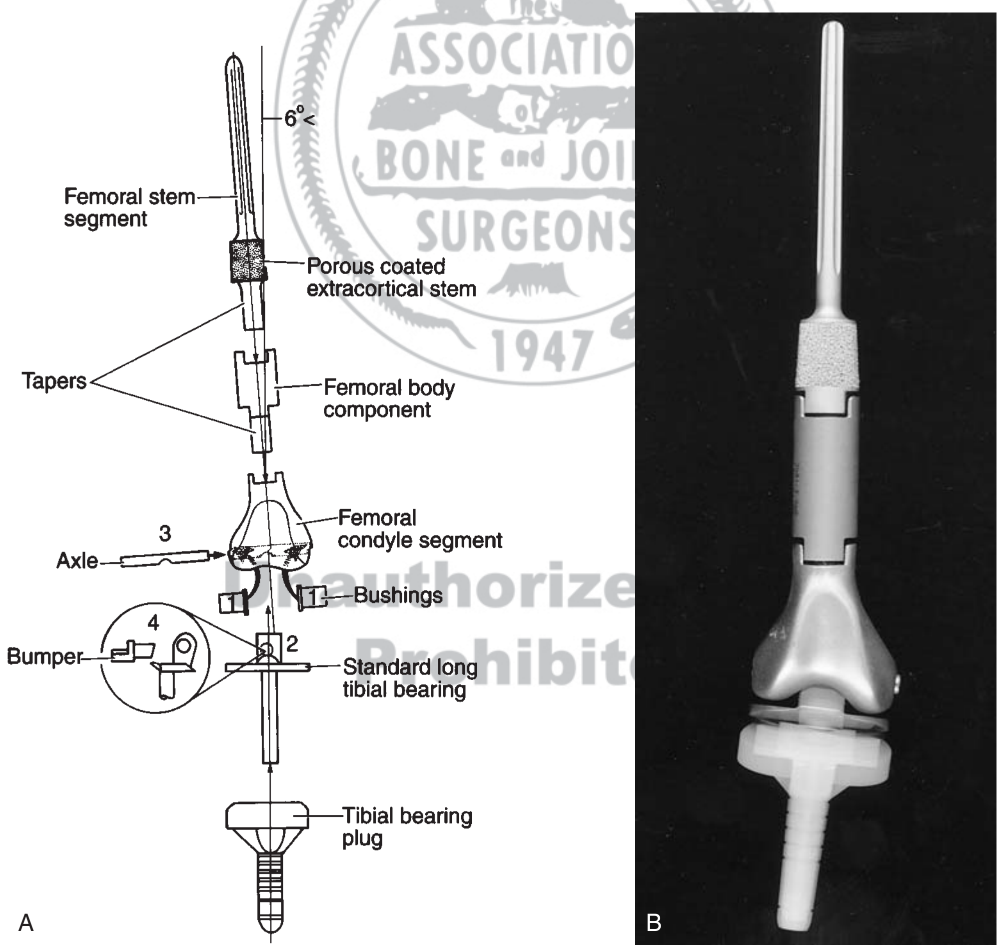

Fig 2. (A) Schematics (Reprinted from Malawer M. Chapter 30 "Distal Femoral Resection with Endoprosthetic Reconstruction" In Malawer MM, Sugarbaker PH *Musculoskeletal Cancer Surgery: Treatment of Sarcomas and Allied Diseases.* Kluwer Academic Publishers Dordrecht 2001. Page 479) and (B) an assembled modular, kinematic rotating-hinge distal femur prosthesis are shown (Howmedica, Rutherford, NJ).

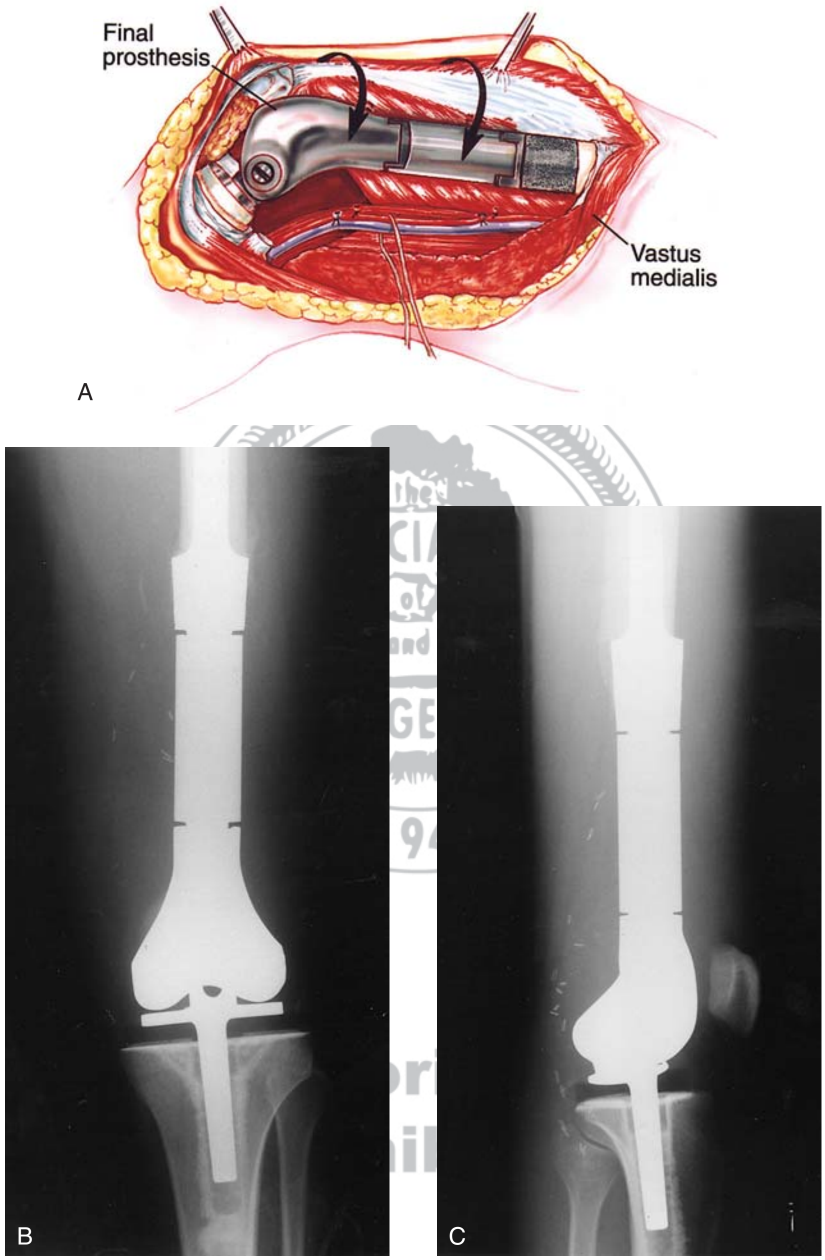

Fig 3A–C. (A) Installation of the definitive modular prosthesis is shown. Reprinted from Malawer M. Chapter 30 "Distal Femoral Resection with Endoprosthetic Reconstruction" In Malawer MM, Sugarbaker PH *Musculoskeletal Cancer Surgery: Treatment of Sarcomas and Allied Diseases.* Kluwer Academic Publishers Dordrecht 2001. Page 480 (B) Anteroposterior Reprinted from Malawer M. Chapter 30 "Distal Femoral Resection with Endoprosthetic Reconstruction" In Malawer MM, Sugarbaker PH *Musculoskeletal Cancer Surgery: Treatment of Sarcomas and Allied Diseases.* Kluwer Academic Publishers Dordrecht 2001. Page 467 and (C) lateral plain radiographs obtained at the 9-year followup show a modular endoprosthetic reconstruction of the distal femur after resection of an osteosarcoma (Howmedica, Rutherford, NJ).

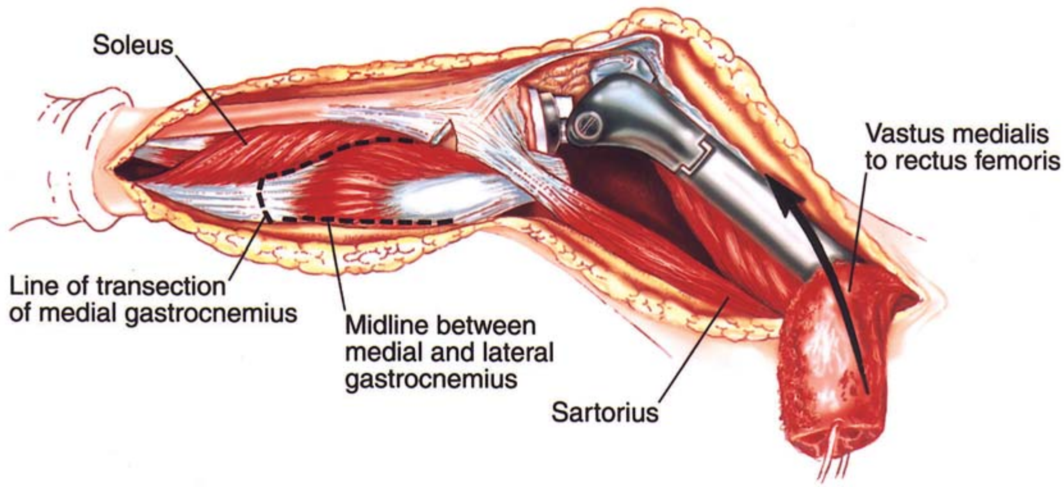

Fig 4. Soft tissue reconstruction with the remaining vastus medialis muscle and mobilization of the sartorius muscle is shown. Reprinted from Malawer M. Chapter 30 "Distal Femoral Resection with Endoprosthetic Reconstruction" In Malawer MM, Sugarbaker PH *Musculoskeletal Cancer Surgery: Treatment of Sarcomas and Allied Diseases.* Kluwer Academic Publishers Dordrecht 2001. Page 480

rius muscle can be mobilized and rotated anteriorly for additional closure of the remaining medial soft tissue defect (Fig 4). A large defect requires a medial gastrocnemius transfer (Fig 5).[21] Similarly, a lateral defect is closed with a lateral gastrocnemius transfer.

Postoperative Treatment

The lower extremity is elevated for 3 days, until the first postoperative wound check, to prevent wound edema. Continuous suction is required for 3 to 5 days, and prophylactic intravenous antibiotic therapy is continued until the drainage tubes are removed. Knee motion is restricted in an immobilizing brace for 2 to 3 weeks to allow healing of the surgical flaps and until the extensor mechanism is functional. During that time, isometric exercises are done and weightbearing is allowed.

All patients were followed up for a minimum of

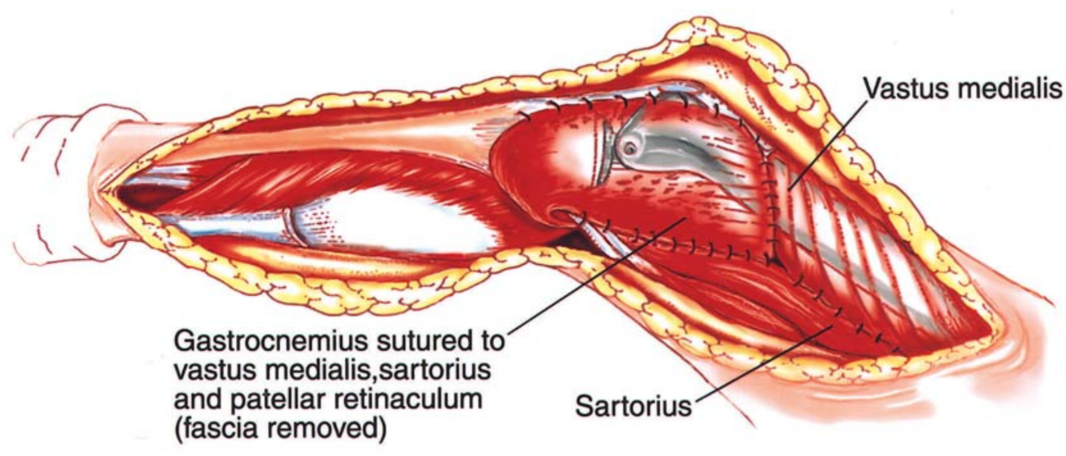

Fig 5. A medial gastrocnemius flap is used to close the remaining medial defect. Reprinted from Malawer M. Chapter 30 "Distal Femoral Resection with Endoprosthetic Reconstruction" In Malawer MM, Sugarbaker PH *Musculoskeletal Cancer Surgery: Treatment of Sarcomas and Allied Diseases.* Kluwer Academic Publishers Dordrecht 2001. Page 481

TABLE 2. Prosthesis Type and Followup of 110 Patients Treated With Distal Femur Endoprosthetic Reconstruction

	Followup		
Prosthesis Type	*2 to 5 Years*	*5 to 10 Years*	*More than 10 Years*
Custom	5	6	16
Modular	25	36	12
Expandable	2	6	2
Total (percent)	32 (29.1%)	48 (43.6%)	30 (27.3%)

2 years (range, 2–16.5 years; median, 7.8 years). Twelve patients were lost for followup after an average of 5.2 years (range, 3.5–8 years). Table 2 shows the followup of the patients in this series according to the prosthesis type. For the first 2 years after surgery, patients were evaluated every 3 months. On each visit, physical examination, plain radiographs, and chest CT scans were done. Patients were evaluated semiannually for an additional 3 years and annually thereafter. An orthopaedic oncologist analyzed the clinical records, imaging studies, and operative reports. The histopathologic diagnoses, techniques of endoprosthetic and soft tissue reconstruction, complications, and rates of local tumor recurrence and revisions were determined. Functional evaluation was based on direct patient examination by one of the authors and done according to the American Musculoskeletal Tumor Society System.[8] This system assigns numerical values of each of six categories: pain, function, emotional acceptance, supports, walking, and gait.[8] Prosthetic survival analysis was based on the Kaplan-Meier survival estimates and log rank and Breslow tests were used to evaluate statistical significances.[16] Results presented here are based on each patient's most recent followup.

RESULTS

One-hundred ten patients with lesions of the distal femur had distal femur resection and endoprosthetic reconstruction. Extraarticular resection of the knee was done in only two of these patients, both of whom had a primary bone sarcoma with tumor extension into the knee along the cruciate ligaments. Reconstruction devices included 73 modular prostheses, 27 custom-made prostheses, and 10 expandable prostheses. Only eight patients had a constrained knee mechanism; the remaining patients had reconstruction with a rotating-hinge knee mechanism. Twenty-one medial, three lateral, and one bilateral gastrocnemius flaps were used for soft tissue reconstruction. Ten patients with expandable prostheses had 14 expansions. The time to the first expansion ranged from 9 to 31 months and the average length of each expansion was 1.8 cm (range, 1–2 cm).

Function was estimated to be good or excellent in 94 patients (85.4%), moderate in nine patients (8.2%), and poor in seven patients (6.4%). Patients who had reconstruction with a rotating-hinge knee mechanism were more likely to have a good-to-excellent functional outcome (91%) than those who had reconstruction with a constrained knee mechanism (50%).

Complications included six deep wound infections (5.4%), which resulted in three amputations, two prosthetic revisions, and one wound debridement. Overall, there were 15 revision surgeries; these included replacement of a failed polyethylene component in six patients and prosthetic revision in nine patients (aseptic loosening, six; deep infection, two; radiation bone necrosis, one). Two of the polyethylene component failures occurred in the same patient; the first occurred 2.5 years after the initial surgery and the second occurred 3.8 years later. Polyethylene failures occurred after an average of 3.7 years (range, 1.25–7.25 years) and aseptic loosenings occurred after an average of 5.5 years (range, 3.2–10.3 years). During revision of their prostheses, all patients who were operated on because of a loosened prosthesis were found to have a concomitant failure of a polyethylene component.

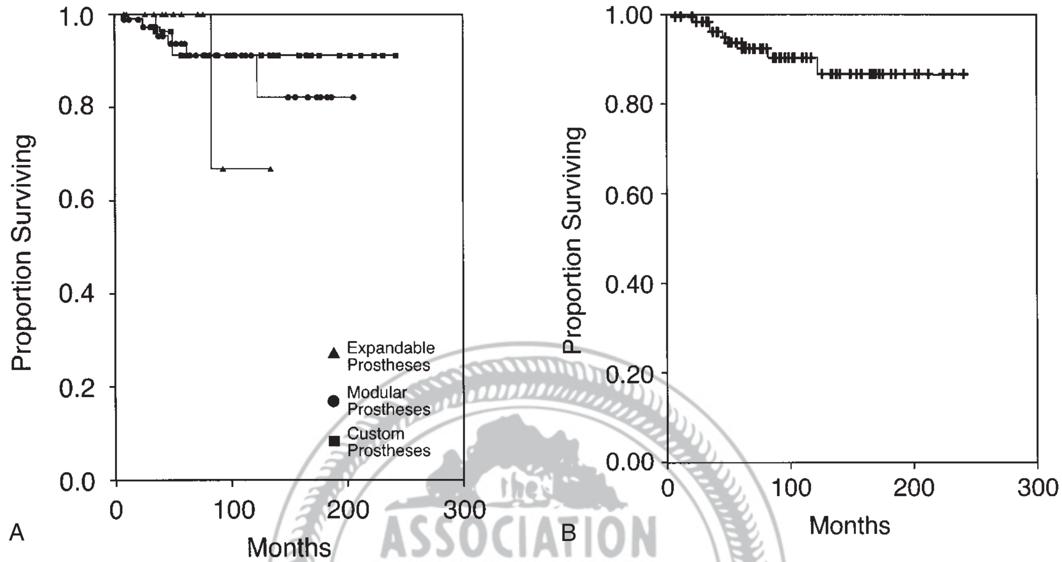

Fig 6. (A) Kaplan-Meier analysis was done of survivorship of custom, modular, and expandable distal femur prostheses, and (B) the survivorship of overall distal femur prostheses. The overall survivorship of prostheses was 93% at 5 years and 88% at 10 years; survivorships of custom, modular, and expendable prostheses were not significantly different.

The overall prosthetic survivorship was 93% at 5 years and 88% at 10 years; custom, modular, and expendable prosthetic survivorships were not significantly different (log rank, 0.83; Breslow, 0.94). Figure 6 shows the Kaplan-Meier prosthetic survivorship analysis and Table 3 shows the prosthesis type, functional outcome, and indications for prosthetic revisions.

Local recurrence developed in five of 93 patients with primary bone sarcomas (5.4%). Four patients were treated with wide local excision with preservation of the prosthesis and adjuvant radiation therapy. Amputation was done in the fifth patient. A fifth recurrence occurred in a patient with a giant cell tumor of bone. It occurred in the soft tissues and was treated with a wide local excision. Overall, there were four amputations. The limb salvage rate was 96%.

DISCUSSION

The purpose of this paper was to describe the functional and oncologic outcomes of distal femur endoprosthetic reconstruction. It is based on the authors' experience with 110 consecutive patients who had this procedure and had a long-term followup. Used in reconstructive surgery, cemented endoprosthetic reconstruction provides immediate stability and allows early mobilization and weightbearing.[19] Initially, custom-made prostheses were used. The preoperative design and manufacturing processes required 8 to 10 weeks; this caused a significant delay in the timing of resections. A second drawback of custom-made prostheses was the difficulty in determining the actual length and width of the resected bone on the basis of imaging modalities alone.[12,28] Introduced in mid1980s, modular prostheses revolutionized endoprosthetic reconstruction. This system enables the surgeon to measure the actual bone defect at the time of surgery and select the most appropriate components to use in reconstruction. Components of these interchangeable systems include articulating segments, bodies, and stems of varying lengths and diameters. A key design feature includes extensive porous coating on the extracortical portion of the prostheses for bone and soft

TABLE 3. Prosthesis Type, Functional Outcome, and Prosthetic Revision of 110 Patients Treated With Distal Femur Endoprosthetic Reconstruction

Prosthesis Type	Functional Outcome[8]			Indications for Prosthetic Revision			
	Good-to-Excellent	*Moderate*	*Poor*	*Aseptic Loosening*	*Polyethylene Failure*	*Deep Infection*	*Radiation Bone Necrosis*
Custom	19	5	3	2	4	1	—
Modular	66	4	3	3	2	1	1
Expandable	9	—	1	1	—	—	—
Total	94	9	7	6	6	2	1

tissue fixation.[12] Custom-made prostheses currently are used by the authors in cases requiring an unusual stem length or diameter.

A wide resection of a high-grade sarcoma of the distal femur necessitates en bloc removal of the surrounding cuff of muscles, joint capsule, and ligaments.[13,19] After this resection, joint stability is determined primarily by the mechanical properties of the prosthesis. The early devices entailed a constrained, hinged-knee mechanism that allowed only flexion and extension with no rotation capability. The constrained hinge mechanism was associated with high rates of mechanical failures because forces were not distributed appropriately around the knee; Inglis and Walker reported fracture around the prosthetic femoral stem as being the most common failure mechanism of constrained prostheses, occurring in 38% of their patients.[15] This was followed by infection (20%) and fracture around the prosthetic tibial stem (5%).[15] Capanna et al[3] reported 95 patients who had distal femur endoprosthetic reconstruction with a constrained hinge mechanism. They also reported an exceedingly high rate of prosthetic failure; 28 patients (29.5%) had failure of the polyethylene bushing and six patients (6.3%) had fracture of the prosthetic stem. Kawai et al[17] reported a similar experience. In their series of 40 patients, aseptic loosening occurred and required revision surgery in 11 patients (27.5%).[17] As a result, Roberts et al[23] who reported a 64% survival rate of hinged distal femur prostheses after 7 years, recommended that hinged mechanisms should not be used for revision of a failed knee prosthesis.

The use of the kinematic rotating-hinge knee mechanism (Howmedica, Rutherford, NJ) allowed external and internal rotations of the knee, in addition to flexion and extension. Because of its improved biomechanical properties, this design was associated with better function and was expected to achieve lower rates of loosening.[4,29] In 1993, Shih et al[24] compared the functional outcome of 45 patients who had a constrained distal femur endoprosthetic reconstruction with that of 16 patients who had reconstruction with a rotating-hinge prosthesis.

Good-to-excellent functional outcomes were achieved in 33% and 69%, respectively.[24] A modular, rotating-hinge, endoprosthetic reconstructive device was used in the majority of the patients in the current study and was associated with a better functional outcome than that of the constrained hinged-knee mechanism.

The presence of polyethylene components within the metal prosthetic knee mechanism allows a staged mechanical failure pattern, according to which polyethylene components fail first and doing so, may prevent additional loosening of the prosthesis. This assumption was supported by the findings of the current study, which showed that all patients who had a loose prosthesis had concomitant failure of a polyethylene component, and patients who had failure of a polyethylene component presented earlier than patients who had prosthetic loosening. This safety mechanism allows less extensive revision surgeries because, compared with revision of a loosened prosthesis, replacing a failed polyethylene component requires limited surgical exposure and is associated with a shorter rehabilitation period. Overall, six patients (5.4%) had their prosthesis revised because of aseptic loosening. This rate compares favorably with that of Unwin et al[28] who reported a survivorship analysis of 493 distal femur, custom-made, endoprosthetic replacements. They did revision surgery in 49 of their patients (9.9%) for aseptic loosening.[28] Wide excision of a primary bone sarcoma requires removal of proportionally significant amounts of bone and soft tissues. As a result, decreased muscle strength and range of motion and change in knee kinematics commonly occur.[2] However, if soft tissue coverage provided at surgery is sufficient, these patients may achieve good function.[14] Eighty-five percent of the current patients had good-to-excellent functional outcome. This rate is similar to the functional outcome reported by Benedetti et al[2] who did gait analysis on 16 patients who had distal femur endoprosthetic reconstruction and found that most patients had a good functional outcome. As recommended by Cowell and Curtiss,[5] the followup of patients in the current study is greater than 2 years, as that period is the minimum time required in reporting functional outcome in patients who have had a reconstructive surgical procedure.

The oncologic objective of distal femur resections is to achieve local tumor control. Patient survival will be determined by the presence of metastatic disease and its response to adjuvant treatment modalities. The rate of local recurrence is the most appropriate criterion with which to evaluate the oncologic adequacy of distal femur resection. Only five of the 93 (5.4%) patients in the current series who were treated for primary bone sarcomas had local recurrence of their disease. That rate is within the range expected after limb-sparing procedures.[22] Distal femur endoprosthetic reconstruction was shown to be a safe and reliable technique of reconstructing a large bony defect, providing good functional and oncologic outcomes in most patients. Although primarily used in the treatment of primary bone sarcomas, distal femur endoprosthetic reconstruction also can be used in the treatment of metastatic bone disease and nononcologic diagnoses.

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