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Reconstructing the Extensor Apparatus with a New Polyester Ligament

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We analyzed the clinical outcome of patients who had reconstruction of the extensor apparatus with a new polyester ligament after extensive resection of malignant tumors around the knee. Twenty-two patients were included; 19 were evaluated after a mean followup of 44 months (range, 8–67 months) to assess active and passive knee range of motion, walking ability, need for revision, and TESS and Enneking scores. The patients were divided into two groups; patients in Group A had a weakened extensor mechanism and patients in Group B had a completely dissected extensor mechanism. Seven patients had excellent knee function with an extension lag less than 5°. Five patients had an extension deficit less than 20°, three patients had a deficit less than 40°, and four patients could not extend their limb against gravity. However, all patients were able to walk without walking aids. They had a mean Enneking score of 83 points and a mean TESS score of 82 points. Patients who had distal femur resections had worse results than patients who had proximal tibia resections. The LARS® ligament proved promising for augmentation and complete reconstruction of the extensor apparatus of the knee after extensive tumor resection, with excellent and good results in 59% of patients.

Level of Evidence: Level II, prognostic study. See the Guidelines for Authors for a complete description of levels of evidence.

Limb salvage surgery is widely accepted as the preferred treatment for patients with primary malignant bone tumors.[26] The region around the knee is the most frequent location of osteosarcoma and other primary malignant bone tumors.[10] A prerequisite for survival is radical surgery, which implies wide tumor resection according to resection margins described by Enneking et al.[9] Intraarticular tumor extension or involvement of the cruciate ligaments close to the joint surface requires extraarticular resection to achieve adequate margins. This usually results in resection of at least part of the extensor mechanism.[18] Reconstructive measures include pedicled muscle transpositions,[1,3,19,20,25] fibula transposition,[21] or allografts.[7] Textile implants have been introduced for reconstruction of the extensor mechanism in conventional total knee arthroplasties (TKA).[2,11] Gosheger et al[12] introduced the Trevira® tube (implantcast GmbH, Buxtehude, Germany) as an artificial joint capsule and a new tool for reattaching soft tissue to the prosthesis.

Polyethelene terephthalate (Polyester®, Dacron® and Trevira® fibers) were used successfully for ACL repair in the ligament advancement reinforcement system implant (LARS®, Arc sur Tille, France).[17] We have used the LARS® implant since January 2000. It was designed as a band of 40-cm long and 6-cm wide fibers used for extensor mechanism reconstruction in patients who required augmentation of a transposed muscle or complete reconstruction of the resected extensor mechanism after tumor resection.[6] We retrospectively evaluated use of the LARS® ligament in tumor reconstructions around the knee, in which the extensor mechanism was deficient or completely absent. We evaluated: (1) active extension after augmentation or complete bridging of the extensor mechanism; (2) patients' ability to walk without aids; and (3) the safety of the procedure with respect to material failure and infection rate.

MATERIALS AND METHODS

From January 2000 to December 2002, 219 primary malignant tumors of the skeleton (in 906 patients treated in our tumor unit during this time) were operated on at our institution. Sixty-nine

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patients had tumors located around the knee. We evaluated 22 consecutive patients (14 males, eight females) with a mean age of 32 years (range, 8–75 years) who needed partial or complete resection of the extensor mechanism for oncologic radicality. All patients had a primary malignant tumor (Table 1). The diagnoses were verified by open biopsy. Neoadjuvant chemotherapy was performed according to the treatment protocols of the different tumors. The specimens were analyzed for tumor regression according to the grading system described by Delling et al.[5]

After preoperative staging including magnetic resonance imaging (MRI) of the adjacent bones for detection of skip metastasis, we performed a wide resection according to the principles described by Enneking et al.[9] The indication for a closed, extraarticular knee resection and an extensor mechanism resection were clinical or radiographic signs of tumor contamination of the knee from effusion at the time of tumor detection, any signs of intraarticular tumor invasion detected by MRI (Fig 1), or if any biopsy specimen was reported as intraarticular.

The tumor was located in the distal femur in 10 patients and the proximal tibia in 11 patients. One synovial sarcoma arose at the lateral meniscus. Depending on the biopsy site, we performed a lateral or medial approach (in distal femur resections) or an anterior tibial approach (in proximal tibia resections) by keeping wide resection margins. The entire knee was resected after carefully dissecting the neurovascular structures, either with the distal femur or the proximal tibia depending on the tumor location, with an intraosseous resection margin of at least 5 cm. In 12 patients, in whom soft tissue extension of the tumor was located dorsally, the patella was osteotomized extraarticularly and the tendon of the musculus rectus femoris was preserved (Group A = augmentation). These patients had augmentation with the LARS® ligament for their weakened extensor mechanism. In three patients, the LARS® reconstruction was performed during the primary intervention. In seven patients, the extensor reconstruction was performed secondarily; three after aseptic prosthetic revision, two after septic revision, one with an additional soft tissue flap, and one after multiple elongation procedures of a growing prosthesis.

Extraarticular resection was performed in 10 patients (six patients with the tumor located in the distal femur, three patients with the tumor located in the proximal tibia, and one patient with an intraarticular synovial sarcoma). The complete extensor mechanism including the complete distal part of the quadriceps, the patella, and patellar ligament were resected (Group B = segmental replacement) (Fig 2).

After proximal tibia resection, four patients had a primary extensor reconstruction. Implantation of the LARS® band was done during a second operation for conversion of a primary arthrodesis in three patients, with additional flap coverage in two patients, during aseptic prosthesis revision in one patient, during elongation of a growing prosthesis in one patient, and during revision for infection in one patient.

The LARS® ligament is a CE (Consultants Europe)-approved (CE 0459) nonresorbable polyester band. It has been used for years in ACL repair[17] and rotator cuff and Achilles tendon reconstruction. It consists of 90 nonwoven longitudinal polyester fibers connected on a molecular level. The knitting process is different than that of the Trevira® tube[12] or the Dacron® Leeds–Kaio[11] band, which results in different stiffness and macroscopic appearance. Histologically, the polyester ligament shows a high potential of ingrowth into connective tissue, and formation of capillaries surrounding the polyester filaments[24] (Fig 3). Formation of granulomas or polyester wear particles has not been observed. Its elongation rate is less than 7% of its original length after 10 million cycles.[23] The minimal load to failure was 4000 N. We used a custom-engineered band 6 cm wide and 40 cm long.

The indications for using the LARS® band were complete defect of the muscle and/or tendon of the extensor apparatus after tumor resection, or thinning of the quadriceps tendon greater than 50% by splitting the rectus tendon from the intermedius tendon, which could not be reconstructed sufficiently by local measures without harvesting tissue from locations distant to the surgical approach for tumor resection (eg, fascia lata or free muscle flaps). The LARS® ligament was attached to the remaining quadriceps stump with nonresorbable sutures (Fig 4). The ligament was attached to the tibial tuberosity by transosseous sutures. In patients having a proximal tibia resection, the LARS® ligament was sutured to the quadriceps tendon with nonresorbable sutures, fixed to the prosthesis body at the level of the tibial tuberosity, and attached distally to the tibial bone by transosseous sutures at the level of bone anchorage of the prosthesis. Additionally, a medial gastrocnemius muscle flap was positioned on top of the artificial ligament reconstruction to provide good soft tissue coverage.

The joint and segmental bone reconstruction was performed using the HMRS® tumor endoprosthesis[16,22] (Stryker Orthopaedics, Mahwah, NJ) (Fig 5). Postoperative mobilization was performed according to the stability of the prosthetic fixation and the intraoperative stability of the soft tissue reconstruction. Restricted weightbearing for 6 weeks was required in patients who had the extensor repair performed simultaneously with the prosthetic implantation (seven patients at the time of tumor resection and three patients with conversion from a previous knee arthrodesis). Patients who had a stable implant at the time of extensor reconstruction were mobilized partial weightbearing with two crutches for 6 weeks. Knee ROM was restricted from 0° to 30° by a DonJoy brace (DonJoy Orthopedics Inc, Vista, CA), and daily passive physiotherapy or continuous passive motion was applied to prevent scar tissue formation at the subcutaneous tissue and LARS® prosthesis interface. The brace was then opened stepwise until 90° flexion within 3 months postoperatively. The patients were seen every 3 months for oncologic and radiographic followups. The mean duration of followup was 44 months (range, 8–67 months) after implanting the LARS® ligament. At the last followup three patients had died, one of whom had an amputation for a local recurrence. We analyzed the functional outcome of the remaining 19 patients using TESS[4] and Enneking et al[8] scores.

Range of motion was evaluated clinically with a goniometer by one of the coauthors (SM) who was not involved in the surgery. Active ROM was measured against gravity with no additional weight. The active extension lag was measured after lifting the leg from a laying position as the degrees lacking to

TABLE 1. Demographic Data

Patient Number	Gender	Age (years)	Diagnosis	Localization	Lars Band Implantation Group A or B Primary/Secondary	ROM Passive (degrees)	ROM Active (degrees)	Tess Score	Enneking Score	Active Extension	Followup (months)
1	M	33	Chondrosarcoma	DF	A, secondary	0-0-100	0-5-100	92	83	Excellent	56
2	M	25	Osteosarcoma	DF	A, secondary	0-0-90	0-10-90	90	86	Good	44
3*	F	21	Osteosarcoma	DF	B, primary	0-0-100	0-10-100	92	93	Good	67
4	F	14	Osteosarcoma	DF	A, secondary	0-0-110	0-70-110	90	90	Poor	38
5*	M	26	Chondrosarcoma	DF	B, secondary	0-0-100	0-30-100	90	83	Fair	32
6*	M	43	Leiomyosarcoma	DF	B, primary	0-0-90	0-15-90	90	86	Good	29
7	M	75	Chondrosarcoma	DF	A, secondary	0-0-95	0-80-95	76	76	Poor	39
8*	M	15	Osteosarcoma	DF	B, secondary						Died, 30
9*	M	21	Osteosarcoma	DF	B, secondary						Died, 8
10*	F	41	Osteosarcoma	DF	B, primary						Died, 48
11*	M	43	Synovial sarcoma	TKA	B, primary	0-0-60	0-0-60	43	67	Excellent	50
12	F	18	Osteosarcoma	PT	A, secondary	0-0-100	0-0-100	100	89	Excellent	54
13	M	16	Osteosarcoma	PT	A, secondary	0-0-90	0-0-90	90	87	Excellent	44
14	M	8	Osteosarcoma	PT	A, primary	0-10-85	0-10-85	90	89	Good	56
15	F	14	Osteosarcoma	PT	A, primary	0-0-100	0-5-100	80	78	Excellent	61
16	M	16	Osteosarcoma	PT	A, secondary	0-0-90	0-15-90	71	69	Good	45
17	F	22	Osteosarcoma	PT	A, secondary	0-0-120	0-30-120	90	92	Fair	46
18	M	43	Malignant fibrous histiocytoma	PT	A, secondary	0-0-100	0-90-100	66	73	Poor	43
19*	F	19	Osteosarcoma	PT	A, secondary	0-0-100	0-30-100	84	76	Fair	61
20*	M	34	Osteosarcoma	PT	B, primary	0-0-95	0-5-95	79	83	Excellent	41
21	F	19	Osteosarcoma	PT	A, secondary	0-0-95	0-5-95	83	75	Excellent	42
22*	M	23	Osteosarcoma	PT	B, secondary	0-0-100	0-90-100	86	80	Poor	33

*Had extraarticular resection; DF = distal femur; PT = proximal tibia; TKA = total knee arthroplasty; Group A – augmention; Group B – segmental replacement

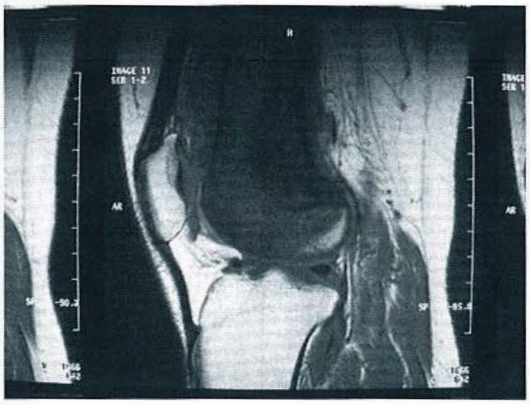

Fig 1. An MR image of the distal femur shows the tumor extension close to the intraarticular joint space.

complete extension. Complete blinding of the observer was not possible because the extent of resection was clinically obvious by the appearance of the patella or its absence.

To determine if the LARS® ligament resulted in a higher prevalence of infection, we compared the study patients with a control group of a previous series of 28 patients who also had large extraarticular resections around the knee and poor soft tissue coverage without LARS® ligament reconstruction. The group was identified according to their tumor localization and prosthetic reconstruction. The group consisted of 19 male and nine female patients with a mean age of 35 years (range, 7–65 years) operated on before we began using the LARS® ligament. The tumor was located in the distal femur in 16 patients and the proximal tibia in 12 patients. All patients had reconstruction using HMRS® tumor endoprostheses. Soft tissue reconstruction consisted of gastrocnemius or sartorius flaps without artificial textile implants. Six patients had revision surgery for deep infections (21%). We compared their infection rate with the rate of our study group using a Student's t test.

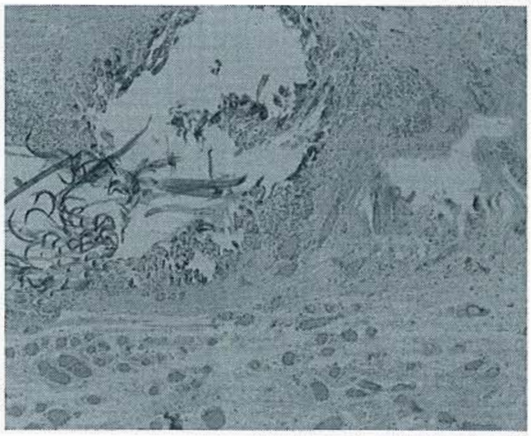

Fig 3. An histologic specimen shows scar tissue surrounding a LARS® ligament (Stain, hematoxylin and eosin; original magnification, ×100).

RESULTS

Nineteen patients could be evaluated functionally at the last followup. Active extension was excellent in seven patients, with an extension deficit less than 5°. Five of these patients were in Group A (augmentation) and two were in Group B (segmental replacement). Only one of the patients had a distal femur resection; the others had proximal tibia resections and one had an intraarticular knee tumor. Good active function was obvious in five patients, with an extension deficit less then 20°. Three of the patients were in Group A and had distal femur resections and two were in Group B and had proximal tibia resections.

Three patients had fair extension with a deficit less than 40°. One of these patients was in Group A and had a distal

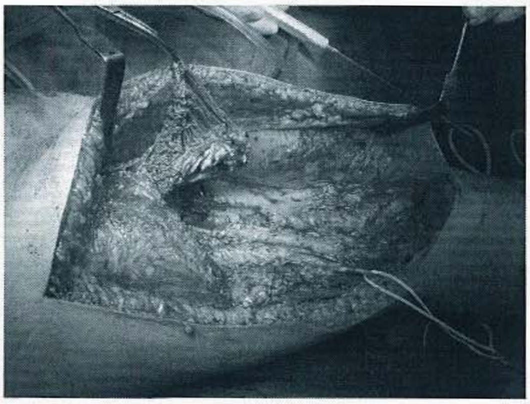

Fig 2. A photograph shows extraarticular tumor resection with complete resection of the extensor apparatus.

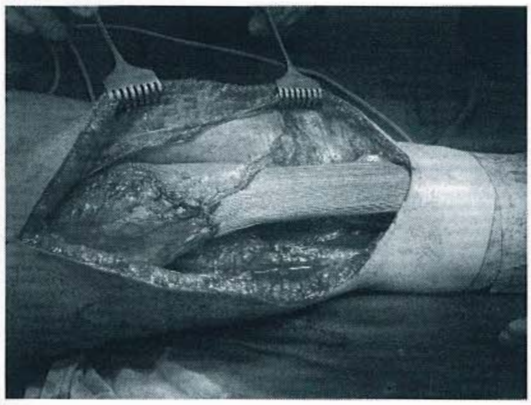

Fig 4. A photograph shows reconstruction of the remaining quadriceps muscle with the LARS® ligament.

Fig 5. A photograph shows reconstruction of the distal femur using an HMRS® fixed hinge prosthesis.

femur resection. Two were in Group B and had proximal tibial resections. Four patients had poor functional results with an active extension lag greater than 40°. Three were in Group A and one was in Group B. Two of these patients had a proximal tibia reconstruction and the other two patients had a distal femur reconstruction.

All patients were able to walk without crutches or any walking aids after a rehabilitation period of 3 to 6 months. The remaining quadriceps strength was sufficient for stabilization of the knee even in patients who had poor active extension against gravity (Table 1).

Comparing the results after distal femur resection and proximal tibia resection in our patients, only one patient had an excellent result after distal femur resection, and six patients had excellent results after proximal tibia or total knee resection. The rate of extraarticular resections was greater in the group of patients who had distal femur resections (60% versus 27%).

The mean TESS score was 81.8 points (range, 67–93 points), and the mean Enneking score was 83.3 points (range, 43–100 points).

At the last followup, all implants were in situ without any signs of loosening. Ligament failure occurred in five patients. The ligament attached to the tibia ruptured in three after trauma (falling accidents). One rupture occurred during physiotherapy 4 weeks after implantation at the junction of the ligament to the patella. One fatigue rupture of the ligament occurred on a sharp edge of the femoral articulation piece of the prosthesis. Four patients had revision surgery and an additional LARS® ligament was implanted.

Endoprosthetic infection was treated successfully treated by surgical débridement, one-stage explantation, and reimplantation of the prostheses and suction. Irrigation was performed in two patients, and a two-stage procedure with an antibiotic-loaded cement spacer was done in two patients before extensor reconstruction. Two patients had recurrent infections with the LARS® ligament. Two patients had revision surgery for infections after primary LARS® ligament reconstruction, which represents a total infection rate with the artificial ligament of 18% four of 22 patients (18%) versus six of 28 patients (21%) in the control group.

DISCUSSION

In limb salvage surgery of malignant tumors around the knee, different techniques have been presented to augment or reconstruct the extensor apparatus. In intraarticular proximal tibia resections, a good reconstruction option after implanting a tumor endoprosthesis consists of attaching the patella ligament to the anteriorly transposed fibula[15] and covering the prosthesis with a medial gastrocnemius flap.[19] Favorable to excellent results have been reported using this technique.[21] Petschnig et al presented an analysis of different reconstruction techniques in 17 patients with TKAs after resections of malignant tumors around the knee by fibula transposition, gastrocnemius transfer, and the combination of both techniques.[21] The best results were achieved using a combined technique of fibula transposition and muscle transfer, with a mean extension lag of 2° (range, 0°–5°).[21] Reconstruction with fibula transfer alone revealed slightly worse results; the largest deficit in extension was observed with the gastrocnemius transfer alone. Other authors reported unfavorable results using transfer of the knee flexors.[20] Emerson et al[7] investigated the results of extensor mechanism reconstruction with allografts after TKAs in 15 patients. The allograft consisted of the tibial tubercle, patellar tendon, and patella with quadriceps tendon.[7] Six patients had no extension lag and three patients had an extension deficit of 20° to 40°.[7] The authors reported the ideal candidate for this technique was an elderly patient with limited or low demand on the knee.[7] They reported four graft failures, one of which fractured after revision of the patella.[7]

The use of artificial ligaments for extensor tendon reconstruction in conventional TKAs with the Leeds-Keio ligament was reported by Fujikawa et al.[11] The authors reported satisfying results (mean ROM, 146°). For reconstruction of muscle attachment and extensor repair in megaprostheses in tumor surgery, Gosheger et al introduced a Trevira® tube as part of the Modular Tumor and Revision System (Mutars®, Implantcast GmbH, Buxtehude, Germany).[12] Their main indication was reconstruction of the joint capsule and muscle reattachment to prevent dislocation in 33 proximal femur resections, five total femur resections, and 16 proximal humerus reconstructions.[12] For proximal tibia resections, total knee resecons, or distal femur resections, the Trevira® tube was sed for reattachment of muscle flaps and extensor appa-atus to the prosthesis.

We used the LARS® polyester band to bridge the soft issue defect in distal femur resections (Fig 4) or to aug-nent biologic muscle transfer reconstructions (eg, sarto-ius muscle transfer to allow early mobilization of the :nee). In proximal tibia resections, the artificial band was ısed to reattach part of the extensor apparatus to the pros-hesis. When repairing the extensor mechanism the liga-nent requires a minimal elongation rate[12] that can be ıchieved by a special nonwoven technique.

Although our small number of patients did not allow ;tatistical comparison between the groups of patients who ıad augmentation versus segmental replacement, or distal ·emur reconstruction versus proximal tibia reconstruction, nost of the excellent functional results occurred after proximal tibia reconstruction with LARS® augmentation. Patients who had distal femur resections did worse, espe-cially in the segmental group.

There was no difference between ROM. The main rea-son for restricted flexion was scar tissue formation be-tween the LARS® ligament and the prosthesis or the sub-cutaneous tissue. Early passive mobilization was crucial in achieving good functional results. This required good pri-mary stability of the soft tissue and LARS® reconstruction. A prerequisite for early postoperative mobilization is pas-sive intraoperative flexion as much as 90°, which should be possible without damaging the sutures.

Infections and wound-healing disturbances in patients who need additional chemotherapy or radiation therapy are the primary cause of failure requiring prosthetic revision.[14] In our cohort, four patients had revision surgery for infec-tions before LARS® ligament implantation. Grimer et al reported high infection rates with proximal tibia recon-struction[13] because of poor soft tissue coverage. We rou-tinely used a medial gastrocnemius flap to improve soft tissue coverage in patients having proximal tibia resection. The use of artificial ligaments did not increase the risk of infection.[2,3,20] Fujikawa et al[11] did not report any wound infections using Leeds-Keio ligament implantation after conventional TKAs. Gosheger et al[12] reported increased infection rates after implanting megaprostheses and exten-sor apparatus repair with the Trevira® ligament. The slightly higher infection rate in our patient group com-pared with the rate reported by Gosheger et al[12] may be explained by their high number of proximal femur recon-structions, which have better soft tissue coverage than ex-tensive resections around the knee. There were no differ-ences between our patients with or without artificial liga-ment reconstruction. Good soft tissue coverage of the prosthesis is important in preventing infection.

The LARS® ligament was an effective and safe textile implant for augmentation or complete segmental recon-struction of the extensor apparatus of the knee after ex-tensive tumor resection in limb salvage surgery. Excellent and good functional results were obtained in 59% of pa-tients and resulted in patients walking without any aids even after complete dissection of the knee and its soft tissue.

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