Knee Reconstruction With Prosthesis and Muscle Flap After Total Arthrectomy

Philippe Anract, MD*; Gilles Missenard, MD**; Cécile Jeanrot, MD*; Vincent Dubois, MD*; and Bernard Tomeno, MD*

A massive prosthesis and medial gastrocnemius muscle transfer were used to reconstruct the knee after extracapsular en bloc excision for bone sarcoma. Magnetic resonance images showed intraarticular involvement. This technique was used in nine patients, six men and three women aged 18 to 51 years, with primary malignant bone tumors of the knee. Extraarticular resection of the knee, including the patella, was done in every case. A knee prosthesis was implanted, and the extensor mechanism was reconstructed by transfer of the medial gastrocnemius muscle and pes anserinus tendons. All resections had negative margins. There were no local recurrences, but metastases occurred in two patients. Infection was the only major complication and was seen in two patients. The mean postoperative Musculoskeletal Tumor Society score was 61% (range, 36%–100%). The mean postoperative range of flexion was 62° (range, 30°–90°), and the mean extensor lag was 12° (range, 0°–40°). Three patients required a crutch to walk. The functional outcome was poor in the two patients whose proximal tibia was removed with the joint, suggesting that arthrodesis may be best in this situation. In properly selected patients, prosthesis and muscle flap reconstruction provides acceptable function and a good cosmetic result.

The options for reconstruction after resection of a bone tumor of the knee include implantation of a custom made total knee prosthesis, osteoarticular allograft, allograft-prosthesis composite, arthrodesis with intercalary bone grafting, and conversion to a rotationplasty.1, 2,6,7,10,12,13,17

Because the extensor mechanism is extremely difficult to reconstruct, arthrodesis usually is done after total en bloc arthrectomy for articular involvement.1,13 Although massive prosthesis reconstruction has been used in this situation,1,3,11 the technique involves splitting the patella and the patellar and crural tendons in the coronal plane, a procedure that carries a risk of contamination of the resection; in particular, contamination of the upper patella can occur via adhesions between the crural tendon fibers and the synovium. Removal of the entire patella and its tendons with the rest of the joint decreases the risk of contamination. An original technique is described that uses a fully constrained megaprosthesi...
MATERIALS AND METHODS

Between 1992 and 1997, nine patients underwent fully constrained prosthesis and muscle transfer re- construction of the knee after total en bloc arthrectomy for primary bone or intraarticular sarcoma. Magnetic resonance imaging (MRI) scans showed intraarticular involvement. The six men and three women ranged in age from 18 to 51 years (mean, 36 years). Intraarticular effusion or stiffness was present in all patients. Plain radiography, MRI of the knee, computed tomography of the chest, and bone scintigraphy were done routinely to evaluate tumor spread. Patients with skip metastases or remote metastases were excluded from the study.

Plain radiographs and MRI scans were obtained in all nine patients. Location of the tumor as assessed on plain radiographs was the distal femur in six patients, the proximal tibia in two patients, and the Hoffa fat pad in one patient. Magnetic resonance images showed extension of the tumor to the articular synovial membrane via the trochlea (n = 5), medial collateral ligament (n = 1), or cruciate ligaments (n = 2).

A biopsy was done before resection in all patients. The histologic diagnoses were conventional osteosarcoma (n = 5), fibrosarcoma (n = 1), hemangiopericytoma (n = 1), angiosarcoma (n = 1), and clear cell sarcoma of the Hoffa fat pad (n = 1). Neoadjuvant chemotherapy was given to all nine patients.

Extracapsular en bloc excision of the joint was done. The resection included any tumor in the distal femur (n = 6) or proximal tibia (n = 2). The length of resected bone ranged from 10 to 15 cm (mean, 11 cm) and usually was shorter for the tibia than for the femur. Histologic examination of the operative specimen confirmed that the tumor had spread to the joint in seven of the nine patients (Fig 1). In all nine cases, the resection margins were free of tumor. All nine procedures were done by two of the authors (PA and GM).

Mean followup was 23 months (range, 6–30 months). Function was evaluated based on the Musculoskeletal Tumor Society score and on postoperative ranges of motion (ROM) and extensor lag as measured using a goniometer. Extensor lag was defined as the difference between maximum passive extension and maximum active extension of the knee. Emotional acceptance of the results, use of walking aids, walking ability, and gait also were assessed. Followup was calculated from the time of surgery to the last evaluation, loosening of the prosthesis, or death.

Operative Technique

Extraarticular resection was done as described by Enneking and Shirley. A tourniquet placed high on the thigh and an anteromedial approach were used in every case. The preoperative biopsy site was excised en bloc with the tumor. After control of the vascular pedicle in the popliteal fossa was achieved,
The proximal part of the medial gastrocnemius muscle was detached from the posterior joint capsule to expose the inferior part of the popliteal fossa. The medial sural artery was isolated; preservation of this artery is essential. In four patients the semitendinosus, sartorius, and gracilis tendons were detached from the tibia.

The knee then was flexed to 90°/H11034, and medial and lateral flaps of skin and subcutaneous tissue were developed to provide good exposure of the distal third of the femur, proximal third of the tibia, and popliteal fossa, medially and laterally. At the lateral aspect of the knee, the peroneal nerve was identified under the biceps femori tendon. In four cases, the biceps femori tendon was detached from the fibula. The crural tendon was sectioned above the joint capsule. The osteotomies of the femur and tibia were placed beyond the insertion of the joint capsule and at least 3 cm beyond any evident tumor. At the tibia, the osteotomy was always below the tibial insertion of the semimembranous tendon and was angulated posteriorly toward the resected insertion of the posterior cruciate ligament. The patella and its tendons were resected en bloc with the joint.

A cemented, fully constrained megaprosthesi was used to reconstruct the knee and the bone defects (Fig 2), and a medial gastrocnemius muscle flap was used to reconstruct the extensor mechanism. The previous incision was extended down the leg, just medial to the tibia. The medial gastrocnemius was divided 3 to 5 cm distal to its insertion into the Achilles tendon (Fig 3). Proximally, the median raphe was identified between the bellies of the medial and lateral gastrocnemius muscles. Using blunt and sharp dissection, the medial gastrocnemius was divided to its proximal tendon, which previously had been mobilized to provide an adequate arc of rotation. The medial sural artery was exposed and preserved. With the knee in full extension, the muscle flap was transposed anteriorly at the level of the knee between the quadriceps tendon and the anterior leg muscles. The distal tendon and upper edge of the gastrocnemius flap were sutured to the crural tendon, and the lower edge of the flap was sutured to the tibialis anterior muscle to reconstruct a continuous extensor mechanism. In addition, the flap was sutured to all of the muscles around the knee, namely the tensor fasciae latae laterally and the sartorius medially. In four patients, the pes anserinus tendons were transferred to the

![Fig 2. A fully constrained prosthesis was cemented in place. A = Quadriceps muscle.](image1)

![Fig 3. The medial gastrocnemius was exposed, and the pes anserinus tendons were detached and released.](image2)
anterior part of the tibia to increase the strength of
the extensor mechanism. The tendons were trans-
lated, attached to the tibia using two staples, and su-
tured to the gastrocnemius muscle flap (Figs 4, 5); however, in the two patients whose proximal tibia
was resected, the tendons were sutured only to the
gastrocnemius muscle flap. The final result was that
a continuous extensor mechanism was restored and
the prosthesis was covered entirely by muscle. The
skin was sutured without tension in all patients.

Aftercare
After surgery, an above the knee cast with the knee
in extension was used in every patient. Gait train-
ing with weightbearing and isometric exercises for
the quadriceps were started immediately. The cast
was opened after 5 days to allow examination of the
incision. If the incision was healing normally, a
new above the knee cast was made with the knee in
extension. Six weeks later, the cast was removed
and active extension exercises were commenced. Flexion was started only after recovery of the full
range of active extension.

RESULTS
The mean followup for the nine patients was
23 ± 10 months (range, 6–30 months). One
patient died of malignancy after 24 months, and another patient was lost to followup after
6 months. Two patients were alive with pul-
monary metastases after 30 months.

Mean postoperative Musculoskeletal Tu-
mor Society score was 61% ± 22% (range, 36%–100%) (Table 1). All patients reported
either no pain or only mild pain. Five patients
were satisfied with the result, three patients ac-
tioned their disability, and one patient was dis-
satisfied. The mean postoperative range of
flexion was 62° ± 20° (range, 30°–90°) overall
and 63° ± 20° in the seven patients followed up
for longer than 6 months. The mean postopera-
tive range of flexion was 64° ± 31° in the four
patients whose reconstruction procedure in-
cluded anterior tendon transfers and 61° ± 19°
in the remaining five patients (Fig 6).

The mean postoperative extensor lag was
12° ± 15° (range, 0°–40°) overall and 11° ± 15°
| Case | Gender/Age (years) | Diagnosis | Localization | Clinical | RJI | HJI | MTS | Flex | Ext | Limp | Crush | Followup | Tumors Status | Complications |
|------|--------------------|-----------|--------------|----------|-----|-----|-----|------|-----|------|-------|---------|------------|---------------|---------------|
| 1    | M, 20              | OS        | Femur        | Sw       | Trochlea | No  | GM + PA | 90   | 90  | 0    | No    | No       | 30         | NED           | No            |
| 2    | M, 18              | OS        | Tibia        | Sw       | Cruciate ligament | No  | GM + PA | 36   | 30  | 0    | Yes   | Yes      | 6          | NED           | Infection arthrodesis |
| 3    | M, 41              | AgS       | Femur        | Sw       | Trochlea | Yes | GM + PA | 100  | 45  | 30   | No    | No       | 36         | NED           | No            |
| 4    | M, 51              | HP        | Femur        | Sw       | Trochlea | Yes | GM + PA | 56   | 90  | 0    | Yes   | Yes      | 6          | NED           | Extensor mechanism rupture |
| 5    | M, 30              | CCS       | Hoffa        | Sw + dec Mob | Trochlea | Yes | GM     | 53   | 45  | 5    | Yes   | No       | 24         | AWD           | No            |
| 6    | M, 47              | FS        | Femur        | Sw       | Condyle | Yes | GM     | 70   | 50  | 10   | Yes   | No       | 24         | NED           | No            |
| 7    | F, 20              | OS        | Femur        | Sw       | Cruciate ligament | Yes | GM     | 40   | 50  | 0    | Yes   | No       | 30         | AWD           | Septic loosening, prosthesis |
| 8    | F, 39              | OS        | Tibia        | Sw + dec Mob | Medial ligament | Yes | GM     | 50   | 90  | 40   | Yes   | No       | 24         | NED           | No            |
| 9    | F, 49              | OS        | Femur        | Sw       | Trochlea | Yes | GM     | 50   | 70  | 20   | Yes   | Yes      | 24         | NED           | No            |

M = male; F = female; OS = osteosarcoma; AgS = angiosarcoma; HP = hemangiopericytoma; CCS = clear cell sarcoma; FS = fibrosarcoma; Sw = swelling; Dec mob = decreased mobility; RJI = radiologic joint involvement; HJI = histologic joint involvement; MTS = Musculoskeletal Tumor Society score; Flex = flexion; Ext = extensor lag; NED = no evidence of disease; AWD = alive without disease; GM = gastrocnemius muscle; PA = pes anserinus tendons.
in the seven patients followed up for longer than 6 months. The mean postoperative extensor lag was 7.5° ± 15° in the four patients whose reconstruction procedure included anterior tendon transfers and 15° ± 16° in the remaining five patients (Fig 6). The ROM of the patient with extensor mechanism rupture (Patient 4) was evaluated before this complication occurred. After the rupture, the patient declined reconstruction and was lost to followup (Table 1).

Three patients were able to walk with the assistance of one crutch because of their knee instability. The six remaining patients walked without a walking aid. Three patients had severe disability with a major limp, four patients had moderate disability with a minor limp of cosmetic significance, and two patients had no disability.

Of the nine patients, four were not able to return to their former occupation because of their disability, two were unemployed, two were students, and one was retired.

Postoperative Complications
Early skin necrosis occurred and healed after simple excision and suturing. One patient had incomplete, transient palsy of the peroneal nerve. Two cases of deep infection were recorded. One infection (Patient 2) occurred 6 months after the procedure and resolved after removal of the prosthesis, followed by nailing and application of antibiotic-loaded methylmethacrylate. The other infection occurred 30 months after the procedure and was treated successfully by one-step cleaning and replacement. Rupture of the extensor mechanism reconstruction was seen in one patient (Patient 4), who declined a repeat surgical procedure and subsequently was lost to followup.

Oncologic Results
There were no local recurrences in any of the nine patients; however, metastatic disease was detected in three patients, of whom one has died of the malignancy.

DISCUSSION
Involvement of the knee by malignant bone tumors of the distal femur or proximal tibia is unusual. The joint cartilage, growth plate, and joint capsule form an effective barrier to tumor spread. This probably is why joint involve-
ment generally indicates an aggressive tumor and should be considered similar to a skip metastasis. Rougraff et al.\textsuperscript{15} found that skip metastases were associated with a bleak prognosis. In keeping with this, three of the nine patients in the current study had pulmonary metastases develop in the absence of any local recurrence; one of the three patients died of the malignancy.

Although MRI is highly sensitive for detecting joint involvement, the diagnosis often is difficult to confirm, particularly when the tumor involves the cruciate ligaments. For instance, Schima et al.\textsuperscript{16} reported a sensitivity of 100\% with a specificity of only 69\%. False positive MRI results may lead to overstaging and consequently to unnecessarily extensive surgical procedures; this was the case in two of the nine patients in the current study (Fig 1).

When joint involvement is suspected, arthroscopy can be done. However, this technique is reliable only when the intraarticular lesions are in a readily accessible part of the joint, such as the trochlea or the condyle. Lesions at other sites are missed easily. Enneking and Shirley\textsuperscript{6} and Malawer and McHale\textsuperscript{11} suggested that the joint should be opened to confirm the presence of intraarticular tumor before the resection is started. However, this carries an unacceptably high risk of contamination.

If joint involvement is probable or certain, extraarticular en bloc excision of the knee should be done. Removing the entire patella and its tendons with the knee substantially increases the safety of this procedure. In contrast, splitting the extensor mechanism coronally carries a high risk of contamination, particularly of the crural tendon. As shown by Rougraff et al.,\textsuperscript{15} extraarticular resection with removal of the entire patella and its tendons is not associated with a higher local recurrence rate than intraarticular resection or above-the-knee amputation.

Resection-arthrodesis is the most widely used limb salvage technique in patients with intraarticular spread of malignant tumors about the knee.\textsuperscript{1,6,11} However, this technique leaves a large skeletal defect.\textsuperscript{14} In a study by Enneking and Shirley,\textsuperscript{6} of 29 patients treated with resection-arthrodesis, implantation of an intramedullary rod, and autografting, initial nonunion occurred in 30\% of cases, although healing eventually was achieved after additional bone grafting in all the patients. Rasmussen et al.\textsuperscript{14} reported better results after arthrodesis with use of a vascularized fibular rotatory graft; there were no late complications, no additional surgery was needed if union was achieved, and no local recurrence developed.

Allografts used to reconstruct the knee after tumor resection have been associated with a high rate of complications,\textsuperscript{7} some of which noticeably reduce the likelihood of achieving sufficient ROM. In addition, there is a high risk of resorption and fracture of the grafted epiphysis.

However, use of a prosthesis rarely is indicated. Preservation of knee mobility after prosthetic joint replacement with resection of the proximal tibia or of the patella and its tendons, or both requires reconstruction of an effective extensor mechanism. Malawer,\textsuperscript{10} Malawer and McHale,\textsuperscript{11} and Dubousset et al.\textsuperscript{3} suggested that this could be achieved by attaching the patellar ligament to the tibial component, then covering this ligament and the prosthesis with a medial gastrocnemius transposition flap. A variant of this previously established technique was used by the current authors.

Jaureguito et al.\textsuperscript{9} obtained promising results with another variant of this technique in patients with extensor mechanism disruption after total knee arthroplasty. To the authors’ knowledge, this is the first report on the use of a fully constrained prosthesis with a medial gastrocnemius transposition flap for reconstruction of the knee and extensor mechanism after total en bloc resection of the knee, including the patella, for a bone tumor.

This technique offers several advantages over other techniques: the flap provides excellent soft tissue cover for the proximal part of the tibia and the components of the prosthesis;\textsuperscript{8} the entire patella and its tendons are resected together with the joint, thus decreasing
the risk of contamination; and the reconstruction of the extensor mechanism is stronger and longer lasting than with artificial ligaments and allografts.\textsuperscript{3,4,11}

In the current series, extension mechanism reconstruction was achieved using a gastrocnemius flap only in five patients. In the remaining four patients, anterior transfer of the tendons of the pes anserinus also was done to increase the strength of the extensor mechanism. No statistically significant differences were found between the two reconstruction subgroups, especially for range of flexion, perhaps because of the small number of patients. However, a good functional result was obtained, without limitation of flexion, in two of the patients treated with anterior tendon transfer (Fig 6).

The aftercare protocol, notably the rehabilitation program, has a considerable influence on the quality of functional results. In the current patients, isometric exercises were begun on the day after the procedure to preserve quadriceps power. The 6-week immobilization period allowed complete healing of the extensor mechanism reconstruction. Only then were active joint movements started, and flexion was not begun until full recovery of active extension was obtained because premature flexion exercises may cause slackening of the extensor mechanism reconstruction and thus extensor lag.

The two cases of extraarticular resection in which the proximal tibia was resected along with the joint should be discussed separately because this situation raises extremely difficult reconstruction problems and carries a high rate of infection because of the paucity of soft tissue and skin overlying the prosthesis.\textsuperscript{1} In addition, the extensor mechanism defect is longer, the flap must be sutured more distally, and any transferred tendons are sutured only to the muscle flap because they cannot be reattached to the tibia. These difficulties explain why the functional result was poor in the two patients. In patients with a tibial tumor involving the joint, the best procedure after extraarticular en bloc excision may be arthrodesis with a gastrocnemius flap to improve soft tissue cover.

The complication rate was high in the current series. However, infection was the only severe complication, occurring in two of the nine patients.

Harris et al\textsuperscript{8} compared function after arthrodesis with arthroplasty for tumors about the knee. Arthrodesis offered better stability but made sitting difficult. The patients treated by arthroplasty led a sedentary life but had the highest scores for self-concept and also felt more normal, acceptable, fashionable, optimistic, useful, worthy, and successful than did the patients who had arthrodesis. However, both groups of patients walked with comparable efficiency. After arthroplasty with extensor mechanism reconstruction, weightbearing was possible earlier, and the cosmetic result was more satisfactory.

Knee reconstruction using a prosthesis and a gastrocnemius flap after extracapsular en bloc excision of the knee is a viable alternative to arthrodesis or amputation when the tibial resection is minimal. However, the higher complication rate should be borne in mind when discussing treatment options with the patient. In properly selected patients, this method provides acceptable function and a good cosmetic result.

References


