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# The extended use of modular knee endoprostheses

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**Rezumat**

***Indicații extinse pentru proteza modulară de genunchi***

Protezele modulare de genunchi au fost folosite încă din anii '80. Scopul lor era de a oferi o alternativă la reconstrucția defectelor osoase extinse prin grefare. La început, ele au fost folosite în cazul rezecțiilor tumorale din vecinătatea genunchiului. Succesul lor a condus la introducerea lor și în tratamentul reviziilor dificile de proteze totale de genunchi decimentate, soldate cu pierderi mari de capital osos și instabilități ligamentare severe. În perioada iulie 2006 – ianuarie 2009 am implantat 7 proteze modulare de genunchi. Au fost 4 cazuri de tumori, 1 caz de dezartrodeză după o procedură tip Campanacci și 2 cazuri de revizii de genunchi. Rezultatele obținute au fost încurajatoare, 6 din cei 7 pacienți supraviețuind la 2 ani postoperator. Toate implanturile au fost considerate ca funcționând normal în ceea ce privește fixarea, mobilitatea, mersul și forța musculară. Tratamentul chirurgical și medical al pacienților cu sarcoame osoase a progresat enorm în ultimii 20 de ani, îmbunătățind rata supraviețuirii acestor pacienți. Chirurgii posedă astăzi posibilități mult îmbunătățite de a efectua intervenții radicale fără sacrificarea membrului său a mobilității articulare.

**Cuvinte cheie:** endoproteze de genunchi, proteze modulare, tumori ale genunchiului, sarcoamele genunchiului, balama rotativ, pierdere de capital osos

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**Abstract**

Modular knee prostheses have been used since the 1980's. Their goal was to offer an alternative to reconstructing large bony defects without using bone grafting. Initially, they were used for reconstruction after resection of tumours about the knee. Their success encouraged their use in the treatment of some failed total knee arthroplasties, with large bony defects and severe ligamentous instability. We have implanted 7 modular knee prostheses between July 2006 and January 2009. There were 4 tumoral cases, 1 case of desarthrodhesis after a Campanacci procedure and two cases of failed total knee arthroplasties. We have achieved encouraging results using these implants with all but one patient surviving at two years after surgery. All the implants were considered to function normally regarding range-of motion, muscle strength and gait. The surgical and medical management of patients with bone sarcomas has advanced greatly during the last 20 years, improving their overall survival. Thus, the surgeons are provided with increased abilities to perform limb-sparing or joint-mobility sparing surgery.

**Key words:** knee endoprostheses, modular endoprostheses, knee tumours, sarcomas about the knee, rotating hinge, bone stock loss

## Introduction

Modular knee prostheses have been used since the 1980's. Their goal was to replace the initial custom made prostheses and offer an alternative to reconstructing large bony defects without using bone grafting. Initially, they were used primarily for reconstruction after resection of tumours about the knee. Successful experience with modular prosthetic reconstruction encouraged its use in the treatment of nononcologic cases, such as selected cases of failed total knee arthroplasties, with large bony defects and severe ligamentous instability. They can also be used to convert a previously performed resection-arthrodesis of the knee to an arthroplasty, restoring the function of the knee. (1)

The distal femur and proximal tibia represent common anatomic locations for bone tumours (1,2). Primary malignant tumours about the knee are usually sarcomas and occur most often in young patients during the adolescent growth spurt (1,3). The medical treatment of these bone tumours has improved dramatically in the last 30 years (4,5). Also, the improvement of the imaging technology has enhanced the rate of early diagnosis in the bone tumours. These advancements meant that the 5 years survival rate among sarcoma patients has improved from 20% in the 1970's to over 80% nowadays (1,2,5,6). The traditional surgical treatment included procedures like resection-arthrodesis, rotationplasty or amputation of the extremity, having unfavourable functional and psychological results. These drawbacks have made traditional surgery less acceptable, so present-day treatment is shifting more and more towards procedures that preserve the limb as well as its function (2,7,8). These goals can be met by using a modular knee endoprosthesis.

Total knee prostheses are a common encounter in the field of orthopaedics. Because of the large number of such implants used in the last 25 years, surgeons are now faced with a new challenge: revision arthroplasty of the knee. The number of people in need of such procedure has increased rapidly and there are a number of cases that are more complicated (bone stock loss, ligamentous instability). Because sufficient experience has been gathered regarding the excellent functional outcome of modular knee prostheses and because they have become more and more available economically, these implants have been put to use in such cases of total knee arthroplasties with severe bone stock loss and/or ligamentous instability, in need of revision.

## *Implant characteristics*

Custom-made prostheses were used at first for tumoral cases. The design and manufacturing process required up to 2 months. This delay was rarely acceptable, especially when faced with tumours. Another disadvantage of these custom-made prostheses was the lack of precision regarding the actual length and width of the resected bone, measured using imaging modalities alone (2,4,7,9).

Modular prostheses were introduced in the mid 1980s and have revolutionized endoprosthetic reconstruction, mainly because they allow the surgeon to measure the actual bone defect intraoperatively and select the appropriate components to use in reconstruction, such as articulating segments, bodies, and stems of varying lengths and diameters. These components include porous coating on the extracortical portion of the prosthesis for bone and soft tissue fixation. Also, modularity has increased their availability and decreased their cost. These metallic prostheses can be fixed to the bone with cement (polymethylmethacrylate) or cementless (press-fit porous stems) (10,11).

Joint stability is determined primarily by the mechanical properties of the prosthesis, even more so when a wide resection is performed, with removal of the surrounding muscles, joint capsule, and ligaments (2). The early devices consisted of a constrained, hinged-knee mechanism that allowing only flexion and extension. Because forces were not distributed appropriately around the knee, this constrained hinge mechanism was associated with high rates of mechanical failure, representing the most common complication of constrained prostheses (2,12).

Nowadays, modern implants use kinematic rotating-hinge knee mechanism allowing flexion and extension as well as external and internal rotations of the knee. This new design provides a better functioning knee and achieves lower loosening and mechanical failure rates (2,13). In order to reduce mechanical failures even more, larger core stems (>12 mm in diameter) are even less prone to mechanical failure and are recommended whenever possible (14). Also, using forged instead of cast material has decreased such complications (14,15). Another feature of these implants is the presence of polyethylene components within the metal prosthesis. This allows a staged mechanical failure pattern, because polyethylene components fail first. Thus, additional loosening of the prosthesis is prevented and less extensive revision surgeries are needed. Replacing a failed polyethylene component requires limited surgical exposure and shorter rehabilitation periods compared to revision of a loosened prosthesis (2).

## *Preoperative planning and surgical technique*

The patients were assessed preoperatively using full-length radiographs to estimate the dimensions of the prosthesis. The tumoral cases were more carefully assessed using computed tomography (CT) and magnetic resonance imaging to estimate the extent of tissue involvement and hence facilitate planning of the level of resection (1,14,16). Also, technetium bone scanning and tumour angiography were performed, the latter only when posterior cortical breakthrough was present, in order to evaluate more accurately the patency of the popliteal vessels and their relation to the tumour (1,2,8,16). Tumour staging was carried out according to the Enneking system.

Revisional arthroplasties require simpler exposure techniques, similar to those used for primary knee arthroplasties (9,17,18). Tumoral cases are more difficult and require extensive incisions, careful dissection and important bone and soft tissue sacrifice. The incision should be centred over the tumoral mass and should include the biopsy site, with a 1 cm margin in all directions. This incision exposes widely the distal 1/2 of the femur, sartorial canal, knee, popliteal fossa, and proximal 1/2 of the tibia. Prolonging the incision distally allows the use of a gastrocnemius flap, if necessary. The popliteal space is approached by detaching and retracting the medial hamstrings, thus exposing the popliteal vessels and sciatic nerve (4,13).

Distal femur or proximal tibia osteotomy is done at the appropriate location as determined by the preoperative imaging studies, bearing in mind that adequate surgical margins prevent recurrence (3). In general, a margin of 1 to 2 cm beyond tumour extension is considered safe for primary sarcoma. The prosthesis is oriented based on the linea aspera and tibial tuberosity as the remaining anatomic guidelines. Patellar resurfacing is performed in every case (4).

The prosthesis must be completely covered with muscle tissue and that can be technically difficult. In order to achieve that, the remaining vastus medialis may be sutured to the rectus femoris, or the sartorius can be mobilized and rotated anteriorly for additional closure of the remaining medial soft tissue defect. A medial or lateral gastrocnemius transfer may be required in order to close a large defect (4,13).

A tricky problem encountered when reconstructing the proximal tibial tumours is the restoration of the extensor mechanism. Various methods may be used, including: special bands, tubes, and Dacron tapes, associated with bone grafts (13,17).

## Material and Method

We have implanted 7 modular knee prostheses between July 2006 and January 2009. The 7 patients, 4 women, 3 men, had ages ranging between 16 and 70 at the time of surgery, with the mean age being 37.1. There were 4 tumoral cases. 3 of these tumours affected the distal femur (1 condrosarcoma, 1 Ewing sarcoma and 1 giant cell sarcoma) and the 4th case was an osteosarcoma of the proximal tibia. There were also 1 case of desarthrodhesis after a Campanacci procedure one case of a failed total knee arthroplasty and one case of severe knee osteoarthritis with great ligamentous instability.

All 7 implants were rotating-hinge modular knee prostheses. Regarding the method of fixation, two implants were cemented, 1 cementless and the other 4 were hybrid. All 7 operations were performed by the same surgeon. We have used either general or spinal anaesthesia with an epidural catheter. Minimising blood loss was a major issue, taking into account the duration of the operation that sometimes exceeded 4 hours and the fact that many of the patients had had preoperative chemotherapy with secondary anaemia. In order to achieve this goal, impeccable surgical technique and careful haemostasis were required. Also, controlled hypotension and monitoring of EAB were used. Another major issue was the high infection risk, due to the same factors (length of the operation, low white cell count after chemotherapy, presence of implant, etc.). A second generation cephalosporin in association with gentamycin was used, and this treatment was continued for up to 7 days postoperatively. The first dose of antibiotic was injected one hour prior to surgery and this dose was repeated intraoperatively in case the operation exceeded 3 hours. Thromboprophylaxis was done using low molecular weight heparine for 5 weeks.

The lower extremity was elevated for 3-5 days, to prevent wound oedema. Continuous suction drainage was maintained for 2 to 3 days. Isometric exercises were started at the second postoperative day and mobilization with crutches was permitted after the drainage was discontinued. Also, range-of-motion exercises were performed in the presence of a physical therapist. The dressing was changed on a daily basis until the 12th post-operative day, when the sutures were removed and the patient discharged. After surgery, the patients were evaluated at 6 weeks, 3 months and yearly afterwards. On each visit, physical examination, and plain radiographs were done. For tumoral cases, chest radiographs were also taken. Functional evaluation was based on direct patient examination by one of the authors included assessment of pain, function, range-of-motion, supports, and gait.

## Results

The results achieved are presented case by case in chronological order:

- Case 1
  - M.C., F, 23 years old;
  - Distal femur osteosarcoma, treated by Campanacci resection-arthrodhesis 5 years before;
  - Length of bone resected, then reconstructed 13 cm;
  - The rehabilitation program went very well, with full weight-bearing and 80° of flexion at 7 days after surgery. The wound healed without any problems;
  - After two years (7 years after resection) she has no sign of local recurrence, is fully weight-bearing with no crutches, achieves 120° of flexion and enjoys the normal life of a 25-year old.
- Case 2
  - P. G., M, 18 years old;
  - Ewing sarcoma of the femur;
  - Resection length 30 cm *(Fig. 1, 2)*;

***Figure 1.*** *Case 2, preoperative X-Ray*

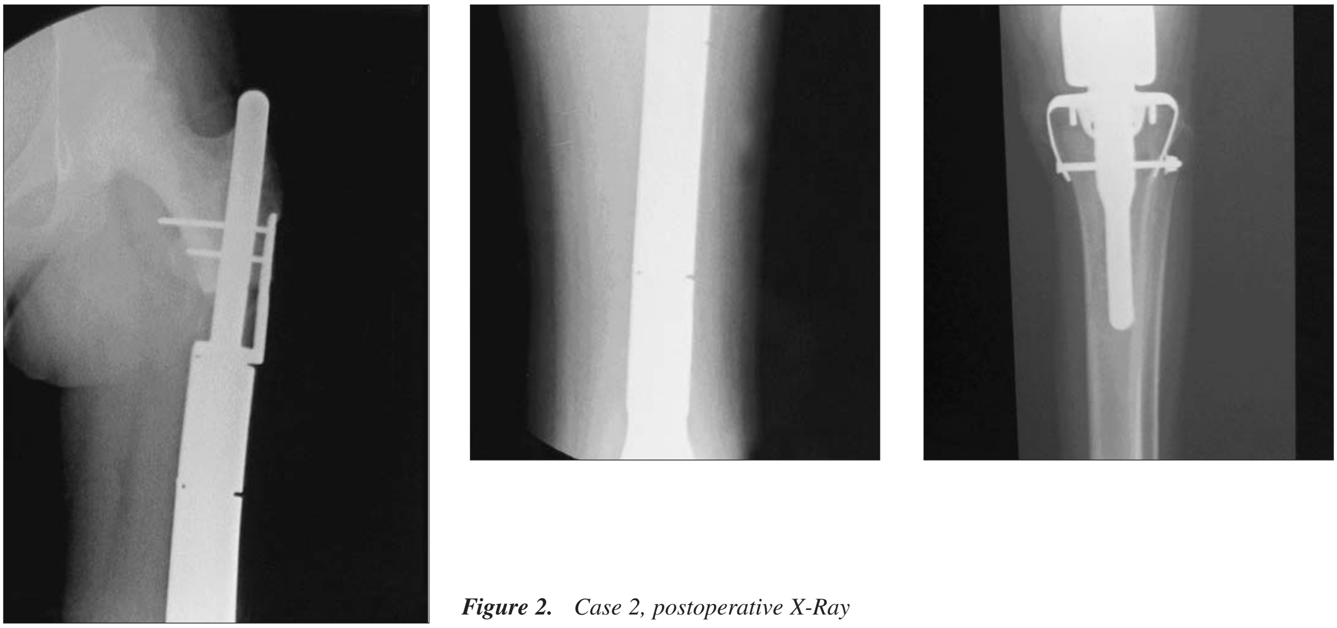

***Figure 2.*** *Case 2, postoperative X-Ray*

- After surgery, the patient has recovered nicely, achieving 110° of flexion with a 10° extension lag and walking with a slight limp and without any leg length discrepancy.
- At two years after surgery there was a mechanical failure at the junction proximal femur-implant, that meant that the proximal femur tilted in varus and the stem migrated less than 1 cm proximally.
- Nevertheless, the patient walks normally, with no crutches and rates his result as excellent

***Figure 3.*** *Case 3, preoperative X-Ray*

- Case 3
  - P. A., M, 47 years old;
  - Giant cell sarcoma of the distal femur, local recurrence after curettage and filling with cement *(Fig. 3)*;
  - Resection length 14 cm;
  - In order to resect the sarcoma, we had to deinsert the extensor mechanism, and reinsert it at the end of the procedure *(Fig. 4)*;
  - After two years there are no signs of local recurrence, the patient is fully weight-bearing without crutches and achieves 100° of flexion and walks without a limp *(Fig. 5)*.
- Case 4
  - D. L., F, 19 years old;
  - Condrosarcoma of the distal femur;
  - Resection length 12 cm;
  - After two years she has no sign of local recurrence, is fully weight-bearing with no crutches, achieves 110° of flexion but has an extension lag of 10° and a slight limp.
- Case 5
  - D. G., M, 16 years old;
  - Osteosarcoma of the proximal tibia *(Fig. 6)*;
  - Resection length 16 cm *(Fig. 7)*;

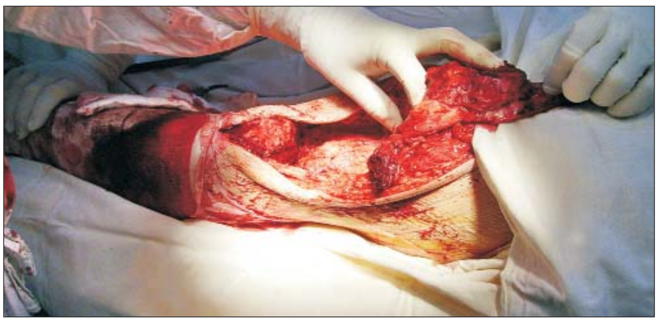

***Figure 4.*** *Case 3, intraoperative X-Ray with dettachment of extensor mechanism*

*Figure 5.* Case 3, X-Ray image at 2 years after surgery

*Figure 7.* Case 5, postoperative X-Ray

*Figure 6.* Case 5, preoperative X-Ray

*Figure 8.* Case 6, preoperative X-Ray

- The extensor mechanism was reattached to the tibial implant using autogenous bone;
- Soft tissue coverage was performed by using a gastrocnemius flap;
- The patient was immobilized for 6 weeks in a long-leg cast to protect the reinserted quadriceps;
- At one year after surgery he had 110° of flexion, no extension lag, walked with no limp and, more importantly, had no sign of local recurrence. He had still to recover the quadriceps amiotrophy that measured 6 cm in circumference at that time;
- Sadly, a few months later, the patient died due to pulmonary metastases.

• Case 6
  - S.L.M., F, 67 years old;
  - Mechanical failure of a total knee endoprosthesis after 5 years, with severe bone stock loss and virtually no ligamentous stability *(Fig. 8, 9)*;
  - At 1 year after surgery she has 100° of flexion, no extension lag, walks without crutches and with no limp *(Fig. 10, 11)*.

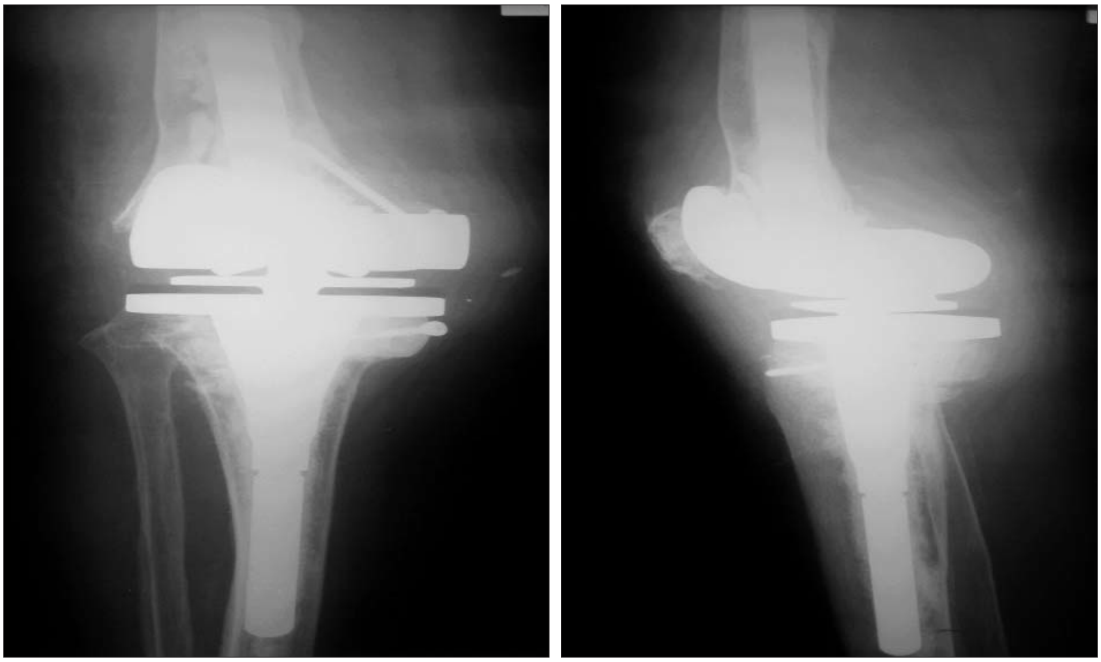

*Figure 9.* *Case 6, postoperative X-Ray*

*Figure 10.* *Case 6, Full extension at one year after surgery*

- Case 7
  - P.V.M., F, 70 years old;
  - Severe knee osteoarthritis with valgus deformity and severe ligamentous instability;
  - At 1 year after surgery she achieves 110° of flexion, has no extension lag and walks without crutches and with no limp.

## Discussions

The surgical and medical management of patients with bone sarcomas has advanced greatly during the last 20 years, improving their overall survival. Advanced imaging has had a positive impact on surgical planning and staging. Several improvements were made regarding instrumentation, modularity of implants and availability. All these factors have provided surgeons with increased abilities to perform limb-sparing or joint mobility sparing surgery, which has proven to be a reasonable method of treatment whenever a wide resection could be achieved (11,12).

*Figure 11.* *Case 6, 100 degrees of flexion at one year after surgery*

A limb-sparing procedure improves cosmesis and function, preserves knee motion and ability to ambulate and is more cost-effective than amputation (5,6,11,18,19). However, it does not shorten the disease-free interval neither does it compromise the long-term survival of these patients if an adequate margin of resection is obtained (1,2,10,19). The implants used can have high complication rates such as infection, fracture, loosening or mechanical failure. Such complicated cases may need several surgical interventions and may eventually lead to the need for amputation (6,8,9,11).

The goal of limb-salvage surgery should therefore be to preserve a useful functioning limb without taking unnecessary risks, while making the surgical treatment more acceptable emotionally for the patient. The use of modular implants is warranted in primary bone tumours around the knee that can be safely excised and sufficient soft-tissue coverage can be obtained at the time of surgery. In these cases, good or even excellent results are expected.

Modular endoprostheses are used more and more frequently because they possess undeniable advantages, such as eliminating the need for junctional healing (as in the case of allografts) and allowing immediate weight bearing. Also, the risk of disease transmission is 0, and great intraoperative flexibility exists because of their modular design (7,19). Another interesting feature is presumably their endurance with time, a critical factor when reminded that most patients with bone tumours are aged less than 30 years.

The growing amount of experience gathered in the field of tumour surgery has encouraged surgeons to use the same kind of modular prostheses for other pathologies, such as failed total knee arthroplasties. When faced with such a case, complicated by severe bone stock loss and ligamentous instability, one of the treatment options should be implanting a rotating-hinge modular knee prosthesis. It provides excellent results such as: pain-free motion, ability to bear weight, mechanical stability and durable survival of the implant that can sometimes exceed that of the patient. In some selected cases, they can be considered to be a reasonable alternative to constrained total knee implants, the latter being more frequently used in such pathologies.

Aside from these advantages, modular knee endoprostheses are fraught with some complications. The most common of them are: infection, aseptic loosening, mechanical failure of the bearing, stem fracture or periprosthetic fracture (7,8,11). Implant survivorship for modular knee prostheses is limited but in some cases it may exceed that of the patient. Nevertheless, several advances have been made in order to improve their durability in time, such as: the use of forged alloys, improved stem designs and biomechanical features, the use of larger stem sizes, etc. Also, another improvement is the staged mechanical failure pattern, according to which polyethylene components fail first means that less extensive revision surgery is needed and that the rehabilitation period is shorter than after revising the entire implant (4,16,19).

In time, these state-of-the-art implants will become more reliable, longer lasting and more available economically, in order to allow more and more patients to benefit from this kind of surgical treatment.

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