Megaprostheses after resection of distal femoral tumors

A rotating hinge design in 30 patients followed for 2–7 years

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Between 1981–1993, we inserted 32 Kinematic Rotating-Hinge Knee tumor prostheses in 30 patients, of which 2 concerned revisions of the same type of prosthesis. The diagnoses were 21 osteosarcomas, 2 chondrosarcomas, 2 Ewing's sarcomas, 2 metastatic breast carcinomas, 1 multiple myeloma, 1 giant cell tumor and 1 Gorham's disease. The median age was 25 (12–60) years and the median follow-up for survivors was 3.5 (2–6.6) years. There were 7 metastases and 1 local recurrence.

20 knees had excellent (MSTS) scores for motion (median flexion 120°), 8 had good (84°) and 4 had fair (45°). The overall function was excellent in 6 cases, good in 14, fair in 9 and poor in 3. The radiographic assessment (ISOLS) gave "excellent" or "good" scores in 27 knees for bone remodelling, 31 for the interface, 28 for anchorage, 31 for the implant body and 30 for the articulation. Extracortical bone bridging greater than 25% was observed in 18 of 27 prostheses.

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Segmental resections followed by mobile reconstructions with prosthetic joints have gained popularity for tumors around the knee, since they afford the patient immediate mobility, stability and weight bearing (Kneisel et al. 1991, Malawer and Meller 1991, Shih et al. 1993, Witt and Marsden 1994). The rotating-hinge knee prosthesis is a newer design that combines movement in three directions—namely, flexion-extension, rotation and proximo-distal translation (Malawer and Meller 1991, Shih et al. 1993). The combination of these 3 degrees of freedom is reported to improve the mechanics of the knee, while facilitating the dispersion of stress through the components of the implant. Specifically, rotational laxity reduces the forces and moments across the joint components by allowing soft tissue and muscular structures to absorb some energy, when the displacement from the neutral position increases. This is also thought to reduce the micromotion and bone resorption at the interfaces, and cause less loosening (Walker 1996).

We previously presented a small pilot series (n 16, follow-up 9 months to 4 years) of Kinematic rotating-hinge knee prostheses (Shih et al. 1993) which suggested better function and survival with the rotating-hinge design than with the Walldius prosthesis. We now report our experience with the rotating-hinge knee prosthesis in a larger group of patients followed over a longer period.

Patients and methods

From 1981 through 1993, 30 rotating-hinge knee tumor endoprostheses were implanted following tumor resection. There were 2 failures in this group, which were revised with the same type of prosthesis. Since the follow-up durations of these latter 2 patients were at least 2 years, they were included in the study group, thus giving a total of 32 knees for analysis. The median age was 25 (12–60) years. There were 12 men and 18 women. Clinical data were retrieved from the clinical charts, radiographs and outpatient interviews. Radiographs of patients followed-up elsewhere were also sent to our institution for review.

Tumors

The diagnoses included osteosarcoma (21), chondrosarcoma (2), Ewing's sarcoma (2), metastatic breast carcinoma (2), multiple myeloma (1), giant cell tumor (1), and Gorham's disease (1). There were 1 IB, 8 IIA, and 16 IIB sarcomas. The median tumor size was 8 (3–15) cm. 5 tumors were epiphyseal and the remainder metaphyseal.

Treatment

Of the 30 primary procedures, 26 patients underwent resection with wide margins, 3 patients had marginal margins and 1 patient had intralesional excision of the

tumor. All sarcoma patients were treated with wide margins. The median length of bone resected was 15 (8–22) cm in the femur and the median proximal bone resection margin was 5 (3–11) cm. All procedures were intraarticular resections. The decision for a medial (16) or lateral (12) approach was dependent on the biopsy site. Combined medial and lateral approaches were used in 4 cases.

The median operating time was 4.5 (2–8.5) hours. A bloodless field was employed in 29 operations. The mean blood loss was 0.8 (0.1–2) L. Intraoperative blood transfusions were required in 15 patients and the median replacement was 1 (1–3) unit of packed red blood cells.

We used the Kinematic rotating-hinge knee tumor prosthesis (Howmedica, Rutherford, New Jersey), which is a Vitallium-constructed modular system designed for cement fixation of the femoral and tibial components. It has a constrained hinge mechanism which also combines a stem that permits axial rotation and distraction within an ultra-high molecular weight polyethylene tibial bearing surface (Figure 1). A porous coating of sintered beads on a segment of the femoral component adjacent to the femoral osteotomy permits cortical bone bridging between the distal

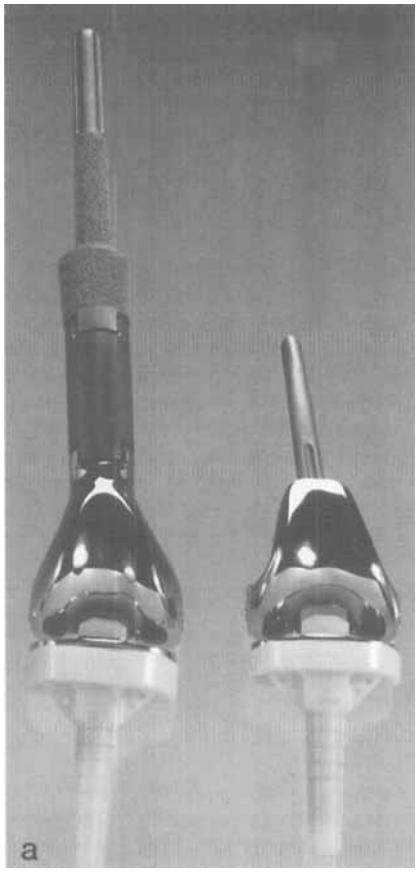
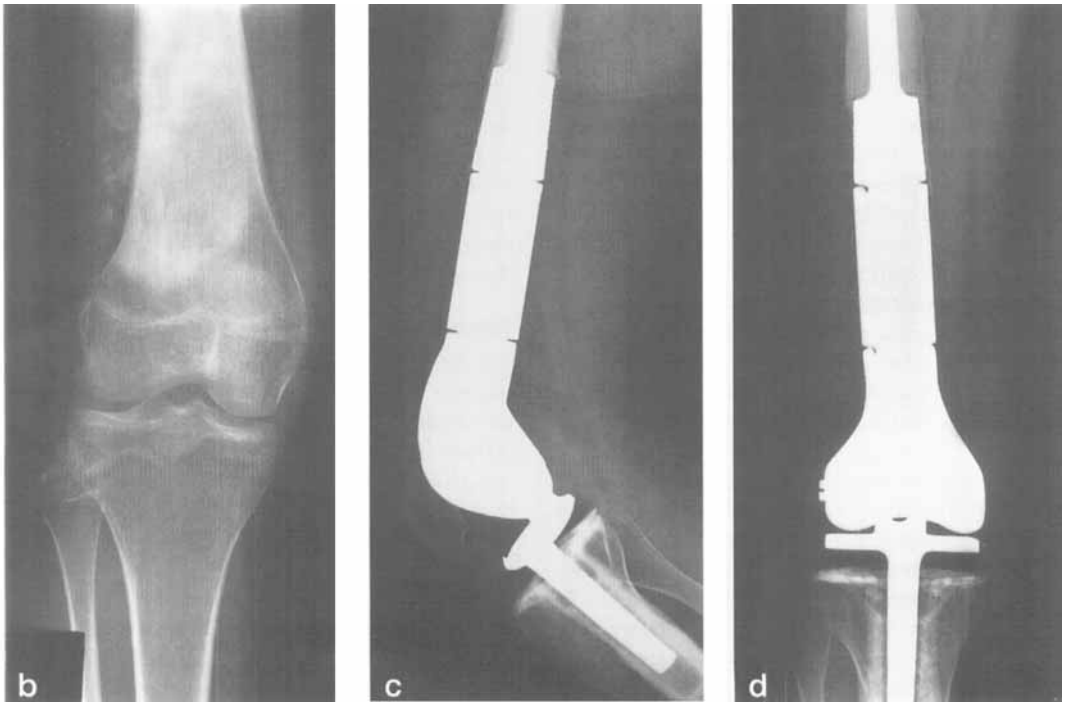


Figure 1. a) Kinematic rotating-hinge knee tumor endoprosthesis (left) with a design based on the revision rotating-hinge knee model (right). b) Stage II B osteosarcoma of the right distal femur and 4 years following reconstruction; c) anteroposterior and d) lateral views.



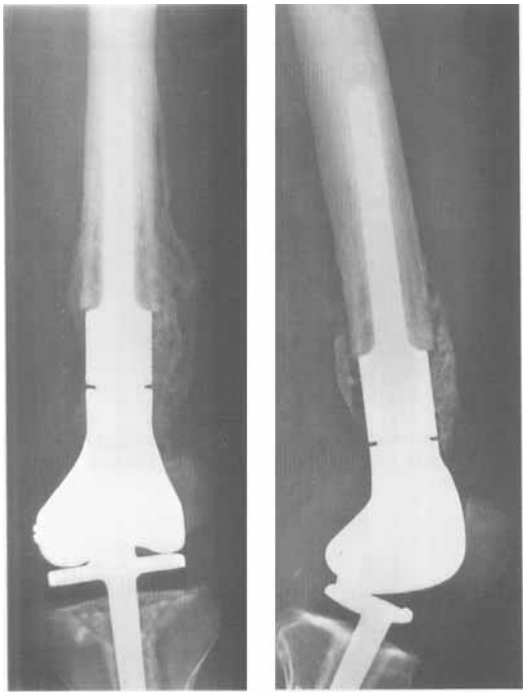


Figure 2. Extensive extracortical bone bridging.

femoral stump and the prosthesis which enhances prosthetic fixation (Chao and Sim 1992) (Figure 2). This was supplemented by morcellized or strips of corticocancellous autograft bone. The non-modular version of this prosthesis (pre-1984) had no porous coating. 13 patellae were resurfaced with a cemented button.

Beginning on the first postoperative day, the operated limb was flexed and extended with a continuous passive motion (CPM) machine, which gradually increased the arc of motion until a range of 0–90 degrees was achieved, which would normally take 3–5 days. CPM was instituted, in addition to postoperative physical therapy. Unless full (passive) extension had been achieved by the second postoperative day, a knee-immobilizer was prescribed to keep the knee extended over-night until full extension was attained. On the third or fourth postoperative day, the patient was allowed protected weight-bearing, as tolerated, using a walking frame or crutches. The median time to ambulation was 4 (3–6) days. Drain tubes were removed when the drainage was less than 10 mL per hour (≈ second postoperative day). 4 prophylactic perioperative intravenous doses of a broad-spectrum antibiotic were used.

2 patients who had metastatic breast carcinoma were treated with adjuvant radiotherapy and 20 patients were also given chemotherapy.

Functional assessment

Function was assessed by the Musculoskeletal Tumor Society's criteria (Enneking 1987). 7 parameters were analyzed—namely, motion, pain, stability, deformity, strength, functional activities, and the patients' emotional acceptance of the reconstruction. Each parameter is rated as excellent, good, fair or poor, according to specific guidelines. Function was classified as excellent, if all 7 parameters were recorded as excellent; function was good if 6 of the 7 parameters were good or excellent; a fair result required at least 6 parameters to be scored as fair or better, and a poor result was obtained when at least 2 parameters were scored as poor. If a femoral or tibial prosthesis was revised, the function for that device was classified as poor. According to these criteria, the use of a support such as a cane gives a poor grade for stability. For patients who no longer required the use of a walking aid for normal activities of daily living, we still recommended the use of a cane when engaging in outdoor activity and extended walking to protect the prosthesis rather than to confer stability. Under such conditions, we did not consider this criterion a negative parameter.

Radiographic assessment followed the guidelines proposed by the International Symposium on Limb Salvage (Glasser and Langlais 1991). 6 parameters were used, namely, bone remodeling, interface, anchorage, implant body problem, implant articulation, and extracortical bone bridging.

Follow-up

Follow-up was calculated from the time of surgery to the last date of review or death. Survival of the prosthesis was estimated by Kaplan-Meier methods from the date of surgery until revision. Failure of device was defined as any cause, except local recurrence, that required exchange of the femoral or tibial components. Cases who died without failure of their prostheses were treated as "censored observations". In the 2 patients who were revised, the follow-up period was calculated from the date of their revision surgery.

At the last follow-up, 23 were disease-free, 3 were alive with disease and 4 had died of their disease. The median follow-up after surgery for survivors was 3.5 (2–6.6) years. There was 1 local recurrence in a 49-year-old patient at 9 months, after a wide resection of a stage IIA chondrosarcoma. This had not been treated surgically, since the patient was also found at that time to have widespread pulmonary and skeletal metastases. The patient died of the disease 10 months later. Of the sarcoma patients, 7 patients developed metastases after limb-salvage surgery, the median metastasis-free period was 8 (5–53) months and 4 have died of their disease.

Results

2 of the 30 primary procedures failed. One was in a 60-year-old man who had a resection of an osteosarcoma. He fell 13 months after surgery and developed persistent pain from a loosened femoral component. The femoral component was exchanged for another cemented component. The second patient was a 44-year-old woman with breast carcinoma who had a resection of a metastasis from the distal femur. She fell 5 years later and sustained a periprosthetic fracture around the stem of the femoral component. This was revised to a longer stem-cemented component. Neither patient had prosthetic problems at review 2 and 5 years later, respectively. The survival rate for prostheses during the first 5 years was 0.9.

Function (Table 1)

There were 6 excellent, 14 good, 9 fair and 3 poor scores. Any prosthesis which is revised is classified as a poor score, therefore the 2 failures were designated as poor, although up to the time of their falls, both patients had good scores. The third poor score was in a 60-year-old woman who developed widespread metastastic breast carcinoma in her long bones, ribs and pelvis and who was incapacitated by the pain of her metastatic disease. Her condition reduced her activities so much that she lost her range of motion and was restricted to a flexion arc of 0–40 degrees.

The overall functional score and the score for each of the functional parameters were reclassified into 2 groups—namely, excellent and good (A) or fair and poor (B), and the relationship between the overall functional score and that for each parameter was examined (Table 2). The overall score had the strongest correlation with activity. Emotional acceptance also strongly correlated with the overall score. There was a trend towards a correlation between the overall functional score and pain or motion.

There were no correlations between any of the functional parameters and the age of the patient or length of the femoral cut. Patella replacement did not correlate with the overall functional score.

Radiography (Table 3)

Radiographs were available for 31 of the 32 procedures. Most of the procedures were rated as excellent or good scores with regard to bone remodeling, interface radiolucent lines and anchorage. There were no implant body problems. 1 patient developed a dislocated patella prosthesis 10 months after operation which was not treated. This patient was rated as poor with regard to implant articulation. Extracortical bone bridging was quite variable. Of the 27 prostheses with porous coating, 18 had more than 25% extracortical bone bridging, as measured on the antero-posterior and lateral radiographs, and covering at least 2.5 cm of the length along the porous section in the segmental shoulder region. The results of extracortical bone bridging did not correlate with bone remodeling, interface lucent lines, anchorage, implant body problems or articulation problems.

Table 1. Results of functional assessment in 32 knees

Parameter	Excellent	Good	Fair	Poor
Motion	20	8	4	–
Median	120°	84°	45°	
Range	100°–130°	70°–90°	40°–50°	
Pain	16	14	1	1
Stability	32	–	–	–
Deformity	28	–	4	–
Strength	15	16	1	–
Function	6	17	8	1
Acceptance	6	19	7	–
Overall	6	14	9	3

Table 2. Correlation between overall functional result and motion, pain, strength, functional activity and emotional acceptance

		Overall functional score		
Parameter		A	B	P-value
Motion	A	19	9	0.1
	B	1	3	
Pain	A	20	10	0.06
	B	0	2	
Strength	A	20	11	0.2
	B	0	1	
Functional activity	A	19	1	0.0002
	B	4	8	
Emotional acceptance	A	20	0	0.006
	B	8	4	

A excellent or good, B fair or poor

Table 3. Radiographic results of 31 patients[a] with rotating-hinge knee prostheses

Parameter	Excellent	Good	Fair	Poor
Bone remodeling	25	2	4	–
Interface	29	2	–	–
Anchorage	28	–	3	–
Implant body	31	–	–	–
Articulation	27	3	0	1
Bone bridging[b]	5	5	8	9

[a] Radiographs of 1 patient were not available.
[b] Not applicable in 4 patients whose prostheses had no porous coating.

Table 4. 9 complications in 7 patients undergoing Kinematic rotating-knee joint arthroplasty

Complication	Treatment
Patella (4)	
Fracture	Cast immobilization
Button fracture	Revised
Dislocation	No treatment
Subluxation	No treatment
Femur (3)	
Periprosthetic fracture after a fall	Revision to longer stem femoral component
Periprosthetic fracture after a fall	Open reduction and internal fixation
Loosening after a fall	Revision of femoral component
Wound (1)	
Infection	Debridement, IV antibiotics, healing by secondary intention
Nerve (1)	
Peroneal nerve palsy	Closed management, recovered after 8 months

Extracortical bone bridging did not correlate with the overall functional score.

Complications (Table 4)

There were 9 complications in 7 patients. 2 patients had 2 complications. The patella was involved in 4 cases, the femur in 3 cases, there was 1 wound problem and one nerve injury. Of the 2 cases of patella maltracking, 1 was approached from the lateral and the other from the medial side.

Discussion

The Kinematic rotating-hinged knee joint prosthesis was designed to allow modular reconstruction of large femoral deficits after tumor resection. Incorporated in its design were several features aimed at minimizing mechanical failure. First, the articulation between femoral and tibial components allowed axial rotation as well as distraction. This was intended to reduce the potentially disruptive forces generated by a hinge. Secondly, a porous coating was applied to the segmental portion of the prosthesis that was adjacent to cortical bone to encourage bone ingrowth, biological fixation and a more graduated transfer of stress across the prosthetic bone junction, thereby reducing sudden changes in elastic moduli (Chao and Sim 1992). At the 8th International Symposium on Limb Salvage (ISOLS, Florence 1995), several presentations referred to the formation of a closed capsule of osseous or non-osseous tissue around the femoral prosthetic junction which they hypothesized may function as a "purse string" around the stem-bone interface to prevent wear particles from migrating into the space and thus initiating the biological loosening mechanism. Long-term retrieval and in vivo studies are required to validate this speculation. The articulation mechanism and the concept of extracortical bone bridging may help to reduce the loosening.

With regard to longevity, the failure of only 2 of 32 prostheses as a result of significant trauma at 5 years was encouraging. The incidence of failure in this series compares favorably with other short-to-medium-term studies. Horowitz et al. (1993) reported on 61 distal femoral reconstructions, using a cemented constrained prosthetic design. The event-free prosthetic survival was 59% at 5 years, the major cause being loosening. However, the limb survival in their series was 88% at 5 years, implying that failures may be successfully reconstructed in most patients. Shih et al. (1993) reported a failure rate of 34% at 5 years for the Walldius hinge-knee prosthesis. Loosening and stem fracture were the commonest causes. Zwart et al. (1994) reported 21 reconstructions, using the uncemented Kotz modular femur tibia reconstruction prosthesis. There were 2 stem breakages requiring reoperation and 2 amputations because of infection. Both stem breakages were in the same patient. The cause or site of the stem breakage was not reported. Of 17 survivors, 7 had been followed up for less than 20 months; therefore, the failure rate in that series could have been higher. The problem of bushing failure in the Kotz prosthesis, which may also be associated with debris synovitis, has been reported to be as high as 42% and may occur as early as 2 years after surgery (Capanna et al. 1994). Although some have recommended elective exchange of this component after 2–3 years to preempt bushing fracture, Capanna et al. (1994) have advised caution, because of the risk of infection. The rotating-hinge design may help to reduce the stresses to which the bushing is normally subjected.

Whether the low failure rate in our series may be attributed to the rotating hinge or the extracortical bone bridging is unclear. It would be interesting to speculate about the contributory role of both of these mechanisms in enhancing prosthetic longevity (Malawer and Meller 1991, Chao and Sim 1992). The impact of extracortical bone bridging of at least 25% in two thirds of cases will require a longer follow-up to assess.

The extracortical bone bridging was not uniform. This may be related to the different ways in which bone graft was applied to the porous-coated area. Bone graft was applied either as corticocancellous autograft strips bound to the host-porous-coated prosthesis junction with dissolvable sutures or as morcellized autograft packed against the porous surface. It is

our impression that more consistent and abundant extracortical bone bridging may be achieved with the former method. The large numbers of excellent or good results related to bone remodeling or interface radiolucent lines makes an analysis of the impact of extracortical bone bridging difficult. Some reports mention an unfavorable effect of chemotherapy on bone ingrowth, while others do not. The influence of chemotherapy on bone growth in this system is controversial. Friedlaender et al. (1984) demonstrated an adverse effect of short-term methotrexate and doxorubicin on bone turnover in a rat model. This finding was supported by a recent study of the effects of cisplatin on the incorporation of fresh syngeneic and frozen allogeneic cortical bone grafts in another rat model (Zart et al. 1993), which showed that the total bone incorporation in chemotherapy-treated rats was less than in those which did not receive chemotherapy. While these 2 studies were confirmed by a report in humans (Usui et al. 1993), that report found that eventual union occurred in all cases after further conventional bone grafts. In contrast, Aho et al. (1994) and Wang (1993) concluded that adjuvant chemotherapy had no major effect on the union rate of host-allograft bone.

The function was good or excellent in two thirds of our cases. If the prerevision scores (good) for the 2 patients who failed following trauma were recorded had an unsuccessful result instead of their classification as poor because of failure, the number of satisfactory functional scores would be better. Furthermore, the remaining patient who had poor function was scored accordingly because of widespread debilitating metastatic disease and not because of the prosthesis.

A complication rate that involved 7 patients out of 30 is comparable to other series (Horowitz et al. 1993, Capanna et al. 1994, Zwart et al. 1994) and was dominated by patella and femoral problems. Patella complications are not uncommon in knee arthroplasty and the problems of patella fracture, button fracture and maltracking are well recognized (Boyd et al. 1993, Levitsky et al. 1993, Keblish et al. 1994). This may be more significant following tumor resection, where large dissections and major resections of the quadriceps musculature may devascularize the patella or alter the normal biomechanical vectors (Capanna et al. 1994). Because of the patella problems encountered in our series and the fact that we found no difference in function between those who did or did not undergo patella replacement, we recommend only selective resurfacing of the patella to reduce any patella-associated complications. One should note that Tsuboyama et al. (1994) examined the knee function of 35 patients who had tumor endoprostheses inserted after distal femoral resection and found a slight decrease in muscle strength in those who did not have their patellae replaced. Whether this translates to better long-term function is not known. Muscle transpositions which are used to reconstruct defects in the quadriceps mechanism may be used to reduce the amount of patella maltracking. Femoral fracture, particularly after falls, is a risk in prosthetic arthroplasty. The alteration in the modulus of elasticity between normal bone and that which surrounds a metal prosthesis increases the stress that predisposes to fracture.

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