Is There a Role for Knee Arthrodesis With Modular Endoprostheses for Tumor and Revision of Failed Endoprostheses?

Andrea Angelini MD, Eric Henderson MD,
Giulia Trovarelli MD, Pietro Ruggieri MD, PhD

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Abstract

Background Knee arthrodeses are performed to treat infection after arthroplasty and tumors requiring extensive soft tissue resection. Many techniques have been described, but most have important disadvantages. Currently, endoprosthetic arthrodesis implants are available, but little is known about them.

Questions/purposes Our objective was to analyze a series of knee arthrodeses with a modular prosthetic system to evaluate (1) survivorship of the implant, (2) complications, (3) whether survivorship differed between arthrodeses done for primary tumor resection and revision reconstructions, and (4) whether survivorship differed based on the presence of previous infection or the use of a gastrocnemius flap.

Methods We present 32 patients with modular knee arthrodeses; arthrodeses were performed in 25 patients with

tumors and in seven patients without tumors. There were 14 implants done at the time of tumor resection and 18 for revision of failed implants. Survivorship and complications were analyzed with Kaplan-Meier curves. Log-rank test was used for comparison between primary and revision implants, not infected and previously infected implants, and use or nonuse of a gastrocnemius flap.

Results Survivorship of arthrodeses with modular endoprostheses was 50% and 25% at 5 and 10 years, respectively. There were nine infections (29%) and one implant fracture (3%). Amputation as final surgery was required in 8 patients (six owing to infection and two to oncologic failures). There was no significant difference in survivorship between arthrodeses done for primary tumor resection and as a salvage procedure for failed implants. No differences were found between patients with and without prior infection or with and without a gastrocnemius flap.

Conclusions Survivorship of a modular arthrodesis implant was 50% at 5 years owing to a high complication rate. Infection is the most common cause of failure of oncologic and revision implants. Implant fracture is a rare occurrence. Modular segmental arthrodesis provides a stable construct for patients in whom limb preservation is possible but a hinged device is contraindicated as a result of major muscle resection.

Level of Evidence Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

Arthrodesis of the knee has been performed since the late 1800s to treat posttraumatic arthritis and chronic sepsis [7]. Currently, the most common indications for knee

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A. Angelini, E. Henderson, G. Trovarelli, P. Ruggieri (✉)
III Department of Orthopedics, University of Bologna, Istituto
Ortopedico Rizzoli, Via Pupilli, 1, 40136 Bologna, BO, Italy
e-mail: pietro.ruggieri@ior.it

arthrodesis are chronic infection after arthroplasty and tumors requiring extensive resection of the bony and soft tissues about the knee, rendering the joint with inadequate soft tissue coverage and extensor mechanism loss [39]. In appropriate patients, arthrodesis provides pain relief, stability, and improved mobility [44]. Contraindications for knee arthrodesis include contralateral knee amputation and ipsilateral hip arthrodesis [44]. Many techniques for knee arthrodesis have been described, including the Charnley compression arthrodesis technique, Putti-Juvara technique, xenograft, external fixation, intramedullary nail with bone graft, intramedullary nail and cement, and segmental allograft [5–7, 12, 14, 21, 27, 28, 30, 35, 40]. Each technique has inherent disadvantages and can yield unpredictable and suboptimal results [5, 6, 9, 30, 40, 48]. To provide improved and more uniform outcomes, modular prosthetic arthrodesis systems were developed [3, 16, 48]. This type of system provides inherent advantages over conventional methods including immediate fixation and weightbearing and modularity allowing for segmental deficit reconstruction [44].

The aims of our study were (1) to evaluate the reconstructive survivorship and functional results after knee arthrodesis with a modular prosthetic system used for primary reconstruction and revisions; (2) to report the most common complications observed with this approach; (3) to analyze survivorship of the reconstruction comparing arthrodeses done for primary tumor resection or as a salvage procedure for prior implants about the knee; and (4) to analyze if survivorship differed based on the presence of infection or the use of a gastrocnemius flap.

Patients and Methods

After institutional review board and ethics committee approval was obtained, our institutional database was queried for patients who underwent arthrodesis of the knee with implantation of a modular prosthesis. From January 1975 to December 2011, 32 patients received arthrodeses with a modular endoprosthesis. Age at surgery ranged from 20 to 80 years with a mean of 52 years. Twenty patients were men and 12 patients were women. Oncologic indications for arthrodesis included periarticular tumors with extraosseous extension requiring extensor mechanism resection and failed segmental endoprostheses implanted for tumor indications (Table 1). Nononcologic indications for arthrodesis included failed TKA with segmental bone loss, inadequate soft tissue coverage, and extensor mechanism incompetence. Arthrodeses were performed for oncologic indications in 25 patients (14 primary implants at the time of tumor resection and 11 implants done for revision of other reconstructions) and for nononcologic indications in seven

Table 1. Characteristics of 32 patients treated with modular knee arthrodesis

Characteristic	Number of patients (%)
Sex	
Men	20 (63)
Women	12 (37)
Primary tumor site	
Distal femur	10 (31)
Proximal tibia	2 (6)
Distal femur and proximal tibia	6 (19)
Extrarticular	13 (41)
Total femur	1 (3)
Diagnosis	
Oncologic disease	25 (78)
Malignant	21 (84)
Osteosarcoma	8
Synovial sarcoma	4
Chondrosarcoma	3
Metastasis	3
Spindle cell sarcoma	1
Radiation-induced sarcoma	1
Malignant fibrous histiocytoma	1
Benign	4 (16)
Giant cell tumor	2
Pigmented villonodular synovitis	2
Nononcologic disease	7 (22)
Osteoarthritis	4
Rheumatoid arthritis	2
Charcot arthropathy	1
Indications	
Primary implants	14 (44)
Extrarticular tumor resection	12
Primary resection of recurrent pigmented villonodular synovitis	2
Salvage procedure for failed implants	18 (56)
Infection of modular megaprosthesis (GMRS [®] or HMRS [®])	5
Infection of TKAs for tumor indications	3
Infection of conventional TKA	7
Infection of transarticular intramedullary nail	1
Fractures of transarticular intramedullary nail	2

GMRS[®] = Global Modular Reconstruction System; HMRS[®] = Howmedica Modular Reconstruction System (Stryker Orthopaedics, Mahwah, NJ, USA).

patients (all salvage procedures for prior implant failures). Eighteen revisions to modular knee arthrodeses were performed: 11 for failed primary reconstructions after tumor resection and seven for failed implants used for nononcologic indications. Segmental endoprosthetic arthrodeses were performed for extraarticular knee resection in 13

Fig. 1A–E A 48-year-old man had distal femur radiation-induced sarcoma after radiotherapy for hemangioendothelioma of the left leg. **(A)** A preoperative lateral view radiograph and **(B)** an MR image show extensive cortical disruption with tumor extension in the soft tissue. **(C)** An AP view radiograph of the implant at 12 months after extra-articular resection and reconstruction with a MUTARS® arthrodesis prosthesis shows absence of radiologic evidence of loosening. **(D)** The lateral view radiographs at 12 months show the cemented stem in the tibia and **(E)** the press-fit femoral stem.

patients, replacement of the distal femur in 10 patients, the distal femur and proximal tibia in six patients, the proximal tibia in two patients (Fig. 1), and the entire femur in one patient. The latter was a patient with achondroplastic dwarfism and juvenile rheumatoid arthritis previously treated with hip and knee arthroplasties. He had an infection develop with failure of the knee arthroplasty and subsequently underwent revision surgery with a total femur custom-made prosthesis (hip arthroplasty and knee arthrodesis).

Histologic diagnoses in patients with oncologic indications were: osteosarcoma, eight patients; synovial sarcoma, four patients; chondrosarcoma, three patients; metastases, three patients; giant cell tumor of bone, two patients; pigmented villonodular synovitis, two patients; spindle cell sarcoma, one patient; radiation-induced sarcoma, one patient; and malignant fibrous histiocytoma, one patient.

The only modular arthrodesis system used in this series consists of a femoral stem, locking intercalary segment, tibial plate, and tibial stem (MUTARS®; Implantcast, Münster, Germany). Two intramedullary stem designs are available; one is intended for cementless fixation and the other for cement fixation. The cementless stem is constructed of titanium alloy with a microporous surface and also is available with a hydroxyapatite coating; the cemented stem is constructed of cobalt-chromium-molybdenum. All stems

are hexagonal in cross-section to prevent relative implant-bone rotation when torsional loading occurs; femoral stem designs are curved and straight. Nine patients underwent reconstruction with uncemented hydroxyapatite-coated implants and 23 with cemented implants. Two of the latter were silver-coated. All prosthetic implants described in this study (GMRS® and HMRS® [Stryker Orthopaedics Mahwah, NJ, USA] removed for failure, and MUTARS®, Implantcast used as the only knee arthrodesis system) were approved by the US FDA for use in clinical practice.

Surgical approaches were dictated by the tumor's location in patients receiving primary implants for oncologic indications. For revision indications, the previous incision was used. The minimum length of this implant system's intercalary span is 145 mm. In our series, the mean length was 172 mm (range, 145–205 mm). Five cases were performed using a medial gastrocnemius flap which was rotated anteriorly and used to cover the arthrodesis component. The five patients for whom a muscle flap was used were treated with extraarticular resection in two and proximal tibia resection in three. The three proximal tibia resections included primary resection in one patient and revision of previously infected implants in two patients.

All patients received perioperative antibiotics. Postoperatively, the patients with primary implants received a

broad-spectrum antibiotic for 30 days; patients who had revision surgery and previously had an infection with an identified pathogen received targeted antibiotics. Low-molecular-weight heparin was started on postoperative Day 1 and was continued for 30 days or until patients were bearing full weight. Weightbearing was begun on postoperative Day 30. At discharge from the hospital, all patients continued physical therapy with assisted walking for 6 weeks. In patients with oncologic indications, routine followups were performed every 3 months for the first 2 years, every 6 months for the next 3 years, and then annually. Patients with nononcologic indications were followed annually. Each followup included clinical examination, standard radiographs, and chest imaging as dictated by the patient's diagnoses. Major complications were defined as events causing failure of the arthrodesis reconstruction, failure of any component of the construct, removal of the prosthesis, or amputation of the limb. Infection was diagnosed by clinical history and physical examination (pain and signs of infection), increased laboratory values for erythrocyte sedimentation rate (> 30 mm/hour), C-reactive protein (CRP > 1 mg/dL), and white blood cell count and differential in joint fluid analysis (> 1700 cells/ μ L leukocytes and neutrophils $> 65\%$). Nuclear medicine as labeled leukocyte imaging was combined with bone or bone marrow imaging in patients in whom diagnosis of infection was doubtful. Treatment of infected arthrodesis (amputation, one-stage or two-stage revision) has been customized to the patient in relation to the onset of infection and general health. In patients in whom the infected modular prosthetic arthrodesis was removed, at least five intraoperative specimens were used for culture. Patients were interviewed periodically in the clinic at last followup or by telephone. Complications were analyzed and survival of the implants was evaluated using Kaplan-Meier actuarial curves and the log rank test. Comparisons were made between constructs implanted for primary and revision indications and whether infection had been present before implantation. Patients who died with their original implant in place were censored. Patients in whom the implant was removed during amputation for local recurrence were not considered as having failed results in the arthrodesis survival analysis, because these were oncologic failures. The starting point was defined as the date of implantation of the constructs and the end point as the date of revision or amputation. Statistical analysis was performed using the MedCalc Software Version 11.1 (MedCalc Software Broekstraat 52, Mariakerke, Belgium).

Results

The survivorship rates of arthrodeses with modular endoprostheses were 50% and 25% at 5 and 10 years respectively (Fig. 2). Thirty-one patients had a minimum followup of 9.5 years whereas one patient with an

oncologic diagnosis was excluded from further analyses because of inadequate followup (less than 1 month). Six patients had local recurrence and two of these patients (one treated for clear cell metastasis and one for radiation-induced sarcoma) underwent amputation for oncologic reasons after failure to control local recurrence.

No data regarding functional results were available for five patients who died during followup. Considering patients who retained their prostheses, 11 were able to mobilize independently and reported little or no pain, whereas the other three walked only with an assistive device. Of the 10 patients with major complications, three walked without pain and assistive devices, one required the use of a cane, and only three of six patients finally treated with amputation were able to walk using an external prosthesis. Of the two patients who had amputations for oncologic reasons, one died 6 months later and one was able to ambulate using an amputation prosthesis.

The most common complication in patients treated with an endoprosthetic modular arthrodesis was infection (nine patients) followed by implant fracture (one patient). No cases of aseptic loosening of implant components were observed. Considering that infection was the most common complication causing implant failure, it was considered as an event at the univariate comparative statistical analysis (Table 2). Infection free-survival rates of the implants were 60% and 30% at 5 and 10 years respectively (Fig. 3). Infection occurred in eight patients with oncologic disease (33%) at a mean of 2.7 years and in only one of the seven patients without an oncologic diagnosis at 3.6 months after surgery. Infections were treated with amputation or one- or two-stage revision. One-stage revision was used for early infections and consisted of irrigation, débridement, and immediate closure. Two-stage revision was used for late infections: the first stage consisted of surgical débridement, removal of components, and insertion of an antibiotic-impregnated cement spacer. At least five intraoperative specimens were used for culture. This was followed by antibiotic treatment based on microbiology results from the tissues and serial estimation of inflammatory markers. Antibiotics were discontinued 2 to 4 weeks after normalization of CRP and inflammatory markers were rechecked for at least 4 weeks. Second-stage reimplantation subsequently was performed. In cases of doubtful healing of infection, scintigraphy and histologic and microbiologic evaluations were performed before prosthetic replacement. As treatment of infection, one patient was treated with antibiotics alone, two received one-stage revision, three received two-stage revision, and three had amputations. Only three of six patients treated conservatively had limb salvage (two patients treated with two-stage revision and one with antibiotics only), while the others underwent amputation.

Fig. 2 The Kaplan-Meier actuarial curve shows survival to all major complications for 31 implants.

Table 2. Infection in 31 patients

Group classification	Patients	Infections	Incidence	Relative risk
Primary implants	13	3	23%	
Revisions	18	6	33%	1.4
Early infection (< 6 months)	–	3	10%	
Late infection (> 6 months)	–	6	19%	1.9
In patients without infection	15	4	27%	
In patients with previous infection	16	5	31%	1.2
Overall	31	9	29%	

Femoral stem fracture occurred 4.7 years after surgery in one patient with a nononcologic indication for arthrodesis. Two years later this patient required a second revision for femoral stem fracture. Therefore, amputation as a final treatment was required in eight patients (six owing to infection and two for oncologic failures).

Survivorship of the implants did not statistically differ between arthrodesis done for primary tumor resection compared with arthrodesis used as a salvage procedure for prior implants about the knee ($p = 0.860$) (Fig. 4). Infection occurred in three of 13 primary implants and in six of 18 revision implants. Two infections occurred within 6 months of surgery and were considered early, and six were late infections occurring at a mean of 42 months (range, 9.6–115.2 months).

Survivorship of the implants was not significantly influenced by the presence or absence of prior infection ($p = 0.938$) (Fig. 5). Sixteen patients underwent revision surgery for a previous infection; of these, there were five

subsequent infections after arthrodesis. Fifteen patients had no prior infection; of these, there were four failures attributable to infection. There was no significant difference in infection failures between patients with and without a gastrocnemius flap ($p = 0.516$) (Fig. 6). Multivariate analysis on survivorship of the implants also failed to show a significant difference for all of the three above-mentioned factors. Limb length discrepancy was studied at followup. Five patients had unequal limb lengths with a mean of 3.7 cm (range, 1–8.5 cm).

Discussion

Articular tuberculosis, sepsis, and poliomyelitis-induced instability were the primary indications for knee arthrodesis in the late 1800s and early 1900s; the most common indication today is failed, unsalvageable TKA [7, 45]. The introduction of effective adjuvant treatments for bone

Fig. 3 The Kaplan-Meier actuarial curve shows survival to infection for 31 implants.

Fig. 4 The Kaplan-Meier actuarial curves show implant survival to infection in 31 patients comparing arthrodesis in primary tumor resection and arthrodesis used as a salvage procedure for prior implants ($p = 0.860$).

sarcomas has led most orthopaedic oncologists to abandon arthrodesis in favor of articulating endoprostheses for limb preservation [26, 38, 41, 43]. The failure rate of these devices is much higher than for conventional total joint arthroplasty; therefore, managing their failures has created a new indication for segmental arthrodesis [18, 49]. The biomechanical demands on these arthrodeses are substantial and consequently the reported failure rates are high

[2, 5, 9, 20, 44, 45, 49]. We report the results of segmental arthrodesis with a modular, metallic implant system. Although infection leading to failure occurred in nearly $\frac{1}{3}$ of patients, the system showed long-term durability with only one implant fracture and no incidences of aseptic loosening if infection was avoided or treated. Moreover, none of the factors analyzed (primary tumor resection versus revision of prior implants, previous infections, or the

Fig. 5 The Kaplan-Meier actuarial curves show implant survival to infection in 31 patients comparing not infected and previously infected implants ($p = 0.938$).

Fig. 6 The Kaplan-Meier actuarial curves show implant survival to infection in 31 patients treated with and without a gastrocnemius flap ($p = 0.516$).

use of gastrocnemius flap) showed a significant influence on implant survivorship.

Our study has several limitations. (1) This study was retrospective and nonrandomized, subjecting it to potential recall and selection biases. (2) The investigation spanned 30 years, during which time adjuvant treatments, antibiotics, and other perioperative protocols changed, therefore introducing the possibility of confounding variables. (3)

There was heterogeneity of the patient population and indications for all patients were either oncologic or revision; therefore, surgical exposures were not standardized and were dictated by the tumor location or preexisting incision. (4) In some patients with oncologic disease, the implant was removed during amputation for local recurrences and this was considered an oncologic failure. (5) The series consisted of cemented and uncemented modular

Table 3. Knee arthrodesis with modular all-metal intercalary implants

Study	Prosthesis	Causes of arthrodesis	Number of infections/patients	Percentage
Bartlett et al. [3]	Stanmore knee arthrodesis*	Primary (tumors)	0/1	0
		Revision (TKAs)	0/5	0
		Revision (tumor)	1/4	25
Gosheger et al. [16]	MUTARS ^{®†}	Primary (tumors)	0/3	0
Current study	MUTARS ^{®†}	Primary (tumors)	3/13	23
		Revision (TKAs)	1/7	14
		Revision (tumor)	5/11	45

* Stanmore Implants Worldwide, Middlesex, UK; † Implantcast, Munster, Germany.

prosthetic knee arthrodeses. With such small numbers we decided to avoid dividing the series in two subgroups for survivorship analyses. (6) Although this study is the largest series of arthrodesis implants to date, it has only 31 patients with adequate followup and heterogeneous surgical indications, thereby limiting the power of the series to show potentially statistically significant trends. Moreover, considering the difficulty of analyzing large homogeneous series, a power analysis to determine how many patients in each group should be included to show a difference was not performed.

Many types of knee arthrodeses, especially after failed knee arthroplasty, have been reported [2, 6–13, 19, 22–24, 29–33, 36, 37, 44, 45, 47, 48]. The earliest biologic arthrodeses were performed using external fixation systems, intramedullary devices, and hybrid methods with union rates from 38% to 100% and different complications [1, 13, 17, 19, 22, 24, 32, 33, 36, 45, 48]. Vascularized fibulae have been used to augment arthrodesis reconstructions of all types with overall excellent results [29, 31, 37, 46]. Septic knee arthritis and failed, septic TKA often require débridement of large volumes of bone, necessitating structural intercalary segments to maintain limb length when arthrodesis is performed [25]. Autograft, in the form of femoral and fibular strut grafts, was the earliest use of interposition materials [21, 24, 35]. Structural bulk allografts also have been used; however, the union rate is generally lower than those for autograft and failures from infection and fracture are higher [4, 10, 25, 44]. Allograft composites have shown some promise in the medium term, but longer-term followup is required [44]. Polymethylmethacrylate bone cement also has been used in combination with plate and nail constructs to provide intercalary length. Capanna et al. [6] used this technique for staging their reconstructions to reduce infection and increase incorporation of allografts. Puri et al. [34] reported the results of definitive primary intercalary cement arthrodesis in 15 patients for whom an endoprosthesis was contraindicated, showing it as a stable construct.

The unsatisfactory results of large interposition grafts led surgeons to seek alternative constructs. The initial step toward a dedicated arthrodesis was introduction of the modular intramedullary nail [1]. To increase rigidity, subsequent nail designs showed expansion in girth at the junction site [48]. These designs, however, were unable to provide inherent intercalary support and required the addition of structural grafts or cement. Gosheger et al. [16] were the first to report the results of an all-metal, modular, intercalary arthrodesis implant (Table 3). Their series of three patients had no failures.

In a series of Stanmore knee arthrodesis prostheses (Stanmore Implants Worldwide, Middlesex, UK), Bartlett et al. [3] described 10 patients with nine receiving the device as a salvage procedure for an infected arthroplasty and one had a primary tumor resection. Complications with a minimum of 15-months followup included one infection resulting in amputation, one wound dehiscence, and one implant fracture. No patients were reported as requiring chemotherapy or other immunosuppressive measures at the time of surgery. Similar to the series of Bartlett et al., only one structural failure occurred in our patients. Combined with the results of other reported series, we conclude that the modular arthrodesis implant concept is structurally sound.

The failure rate in our series (approximately one in three) is higher than in series of primary articulating endoprostheses for tumor indications. In the largest series of endoprosthesis failures, the overall failure rate was approximately one in four [18], with an incidence of infection of 8.4% [18]. In our series of primary arthrodesis implants for tumors, the failure rate was three of 13 (23%). Tumor surgery is fraught with pitfalls that contribute to failure. Extensive dissections causing undermining of the subcutaneous tissues and gross removal of muscle lead to poorly vascularized skin and soft tissues, leading to less viable tissues that are vulnerable to infection; the addition of chemotherapy, radiation, and general patient deconditioning exacerbate this trend [15]. However, we did not

observe a significant difference between failure rates of primary arthrodeses for tumors compared with revision procedures of a prior implant with segmental bone loss.

Although success rates of 80% to 100% have been reported after primary, biologic arthrodesis in patients without prior TKA [9, 14, 19, 30, 31, 37, 44], the success rate of arthrodesis performed in patients with an infection at the site of a TKA has been reported to be much lower [8]. However better results in terms of complication rates have been reported using metal implants than biologic reconstruction [2, 8, 9, 11, 13, 23, 33, 42, 45, 47]. Whereas Gosheger et al. reported no infections in three arthrodeses with the MUTARS® implant [16] and Bartlett et al. reported one infection in 10 Stanmore implants [3], there were nine infections in our 31 patients. This finding might be because the mean followup for our series was substantially longer at 9.5 years compared with the other series and ¾ of our infections were late infections. In a longitudinal study of endoprosthetic reconstruction for treatment of musculoskeletal tumors (776 patients), Jeys et al. [20] reported that late infection is a common problem with the use of megaprotheses and that routine use of pedicled medial gastrocnemius flaps with arthrodesis or articulated implants of the knee have enhanced implant survival, dramatically reducing the infection rate. To reduce the infection rate, in 2003 we began using medial gastrocnemius rotation flaps to cover (when feasible) our arthrodesis implants; this practice also was used by Gosheger et al. [16]. Possibly because of low numbers, our series did not show a statistically significant correlation with muscle flaps and decreased infections; however, with strong results with articulated megaprotheses, we will continue to support their routine use.

A high complication rate was seen with use of a modular arthrodesis implant for oncologic and revision indications. Infection is the most common cause of implant failure for oncologic and revision indications for segmental arthrodesis implants. Implant fracture is a rare occurrence and other failure modes, although possible, were not seen in our series. Amputation as final surgery was required in most of the patients who had an infection (67%). Despite increased use of articulating modular endoprostheses for tumor resection, modular segmental arthrodesis provides a stable construct for patients in whom limb preservation is possible but a hinged device is contraindicated as a result of major muscle resection.

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