Megaprotheses for the treatment of malignant bone tumours of the lower limbs

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Abstract Lower limb salvage surgery remains a challenge in orthopaedic oncology. Both cemented and cementless, modular, endoprosthetic systems are widely used to treat defects of different sizes. The systems have changed over the years, and each major orthopaedic company offers a modular tumour and revision system for the lower extremities. All systems have worse long-term results compared to conventional total hip or total knee systems. This is due to the large defects that need to be bridged with a more difficult fixation in the diaphysis of the femur and tibia and a more complex restoration of joint biomechanics. This article summarises the results of several clinical studies with different systems. Newer systems without clinical follow-up are described. We previously reported a prospective study of 50 consecutive patients treated with the MUTARS endoprostheses. The follow-up was 2–7 years. Clinical evaluation showed good results compared to other systems. The review of the literature and our own results do not validate the support or favouring of one specific system. The surgeon should choose a system with which he/she is familiar and that provides the modularity needed intraoperatively to bridge any defect in the lower limbs.

Résumé Le sauvetage des membres demeure un challenge en oncologie orthopédique. Les prothèses modulaires, cimentées ou non, sont largement utilisées et chaque grand fabricant offre des systèmes pour reconstruction des membres inférieurs. Tous les systèmes ont de moins bons

résultats à long terme que les prothèses conventionnelles de hanche ou de genou. Ceci est due aux larges défauts osseux nécessitant la fixation dans les diaphyses fémorales et tibiales et la difficile restauration de la biomécanique articulaire. Cet article résume les résultats de plusieurs études cliniques avec différents systèmes. Nous avons rapporté une étude prospective de 50 patients traités avec une prothèse MUTARS, avec 2 à 7 ans de recul et un bon résultat comparable aux autres systèmes. La revue de la littérature et notre expérience ne permet pas de conseiller un système particulier. Le chirurgien doit choisir un système avec lequel il est familier et qui lui donne la possibilité opératoire de compenser les pertes de substances du membre inférieur.

Introduction

The treatment of massive bone defects caused by bone resection of tumours has changed over the years. If the oncological treatment is not impaired, limb salvage surgery is performed to avoid amputation whenever possible.

Reconstruction with modular megaprotheses plays the main role in the treatment of bone defects today, but remains problematic if outcomes are compared to primary total hip or knee arthroplasty [5]. A higher complication rate is well known and accepted because of the extended bone and soft tissue defects, the complex biomechanical reconstruction and the size of the implants [5, 7, 24].

With the growing number of revisions for conventional total hip and knee implants, a new market for megaprotheses has evolved, and a large number of modular and custom-made prostheses are available [9, 11, 14, 18, 19, 27]. Through the conversion from megaprotheses that were developed to treat malignant bone tumours to universal

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revision systems, all orthopaedic companies are offering modular tumour and revision systems today.

For clinically established systems, many studies have been reported, but the value of these studies has to be examined thoroughly. There are a few problems with the review of existing studies. No randomised controlled studies have been published yet. Most of the studies have been presented by the developers of the specific system or by their institution; independent studies are rare. The number of patients treated is often small, and the follow-up usually covers less than 10 years. In comparing one study with another, there are additional problems. The classification of complications is not uniform; the definition of minor and major complications varies. Some studies exclude deceased patients in the review, especially with regard to complications.

This article summarises results from different clinically established systems, newer systems and our own experience.

Established systems with clinical follow-up

KMFTRTM/HMRSTM (Kotz Modular Femur-Tibia Reconstruction System/Howmedica Modular Reconstruction System)

This system was one of the first modular systems and was developed in 1982 by Prof. Kotz at the Orthopaedic University of Vienna, Austria, [14–16, 22] and supported by Prof. Campanacci of the Rizzoli Institute of Bologna, Italy [3, 4, 21]. This system evolved into the HMR System, which has been available since 1990 (Stryker Corp., Mahwah, NJ). The advanced stem design is supported by only one screw plate (instead of two), the distal third of the stem is no longer porously coated, more stem sizes are available, and curved stems have been introduced. Additionally, the design of the polyethylene bushing of the hinge at the knee has been changed.

Most follow-up studies have come from Vienna and Bologna. Ritschl et al. [22] reviewed 206 tumour patients with a follow-up of 2 to 8 years (mean 3.2) who had been treated in these two centres. Of the patients, 27.1% required revision for infection, implant fracture, loosening, nerve palsies, postoperative fractures and dislocation (8.2, 6.8, 5.8, 2.4, 2.4 and 1.5%, respectively). One specific problem with the KMFTR was progressive wear of the PE bushing with subsequent loosening of the hinge in most of the patients after 7 years [22]. Mittermayer et al. reported the long-term results of 100 patients from Vienna [20]. After a median follow-up of more than 10 years (127.5 months), 51 patients had died and 8 were lost to follow-up. The remaining 41 patients had a follow-up of 138 months and were examined clinically and radiographically. The mean

Enneking Score was 80% [6]. The most common reason for failure was aseptic loosening in 27% of the patients ($n=11$), followed by infection ($n=4$) and implant fracture ($n=4$). The PE bushing was exchanged in ten patients.

There are only limited results with sufficient follow-up from other tumour centers around the world. Griffin et al. reviewed 99 patients with a median follow-up of 6 years (3.2–158.9 months) [8]. In 74 cases the distal femur and in the remaining 25 the proximal tibia were reconstructed. Eighteen of the 99 patients had complications directly related to the prosthesis that resulted in failure (10 deep infections, 6 stem fractures and 2 aseptic loosening). Additionally, 17 patients required further surgery because of complications. These included superficial wound infections ($n=10$), open reduction of periprosthetic fractures ($n=4$) and revisions for bushing wear ($n=7$).

With the modified HMR System only short-term results have been published to date. Ilyas et al. reported fewer wear problems in 48 patients with the newly designed PE bushing after a mean follow-up of 5.6 years [10]. Zeegen et al. reviewed 141 patients with a HMRS reconstruction after a mean follow-up of only 1.5 years (6 months–8 years) [28]. Reconstructions of the upper and lower limb were included. Unfortunately, they did not subdivide the group in relation to location, but they could show that at early follow-up, reconstructions of the shoulder or proximal femur fared better than reconstructions around the knee.

HSS (Hospital for Special Surgery)-modular-linked systemTM/FINNTM prosthesis

This system was developed at the Hospital for Special Surgery, New York, and distributed by Biomet (Warsaw, IN). Until 1988 it was a custom-made prosthesis and evolved to a modular system. That hinged design showed a high percentage of failure after a mean follow-up of 8.3 years (5–17 years) with aseptic loosening in 40% of the cases and a survival rate after 10 years of only 48% [13].

Another prosthesis distributed by Biomet was the FINN prosthesis, which was developed by Prof. Finn at the University of Chicago in 1989. This prosthesis, in contrast to the HSS design, featured a rotating hinge knee. In a follow-up study, Kawai et al. [12] compared both designs in 82 patients with a follow-up of at least 2 years. The HSS showed aseptic loosening in 31.4% ($n=51$; FU=7 years) compared to 6.5% in the FINN group ($n=31$; FU=3.2 years). The 5-year survivorship was 64% for the HSS prosthesis and 82% for the FINN prosthesis.

The experience with these two designs led to the development of the Biomet Oncology Salvage System (OSS, see below).

STANMORE™ prosthesis

The Stanmore prosthesis has the longest clinical history and was first implanted in 1949 [26, 27]. It is a custom-made prosthesis with cemented fixation. Since 1991 a cementless version has been available with a hydroxyapatite-coated titanium stem. Additionally, parts of the implant body are HA-coated to enhance extracortical bone bridging [1]. At the knee the single-axis hinged knee was changed to a rotating hinge. Unwin et al. reviewed 1,001 patients in whom the implant had been used up to 1993 with a mean follow-up of 46 months (3–287 months) [26]. The reconstruction was performed in 49% at the distal femur, 26% at the proximal femur and in a further 25% at the proximal tibia. The principal cause for failure was aseptic loosening with a rate of only 9.9% at the distal femur, 6.5% at the proximal tibia and 2.3% at the proximal femur. The probability of a patient surviving aseptic loosening for 10 years was 93.8% for a proximal femoral replacement, 67.4% for a distal femoral prosthesis and 58% for a proximal tibial implant. At the distal femur the risk of loosening significantly increased with the length of resection.

Bradish et al. [2] and Roberts et al. [23] also reported very low rates of revisions due to aseptic loosening in their long-term studies.

For the cementless design with HA-coating only short-term results have been reported to date. Blunn et al. reviewed 47 reconstructions at various locations (28 distal femur, 9 proximal tibia, 4 proximal femur, 5 humerus and 1 mid-tibia) and observed aseptic loosening in only one case after a minimum follow-up of 12 months.

GUEPAR™ prosthesis

This system was developed in Paris, France, and Mascalcard et al. reported the results in 90 patients with prostheses implanted between 1972 and 1993 [19]. It is a custom-made CoCr cemented prosthesis with a single-axis hinged knee. Some significant design changes were made over time. In 1977 a rotating hinge design was implemented with a PE bushing, which commonly tended to fail. In 1992 the original design was reintroduced. In the above-mentioned study, 102 prostheses were reviewed. The distal femur was the most frequent location, and an allograft-implant composite was used in 39 cases. The follow-up varied between 1 and 22 years with a mean follow-up of 4.3 years. Ten-year survivorship of the implant was 60%, but 94 revisions were necessary in the 90 patients. There were 13 aseptic loosening and 18 times wear of the axis with subsequent instability and an infection rate of 13%. The prosthesis had to be changed in 28% of the patients.

Newer developments without peer-reviewed clinical results

Orthogenesis LPS™ (Limb Preserving System)

The LPS is based on experience with the S-ROM knee system and the AML hip system (DePuy, Warsaw, IN). The system offers totally porous-coated stems in different sizes and shapes, resection adjustments in 5-mm increments and a load-sharing tibial hinge design. The polyethylene insert with the hinge articulates as a rotating mobile bearing to the polished tibial tray.

OSS™ (Oncology Salvage System)

The OSS system was developed on the basis of the FINN prosthesis. The OSS allows extended modularity from the proximal femur to the proximal tibia. The knee joint is still a rotating-hinge design with an axle-and-yoke mechanism. An axle rotates in a polyethylene bushing at the distal femur, and the tibial components accept a reinforced yoke that rotates in another polyethylene bushing. Diaphyseal segments are available in 2-cm increments as well as cemented and porous-coated cementless stems.

MOST Options™

The MOST system was introduced in the late 1990s and is distributed by Zimmer (Warsaw, IN). It allows the bridging of defects from the proximal femur to the proximal tibia with a rotating-hinge knee design. Diaphyseal segments are available in 12.5-mm steps.

Our own experience with MUTARS™

The prosthesis

The MUTARS system (Modular Universal Tumor And Revision System, Implantcast, Buxtehude, Germany) has been used in our hospital since 1995. Over this period, we prospectively followed up all patients who received a lower limb implant. With this modular system, it is possible to bridge any bone defect from the proximal femur to the proximal tibia. The fixation is achieved with an intramedullary stem, which can be inserted cementless or cemented. In the cementless version the stem is inserted press-fit in order to achieve sufficient primary stability. The stem has a rough surface with a pore size of 100 µm to allow the bone to grow onto the surface. The stem has a hexagonal cross section and is made of titanium alloy (TiAl6V4) in the cementless and of CoCrMo alloy in the cemented version. The stem is curved to follow the anterior

bow of the intramedullary cavity of the femur, and the correct size of the stem is determined preoperatively with templates on AP and lateral radiographs, or computer-assisted planning is available online through the company. At the knee a hinged system with minimal rotation is used with a metal pin-and-ball design in line with the axis of the tibia (Fig. 1). This axis on the tibial components fits into a polyethylene locking device. After insertion and fixation of the intramedullary stem, the prosthesis can be adjusted for rotation at the end of surgery in 5°-increments using an axial fixation screw.

Patients and evaluation methods

Since 1995 the MUTARS system has been implanted in more than 100 patients. The first 50 consecutive patients have been reviewed and presented previously [9]. The follow-up period was 2 to 7 years with an average of

46 months (SD±17). The most common location was the distal femur (20), followed by the proximal tibia in 14 and the proximal femur in 13 cases. In three patients a total femur was implanted (Fig. 2). The implant fixation was cementless in 27 cases, 7 stems were fixed with bone cement, and in 16 patients a hybrid fixation was performed. The mean length of the bridged defect area was 17.7 cm (6–39 cm; SD±6.8).

Results

Seventeen patients died during the follow-up due to their underlying malignancy. Thirty-three patients were followed up clinically for more than 2 years. A mean Enneking score [6] of 72% (33–100; SD=±19) was recorded at the last follow-up. Thirty-one patients (94%) had a score over 50%, which corresponds to a good or very good result.

All 50 patients were included in the evaluation of complications. Thirty-one (62%) patients presented 40 different complications. Thirty complications in 25 patients (50%) were treated with further revision surgery. The main complication was aseptic loosening in 11 (22%) cases. We looked at different variables influencing the incidence of aseptic loosening, but side ($P=0.117$), intra- or extraarticular resection ($P=0.368$), location ($P=0.385$), the use of cement for stem fixation ($P=0.467$), body mass index ($P=0.495$), gender ($P=0.56$), defect length ($P=0.561$), Enneking Score ($P=0.613$), range of motion at the knee joint (0.6172) and age ($P=0.761$) all showed no significant influence.

Five patients (10%) experienced dislocation of their constrained knee joint. The polyethylene locking that connects the metal post on the tibial plate with the distal femoral implant failed and the knee joint became unstable. All these patients had to be revised, and the polyethylene locking was exchanged.

Six patients developed deep infections (12%). Further complications included three dislocated hips, which were treated twice by open reduction and once by closed reduction.

Stress shielding around the stem was found in 17 of 34 patients with sufficient radiographic follow-up. These 17 cases with cortical bone resorption showed a higher incidence of aseptic loosening than cases without these radiological changes ($P=0.011$). No fractures around the bone-prosthesis junction occurred. Radiographically radiolucent lines according to the ISOLS poor or fair category were detected in 14 cases. These patients also had a significant increase of clinical loosening ($P=0.001$). Extra-cortical bone bridging in 11 patients showed no influence on the stability of the prosthesis or on the prevention of loosening ($P=0.359$).

Fig. 1 A 43-year-old patient after resection of a malignant fibrous histiocytoma of the distal femur. The cementless distal femoral fixation became loose and was changed to a cemented stem fixation. The lateral view shows the pin-and-ball hinge design of the knee

Fig. 2 A 20-year-old patient with Ewing's sarcoma. After resection of the tumour and implantation of an i.m. nail with allograft, exchange to a revision total hip prosthesis and subsequent infection, the patient was referred for the implantation of a total femoral prosthesis. With a follow-up of more than 10 years after diagnosis, the patient is still disease free

Discussion of the results

The good clinical results proved a sufficient function for the reported patient group. On the other hand, there are still a few serious problems associated with the implantation of tumour prostheses that have not so far been solved.

An infection rate of 12% in our group is comparable to the results in the literature where postoperative infection rates are reported to range from 2 to 13% [4, 18, 19, 27].

In five cases the prosthesis developed mechanical failure with unlocking of the insert that connects the tibial post to the distal femur. As a consequence the manufacturer has introduced a new locking mechanism. A close follow-up of this newly designed locking insert is necessary to see if this complication can be prevented.

Of greater concern was the aseptic loosening of the prosthesis in 11 patients because its cause remains uncertain. Larger prosthesis (= longer defect length) may increase the lever arm on the intramedullary fixed stem [26], and extraarticular resections with wide soft tissue resection or high activity (= younger age) [26] may additionally increase the stresses on the stem-bone and stem-cement interface. In our series we could not find a significant correlation between one of these factors and aseptic loosening. A longer follow-up and a larger number of patients may help to address this question.

Conclusions

Megaprotheses have a significantly higher failure risk than conventional total hip or knee systems [5]. This is demonstrated in the literature by the usually high complication rates for infection, mechanical failure and loosening. The complication rates in the literature range from 25 to 92% [4, 7, 11, 17–19, 25], but a comparison is not always possible due to the different definitions and classification systems used. Independent, well-controlled studies are rare.

Aseptic loosening as a complication is reported to be from 0 to 31% [4, 12], but most of the reported results lie somewhere in between.

The implantation of a megaprosthesis seems a valuable treatment for major bone defects at the lower limb despite the existing problems with fixation to the bone. Surgeons have to remember the problems and complications that can occur with any of the available systems. A patient-specific treatment is necessary, and the problems have to be discussed with the patients in advance. With regard to the published studies, the support of one specific system is not possible. Surgeons should choose systems with which they are familiar and provide the modular options needed intraoperatively to bridge any defects of the lower limb. Because of the difficulties with the implantation of such

highly modular systems and the known complications connected with the use of these systems, the treatment of patients with malignant bone tumours should only be carried out in specialised centres.

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