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Megaprosthesis in large bone defects: Opportunity or chimaera?

G.M. Calori *, M. Colombo, C. Ripamonti, E. Malagoli, E. Mazza, P. Fadigati, M. Bucci

Orthopaedic Institute, G. Pini, University of Milan, Italy

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ABSTRACT

Introduction: The development of new megaprosthesis for the treatment of large bone defects provides important options to orthopaedic oncologic surgeons for the replacement of skeletal segments, such as the long bones of the upper and lower limbs and the relative joints. We implanted megaprosthesis using either a one-step or two-step technique depending on the patient's condition. The aim of this study was to evaluate retrospectively both clinical and radiological outcomes in patients who underwent lower limb megaprosthesis implant.

Materials and methods: A total of 32 patients were treated with mono- and bi-articular megaprosthesis subdivided as follows: proximal femur, distal femur, proximal tibia and total femur. The mean follow-up of patients was about 18 months (range 3 months to 5 years). Clinical and serial radiographic evaluations were conducted using standard methods (X-ray at 45 days, 3, 6, 12, 18 and 24 months) and blood parameters of inflammation were monitored for at least 2 months.

Results: Although the mean length of follow-up was only 18 months, the first patients to enter the study were monitored for 5 years and showed encouraging clinical results, with good articulation of the segments, no somato-sensory or motor deficit and acceptable functional recovery. During surgery and, more importantly, in pre-operative planning, much attention should be given to the evaluation of the extensor apparatus, preserving it and, when necessary, reinforcing it with tendon substitutes.

Discussion: Megaprosthesis in extreme cases of severe bone loss and prosthetic failure is a potential solution for the orthopaedic surgeon. In oncological surgery, the opportunity to restore functionality to the patient (although not ad integrum) is important for both the patient and the surgeon. The high mortality associated with cancer precludes long-term patient follow-up; therefore, there is a lack of certainty about the survival of this type of prosthesis and any medium- to long-term complications that may occur. Nevertheless, patients should be considered as an oncologic patient, not because of the disease, but because of the limited therapeutic options available.

Conclusions: Megaprosthesis provides a valuable opportunity to restore functionality to patients with highly disabling diseases.

Introduction

Massive bone loss of the lower limb is a complex problem, particularly in patients who have already undergone many surgical procedures. Several clinical scenarios may be associated with massive bone loss, including severe trauma with multiple failed osteosynthesis with a non-union [1] or with a previous prosthetic replacement of a neighbouring joint; multiple revision of arthroplasty with or without infections, or large resection of tumours. There are various possible reconstructive strategies to treat bone defects, including autograft [2], allograft, biotechnologies [3,4] in mono or polytherapy [5,6,31–35], standard arthroplasty and, last but not least, megaprosthesis. The use of megaprosthesis to treat large bone segmental defects arises from biomedical application of metallurgical techniques in surgical oncology. The development of new megaprosthesis for large resections has provided important options to orthopaedic oncologist surgeons for the replacement of skeletal segments, such as the long bones of the upper and lower limbs and relative joints.

In our experience [7–11], treatment of non-unions and severe bone loss is not always successful, even with the use of advanced technologies, such as biotechnologies in mono or polytherapy. Although we still consider autologous bone graft (ABG) to be a gold standard for the treatment of some bone defects, this option has limited use because of infection, recalcitrant non-unions, presence of great bone deformity and/or nearby arthroplasty, even if more complex reconstructive strategies [12] are applied.

In 2008, we developed a classification system that enables the relevant risk factors affecting the patient, bone and soft tissues to

* Corresponding author at: G. Pini, University of Milan, P.za Cardinal Ferrari 1, 20122 Milan, Italy. Tel.: +39 02 58296903; fax: +39 02 58296905.
E-mail address: gmc@studiocalori.it (G.M. Calori).

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be recorded and assessed, and which can be used to derive prognoses for treatment indications. This system is called the Non-Union Score System (NUSS) [13,14]. The NUSS employs a score between 0 and 100 to enable surgeons to identify four groups of non-unions and, in cases of critical bone defects, to weigh up the treatment options of bone preservation and restoration of biomechanical function:

- Group 1 (score < 25): external shock wave therapy (ESWT), more stable osteosynthesis, etc.
- Group 2 (score 26–50): external fixator, more stable osteosynthesis, ABG, growth factors, osteogenic cells, scaffolds in monotherapy, etc.
- Group 3 (score 51–75): microvascular grafting, ABG, growth factors [15–17], osteogenic cells, scaffolds (available also in polytherapy), biological chamber, etc.
- Group 4 (score 76–100): arthrodesis, amputation, arthroplasty, megaprosthesis.

In non-unions with a NUSS score of 76 to 100, the severity of the injury and the clinical conditions are so serious that the surgical options of arthrodesis and amputation are usually implemented. The quality of life of patients with such non-unions is severely restricted: often the patient can no longer work as before, they may have psychological and social problems, and they have very restricted mobility. Significantly, many of these patients are relatively young and therefore have high expectations of their current medical and surgical care. Non-unions in this group are a major challenge for the surgeon. Furthermore, the health system has to provide considerable resources, including medical and nursing staff, rehabilitation time, and lengthy hospitalisation, because numerous follow-up operations are often necessary. The direct and indirect costs associated with patients in this group are especially high for the health system and society, particularly considering the demanding revision arthroplasty required in subsequent decades.

Faced with these drastic situations, and patients who did not consider amputation as a solution for their problem, we wanted to apply the principles of surgical oncology and try to recover the "extreme" cases with prosthetic replacement solutions [18–27]. We implanted megaprosthesis using either a one-step or two-step technique depending on the patient's condition. Implantation of megaprosthesis is not technically demanding, although we would not recommended it is conducted by inexperienced surgeons. Megaprosthesis enables a shorter rehabilitation programme compared with some reconstructive strategies and may circumvent the possibility of disease transmission; however, dilocation, instability and prosthesis failure can occur.

Method

The aim of this study was to evaluate retrospectively both clinical and radiological outcomes and any complications in patients who underwent lower limb megaprosthesis implant. From January 2008 to April 2013 a total of 32 patients were treated with mono-and bi-articular megaprosthesis subdivided as follows: 11 proximal femur, 13 distal femur, two proximal tibia and six total femur. Surgical reconstructions were conducted by one surgeon during this period. Clinical and serial radiographic evaluations were conducted using standard methods (X-ray at 45 days, 3, 6, 12, 18 and 24 months) and blood parameters of inflammation were monitored for at least 2 months. The mean follow-up of patients was about 18 months (range 3 months to 5 years). The mean age of the patients was 64 years (range 33–89 years). Of the 32 patients, 24 were female and eight were male.

Table 1
Patients in the study.

N	Patient	S	Age	*N* previous treatment	Aetiology	Sepsis	Length PRE-op (cm)	Length POST-op (cm)	Tendon device	Ag	Type	Complication
1	G.F.	F	44	3	NU	N	0	0	N	N	DF	N
2	G.M.F.	F	66	5	THR	Y	>2	0	N	Y	PF	N
3	B.G.M.	F	42	3	NU	N	<3	0	Y	N	DF	N
4	E.A.	F	68	1	NU	Y	<1	0	N	N	DF/TF	Fracture p-o
5	B.M.	F	72	2	THR	N	<2	0	N	N	PF	N
6	M.T.	M	64	1	NU	Y	0	0	N	Y	PT	N
7	B.P.	F	65	5	THR	N	<3	<1	Y	N	TF	N
8	B.M.T.	F	84	0	Fracture	N	<1	0	N	N	PF	N
9	P.F.	M	42	11	NUs	Y	<8	<4	Y	Y	TF	N
10	Z.L.	F	33	3	NU + Fracture	N	<2	0	Y	N	DF	N
11	P.A.	F	42	4	NU	N	<1	0	N	N	PF	Hip dislocation
12	C.A.	F	87	4	NU	N	<1	<1	N	N	PF	N
13	M.A	M	51	3	NU	Y	<5	<1	N	N	PF	N
14	U.G.F.	F	81	0	Fracture	N	<1	0	N	N	DF	N
15	S.L.	F	76	3	NU	N	0	0	N	N	DF	N
16	C.A.	F	70	7	NU	N	<5	<2	N	N	DF	N
17	V.A.	F	65	1	NU	N	0	0	N	N	PF	N
18	B.V.	F	89	0	Fracture	N	<8	<4	N	N	TF	N
19	B.M.	M	39	2	NU	Y	<2	0	N	N	DF	N
20	D.M.	F	43	3	NU	N	0	0	N	N	DF	N
21	L.E.	F	82	1	TKR	Y	0	0	Y	N	DF	N
22	L.A.	F	72	2	THR	Y	<4	<1	N	Y	PF	N
23	C.M.	F	71	2	NU	N	0	0	N	N	PT	N
24	G.C.	M	68	4	NU	N	<4	<2	N	N	TF	N
25	E.M.	F	76	6	NU	N	<1	0	N	N	PF	N
26	M.E.	F	70	0	Fracture	N	0	0	N	N	DF	N
27	B.M.S.	M	65	3	NU	Y	0	0	N	N	TF	N
28	P.F.	F	78	1	NU	N	0	0	N	N	DF	N
29	C.R.	F	49	2	TKR	Y	0	0	Y	Y	DF	N
30	A.M.	F	63	2	THR	Y	<1	0	N	N	PF	N
31	C.A.A.	M	72	8	NU	Y	0	0	N	Y	DF	N
32	L.M.B.	M	70	4	NU	N	<2	0	N	N	PF	N

NU, non-union; THR, total hip replacement; TKR, total knee replacement; DF, distal femur; PF, proximal femur; PT, proximal tibia; TF, total femur.

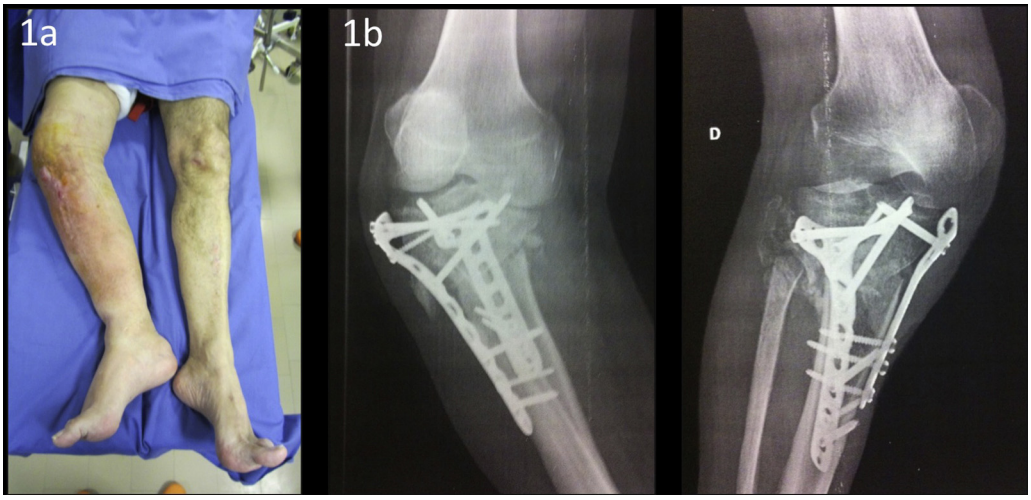

Fig. 1. (a) Clinical and (b) X-ray conditions of a 70-year-old male affected by proximal tibial septic non-union with varus deformity, device failures and high risk of septicaemia. NUSS: 82.

Surgical techniques and perioperative procedure

All patients received prophylaxis with endovenous Teicoplanin 800 mg 3 h before surgery and Cefazolin 2 g 1–1.5 h before surgery, unless bacterial culture indicated previous infection with another kind of microorganism. We implanted megaprosthesis using either a one-step or two-step technique depending on the patient's clinical and radiographic condition. A two-step technique was used where a better control of infections was required, for example, in cases of confirmed sepsis, or suspected infection that can be confirmed by clinical and laboratory tests (elevation of C-reactive protein [CRP], and other inflammatory indices). If there was doubt, a scintigraphic evaluation was conducted.

In both the one- and two-step procedures, we performed a complete resection of bone (the bone was usually poor quality and very deformed), a resection of granulation tissue and fibrotic material that surrounded non-union sites, and removed all foreign bodies. After resection and cleaning, we implanted a custom-made antibiotic-loaded cement spacer that enables infection control and helped us to create a membrane, according to the principles of the biological chamber, that creates a vital, aseptic and safe environment where the prosthesis can be implanted more safely and for longer.

All implants were inserted using a lateral approach for the proximal femur and, where needed, continued in a subvastus approach, preserving the extensor apparatus where possible and reinforcing it where needed with a customised tendon device. For the proximal tibia we performed a direct anterior approach, as used in total knee replacement. Previously, we have implanted prostheses coated with silver (PorAg^{TM} surface by LINK®) in infected patients, and these have decreased the infection rate [28].

All patients were mobilised on the second day following surgery. Partial weight-bearing was usually possible 2 months after surgery, and full weight-bearing was allowed 3 months after surgery following radiographical evaluation. Physiotherapy during the post-operative period comprised a programme of muscle

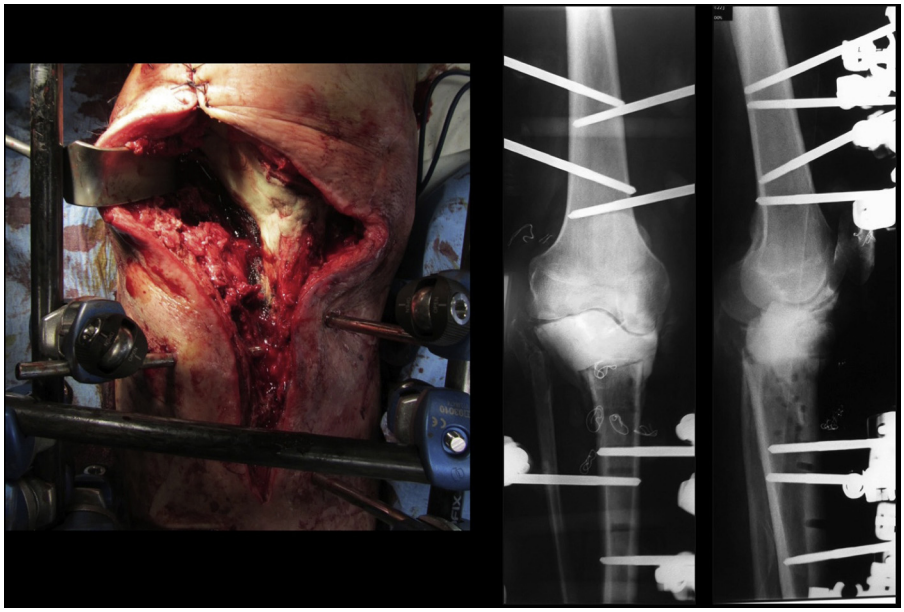

Fig. 2. Total resection of the necrotic and infected bone, deep debridement of the tissues, implantation of antibiotic-loaded cement spacer and stabilisation using external fixator.

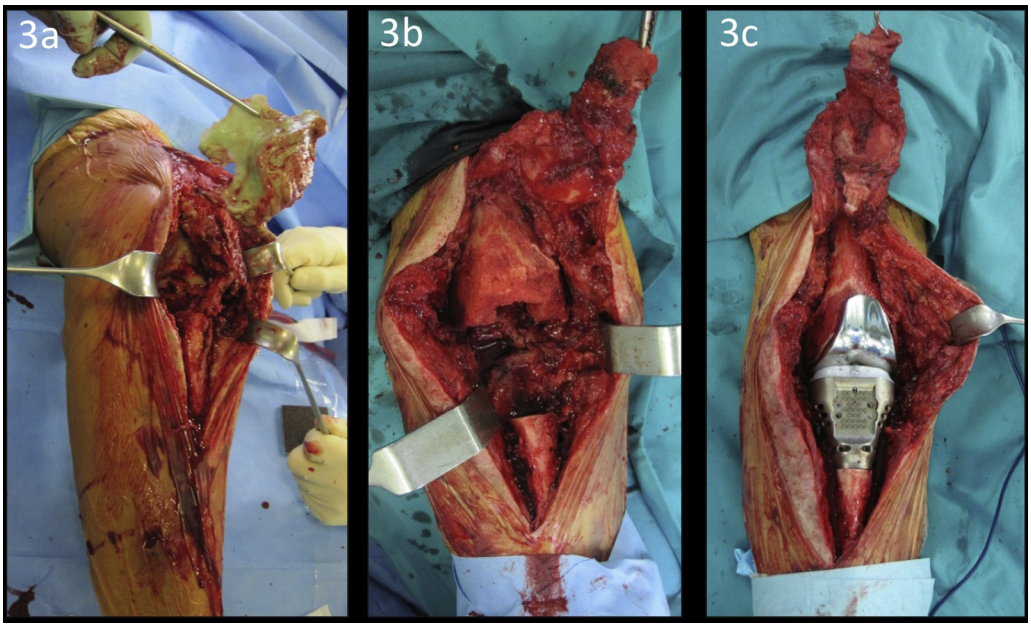

Fig. 3. After 3 months spacer removal (a) and resection of the femur and tibia (b) to implant the silver coated (PorAg™ surface by LINK®) megaprosthesis.

reinforcement that required a proper passive and active mobilisation to improve the range of motion of the joint treated (hip, knee or both).

Results

Although the mean length of follow-up was only 18 months, the first patients to enter the study were monitored for 5 years and showed encouraging clinical results, with good articulation of the segments, no somato-sensory or motor deficit and acceptable functional recovery. In the literature, there are reports of between 81.5% and 92% of limb salvage at 10-year follow-up in oncology patients. There was only one case of dislocation of the femoral endoprosthesis in a young patient with an elusive acetabulum; this patient was subsequently converted to arthroplasty with a good and stable result. Another complication in this study was a proximal femur periprosthetic fracture that occurred in the seventh post-operative day when a patient recovering from distal femur megaprosthesis fell accidentally. This patient required another operation to treat this complication: the distal femur megaprosthesis was converted into a total femur megaprosthesis because the patient had poor bone quality and arthritis, and the fracture was complex. The results of the study are shown in Table 1 and Figs. 1–5.

Discussion

The treatment of non-unions is always a challenge. Patients with a NUSS score of 51 or higher have usually been treated with ABG, but this treatment can be associated with complications such as pain or sepsis at the harvest site. Tissue regeneration techniques that use bone growth factors, multipotent mesenchymal cells and scaffolds are further options. An interesting alternative is the use of megaprosthesis, the advantages of which include improved patient

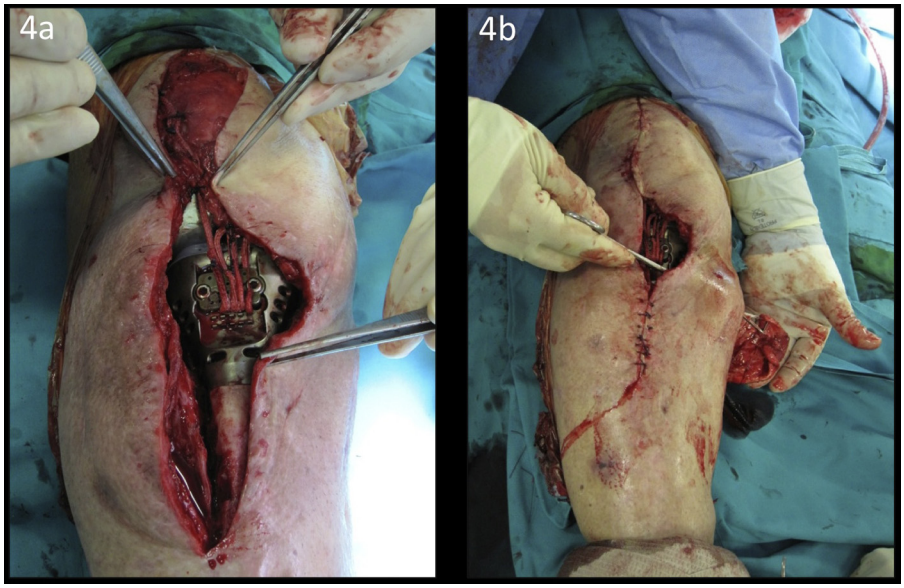

Fig. 4. Reconstruction of the extensor apparatus using tendon substitute devices (a) and muscular flap for closing the skin (b).

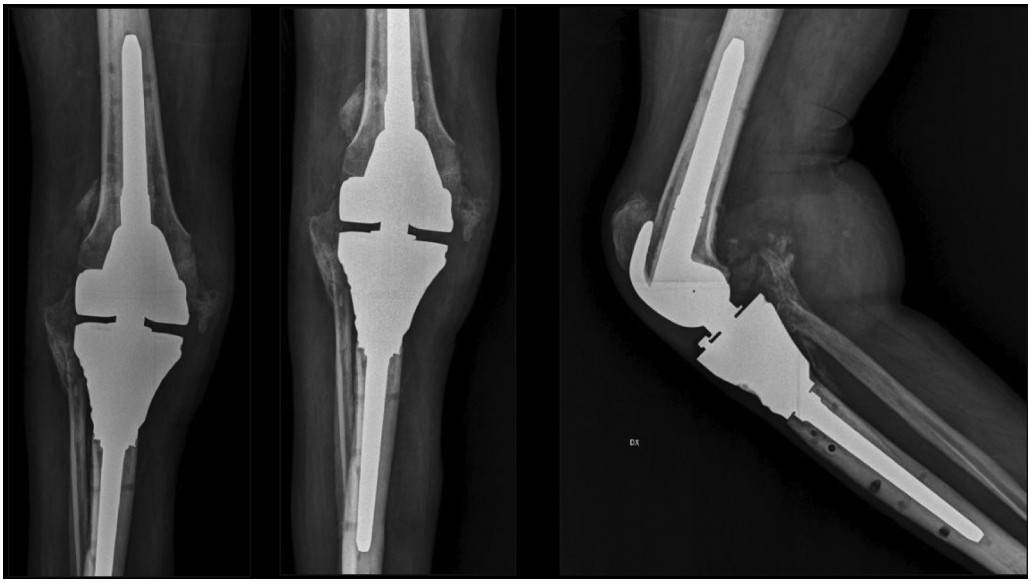

Fig. 5. Final X-ray images of the implant.

compliance, lower cost of surgery, reduced healing time and improved healing rate. During surgery and, more importantly, in pre-operative planning, much attention should be given to the evaluation of the extensor apparatus, preserving it and, when necessary, reinforcing it with tendon substitutes. Attention should also be focussed on the anatomical reconstruction on muscle such as gluteous and extrarotator of the hip or the ileopsoas that have to be preserved, where possible, with their bone insertion and linked with the prosthesis in their specific anchoring sites.

On the other hand, using these devices for limb reconstruction enables better management of limb length than is achieved with traditional reconstruction techniques. Megaprosthesis also allows better control and management than other solutions of torsional vices that can afflict long bone after a large number of previous failed treatments. Although megaprosthesis is considered a drastic solution, this kind of treatment enables the surgeon to find the best correction of lower limb deformity, taking into consideration the patient's expectations and restoring as far as possible the functionality of their injured limbs.

Conclusion

When treating critical bone defects, the patient's life situation and their level of compliance must be taken into account. The NUSS score is suitable for critically assessing whether bone preservation or rapid restoration of biomechanical function is the appropriate treatment strategy. The traditional techniques of stabilisation have their place here. Megaprosthesis in extreme cases of severe bone loss and prosthetic failure can be considered a potential solution for the orthopaedic surgeon, or is it still seen as a chimaera?

In oncological surgery, the opportunity to restore functionality to the patient (although not ad integrum) is important for both the patient and the surgeon. The high mortality associated with cancer precludes long-term follow-up of patients with large resections prosthesis [29,30]; therefore, there is a lack of certainty about the survival of this type of prosthesis and any medium- to long-term complications that may occur. Patients with severe post-traumatic deformities and/or significant bone loss who have had previous septic complications should be considered as an oncologic patient, not because of the disease, but because of the limited therapeutic options available. Megaprothesis should be considered a valuable opportunity to restore functionality to patients with highly disabling diseases. These patients should be treated in specialist centres, where all the technologies have been tested and undergo continuous improvement.

Conflict of interest statement

The authors have no conflicts of interest to declare.

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