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Research Article

Long Term Outcomes Using Global Modular Replacement System for Massive Bone Loss Around the Knee

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Abstract

Background/ Aims:

This study investigates long-term clinical and functional outcomes of the Global Modular Replacement System (GMRS) in patients with complex knee pathologies and massive bone loss.

Materials and Methods:

A cohort of 36 knees in 35 patients who underwent limb salvage using GMRS between 2007 and 2020 was retrospectively reviewed. The study assessed outcomes using the Knee Society Score (KSS), Oxford Knee Score (OKS), Musculoskeletal Tumor Society (MSTS) score, range of motion (ROM), and radiographic evaluations.

Results:

Significant improvement was observed across all measures at a mean follow up of 10.6 ±4.4 years. The KSS improved from 40.1 ± 21.6 preoperatively to 88.1 ± 6.4 postoperatively. Similarly, the OKS increased from 10.9 ±4.1 preoperatively to 39.7 ± 3.9 postoperatively, and the MSTS score rose from 9.9 ± 3.0 to 27.6 ± 3.3, indicating significant functional gains. The mean ROM improved from 62.8° ± 33.6° preoperatively to 96.1° ± 18.4° postoperatively. The overall complication rate was 14.28%, with no instances of aseptic loosening or mechanical failure.

Conclusion:

GMRS is a reliable and effective option for limb-salvage procedures in complex knee cases, offering substantial improvement in pain relief, knee function and mobility. It has low complication rates in the long-term follow-up.

Keywords: global modular replacement system; complex knee pathology; massive bone loss; limb salvage surgery; functional outcomes; revision knee surgery

Abbreviations:

GMRS- Global Modular Replacement System

KSS- Knee Society Score

OKS- Oxford Knee Score

MSTS- Musculoskeletal Tumor Society Score

TKA- Total Knee Arthroplasty

ROM- Range of Motion

DAIR- Debridement Antibiotic and Implant Retention

ORIF- Open Reduction and Internal Fixation

GCT- Giant Cell Tumor

Introduction

Advancements in medical oncology, surgical techniques, and reconstruction options have made limb-salvage surgery the preferred treatment over amputation [1,2]. Several reconstructive strategies are available for managing bone defects, including autografts, allogeneic bone grafting, bone transport, and the use of standard or megaprostheses. While modular megaprostheses are commonly used following bone tumor resection, they also provide an effective limb-salvage solution in complex cases following trauma and revision total knee arthroplasty (TKA) [3]. A key advantage of megaprostheses is their intraoperative flexibility, allowing surgeons to reconstruct large bone defects [3,4,5]. Early knee megaprostheses, featuring either fixed or rotating hinge articulation, were custom-made and primarily used for limb salvage after distal femoral or proximal tibial tumor resections [6,7,8]. However, technological advancements and growing expertise in limb salvage procedures have increased the demand for modular revision

implants. Systems like Global Modular Replacement System (GMRS), Mutars, Compress, Stanmore, and Exactech modular implants are integral to limb salvage surgeries, offering tailored solutions to address a wide range of bone deficiencies and ensuring effective treatments for patients with complex bone conditions [9].These implants are now used for metastatic disease, comminuted periarticular fractures, knee non-union following failed open reduction and internal fixation (ORIF), and salvage revision TKA [10,11,12,13]. The GMRS features a dual-axis **rotating hinge**, which better replicates physiological knee motion and minimizes torsional stress at the implant–bone interface, unlike fixed-hinge systems, which are associated with higher rates of aseptic loosening and mechanical complications [6, 7, 14]. It additionally offers extensive modularity and incorporates a hydroxyapatite-coated collar to promote biological fixation, contributing to its durability and favourable long-term outcomes in both oncologic and non-oncologic reconstructions [9, 15, 16]. A key strength of the present study lies in its inclusion of a heterogeneous cohort with diverse and complex indications ranging from oncologic resections to peri articular comminuted fractures, non- union and failed arthroplasties, all characterized by massive bone loss around the knee joint. This clinical diversity underscores the versatility and adaptability of the GMRS system in addressing extensive skeletal defects where conventional reconstructive options are insufficient.

The aim of this study was to evaluate the long-term clinical and functional outcomes of the GMRS in patients with complex knee pathology, not amenable to standard TKA implants.

Hypothesis: The use of the Global Modular Replacement System in complex knee pathologies with massive bone loss is a promising option and offers good outcomes that are sustained over a long term follow up.

Materials and methods:

Following institutional review board (IRB) approval, we conducted a retrospective study of 36 knees in 35 patients who underwent limb salvage surgery using the GMRS between 2007 and 2020. The study was conducted in accordance with the Helsinki Declaration. One patient underwent bilateral reconstruction. Data was collected from institutional records. The average follow-up was 10.6 ± 4.4 years (Range: 4 – 17).

Patient Demographics:

The mean age at surgery was 51.1 years (range: 15–75), with a median age of 55 years (IQR: 45–65).The cohort consisted of 29 females (82.9%) and 6 males (17.1%). Patient demographics are tabulated in **Table 1.**

Age	No. of patients	%
≤21 years	3 patients	8.6%
21–30 years	3 patients	8.6%
31–40 years	2 patients	5.7%
41–50 years	3 patients	8.6%
51–60 years	12 patients	34.3%
61–70 years	10 patients	28.6%
70 years	2 patients	5.7%

Table 1: Patient Demographics

Inclusion Criteria:

Patients with complex knee pathology unsuitable for conventional TKA, including:

- Aggressive peri-articular bone tumors
- Extensive bone loss due to metastatic disease
- Failed previous TKA with extensive bone loss (AORI classification Type 2B and 3)[17]
- Comminuted periarticular fractures
- Non-union after failed ORIF

Exclusion Criteria:

- Active systemic or local infection
- Inadequate soft-tissue envelope precluding reconstruction
- Severe neurovascular compromise

Patients underwent preoperative clinical evaluation, radiographic imaging, and oncologic staging when applicable. All procedures were performed by a single surgeon. The selection of GMRS components was individualized intra-operatively, tailored to anatomical and defect-specific considerations. Indications for using the GMRS components in this study included revision TKA, malignancies and Giant Cell Tumors (GCT) of the distal femur and proximal tibia, and peri- articular trauma around the knee. These indications are tabulated in Table 2.

S. No	Condition	Cases
1	Revision TKA	10
2	Distal Femur Osteosarcoma	8
3	Osteoblastoma Distal Femur	1
4	Chondrosarcoma Proximal Tibia	1
5	Distal Femur Metastases	3
6	Distal Femur Giant Cell Tumor (GCT)	4
7	Proximal Tibia GCT	1
8	Comminuted Distal Femur Fracture	3
9	Distal Femur Non Union	5

Table 2: Indications for GMRS

All patients operated for malignancies underwent intraoperative marrow biopsy and frozen section to confirm disease free margins.

Postoperative care followed a standardized rehabilitation protocol, with early mobilization based on intraoperative stability and patient-specific factors. Patients were evaluated at 3 months, 6 months, 12 months, and annually thereafter.

Outcome Measures:

- Knee Society Score (KSS) [18]

- Oxford Knee Score (OKS) [19]
- Musculoskeletal Tumor Society (MSTS) score [20]
- Knee range of motion (ROM), measured with a goniometer[21].
- Radiographic assessment at each follow-up to evaluate implant positioning, loosening, and complications such as infection or periprosthetic fracture.

Statistical Analysis:

Statistical analysis was conducted using SPSS version 24.0 (IBM Corp., Armonk, NY). The analysis included demographic profiling of patients, along with clinical and functional measures. Quantitative data were summarized as means with standard deviations, while categorical data were presented as absolute numbers and percentages. Preoperative and postoperative scores for the Knee Society Score (KSS), Oxford Knee Score (OKS), Musculoskeletal Tumor Society (MSTS) score, and range of motion (ROM) were compared using paired t-tests to assess significant changes over time. Cross-tabulation was performed, and Chi-square tests were used to evaluate associations between categorical variables. A p-value of less than 0.05 was considered statistically significant. The clinical relevance of improvements in functional scores (KSS, OKS, MSTS) and ROM was assessed using 95% confidence intervals (CIs) and mean differences. Additionally, complication rates were calculated as proportions.

Results:

Mean follow-up in years was 10.6 ± 4.4 years (Range: 4 – 17), and favourable clinical and functional outcomes were achieved in the majority of patients. The KSS, OKS and MSTS scores were further categorised into Excellent, Good, Fair and Poor based on classifications by Miralles-Muñoset al. [22], Edmondson et al. [23] and Enneking et al. [20] respectively.
KSS improved *from* preoperative values of 40.1 ± 21.6 to 88.1 ± 6.4 at the last follow up. This improvement was statistically significant with p<0.001, indicating substantial clinical and functional recovery.

- Excellent (90–100): 23 patients (65.7%)
- Good (77–89): 9 patients (25.7%)
- Fair (65–76): 1 patient (2.9%)
- Poor (<65): 2 patients (5.7%)

The *OKS improved from* 10.9 ± 4.1 preoperatively to 39.7 ± 3.9 at the last follow up (95% CI: −30.3 to −27.2; t = −38.000; p < 0.001).

- Excellent (OKS 40–48): 21 patients (60.0%)
- Good (30–39): 11 patients (31.4%)
- Fair (20–29): 3 patients (8.6%)
- Poor (<20): 0 patients (0%)

The **MSTS score** improved significantly from **9.9 ± 3.0** preoperatively to **27.6 ± 3.3** at the last follow-up ($p < 0.001$; 95% CI: –18.8 to –16.7; $t = -33.968$). The MSTS scoring system evaluates six parameters (pain, function, emotional acceptance, supports, walking, and gait), each graded 0–5, for a total maximum score of 30 [20].

- Excellent (23-30): 11 patients (31.4%)
- Good (21–22): 20 patients (57.1%)
- Moderate (18–20): 2 patients (5.7%)
- **Fair (15–17)**: 2 patients (**5.7%**)
- **Poor (<15)**: 0 patients (**0%**)

The mean ROM improved from 62.8° ± 33.6° preoperatively to 96.1° ± 18.4° at last follow up. (mean difference −33.3° ± 4.8°, 95% CI: −43.0 to −23.7; t = −6.997; p < 0.001).

All functional scores demonstrated statistically significant improvement from baseline, confirming the efficacy of GMRS in complex knee reconstruction across a spectrum of challenging indications.

The improvement in outcome scores is shown in Figure 1

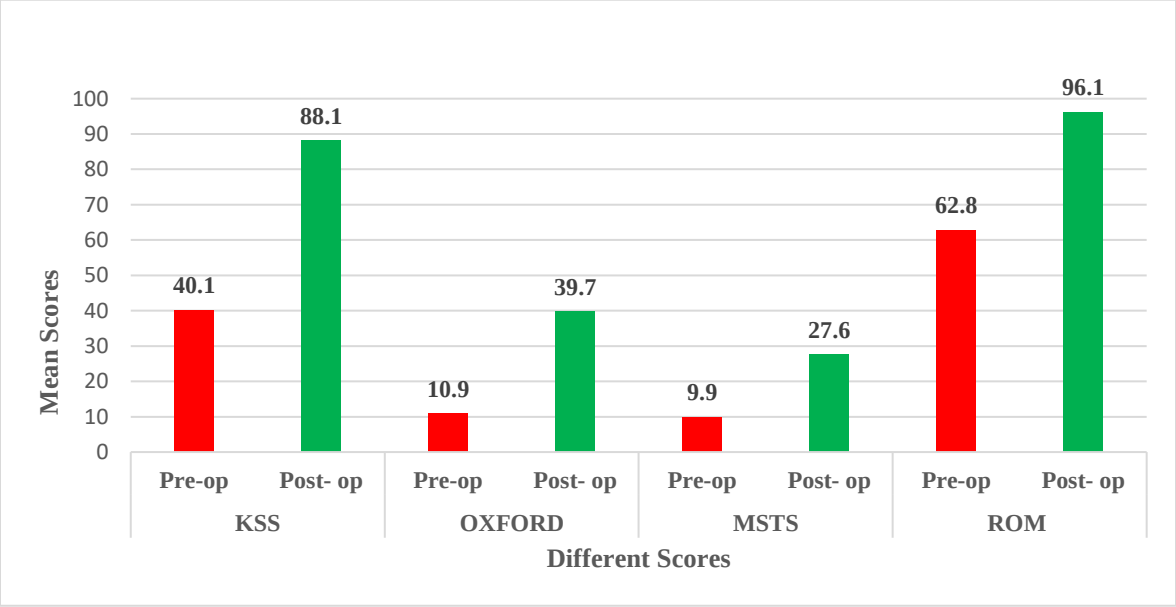

Figure 1: Improvement in Outcome Scores

The overall complication rate in our study was 14.28 %.

No cases of aseptic loosening, mechanical prosthetic failure, or periprosthetic fractures occurred during the follow-up period. Figure 2 shows pre and post-operative X-Ray images of a patient with osteosarcoma right distal femur at ten years follow up.

Figure 2: Pre- and Post-Operative X-Rays at 10 years

One patient, who underwent distal femoral replacement for osteosarcoma, required hip disarticulation for an aggressive recurrence.

One patient, with a distal femoral replacement for post traumatic bone loss, sustained a patellar tendon rupture following a fall eight years postoperatively which was successfully managed with surgical reconstruction using a Tendo Achilles allograft. One patient developed postoperative stiffness due to non-compliance to physiotherapy protocols. A deep surgical site infection occurred in one case and was treated with early debridement, antibiotics and implant retention (DAIR procedure). Intravenous antibiotics were administered for 6 weeks, followed by oral antibiotics for a further 6 weeks. One patient sustained an intraoperative popliteal artery injury during revision TKA, which was managed successfully with immediate vascular repair. Complications are tabulated in Table 3.

	Complications	Treatment	No. of patients
1.	Recurrence	Disarticulation	1 patient
2.	Patellar tendon rupture	Reconstruction of patellar tendon	1 patient
3.	Stiff knee	Refused intervention	1 patient
4.	Infection	DAIR and antibiotics	1 patient
5.	Popliteal artery injury intra-operatively	Vascular repair	1 patient

Table 3: Complications

Discussion:

The results of this study demonstrate that the GMRS offers favourable mid to long-term outcomes in patients with complex knee pathologies that are not amenable to standard TKA. Significant improvements were observed across multiple functional scores, including the KSS, OKS, MSTS score, and ROM, which were sustained over the study period. These favourable outcomes warrant further discussion in terms of their clinical relevance, particularly in comparison with existing literature. Our findings are similar to those of Capanna et al. [5], who reported excellent functional outcomes and high implant survival rates in patients undergoing lower limb reconstructions using modular megaprostheses. Bernthal et al. [4] reported high MSTS scores and acceptable complication rates for endoprosthetic reconstructions following tumor resection, consistent with our results, where 31.4% of patients achieved excellent and 57.1% achieved good MSTS outcomes. Holm et al. [24] reported an improvement in the MSTS score to 20.2 (67%) in a cohort of 72 patients at a mean follow up of six years. Our study demonstrated significantly higher MSTS scores, with a mean of 27.6 ± 3 (92%) at a mean follow up of 10.6 ±4.4 years, which was statistically significant. Pala et al. [14] reported an improvement in the functional MSTS score to 24.5 (81.6%), in a series of 295 patients, utilising the GMRS for reconstruction of bone defects, further supporting its efficacy. Nongdamba et al. [30] reported an average MSTS score of 28.35 ± 9 in 30 patients undergoing megaprosthetic reconstruction for tumors around the knee, with functional outcomes comparable to those reported by us. Marczak et al. [25], reported on a small cohort of nine patients (average age 73.7 years) achieving a mean KSS of 77.9 at a mean follow-up of five years, reflecting satisfactory functional outcomes. Our study demonstrated a more pronounced functional improvement, with KSS increasing from a preoperative mean of 40.1 ± 21.6 to 88.1 ± 6.4 postoperatively, with 65.7% of the patients achieving excellent results. Ben Bouzid et al. reported a lower average KSS of 58.4 in a series of 28 patients, corresponding to a poor functional outcome [32]. Despite the longer follow-up in our study, the consistently favourable results, particularly the high rate of excellent outcomes, highlight the efficacy and durability of the GMRS system in managing complex knee pathologies. These findings are further supported by Park et al. [6], who demonstrated high levels of patient satisfaction and prosthesis survival in cases managed with massive endoprostheses for metastatic bone disease, consistent with our observation that 91.4% of patients achieved good to excellent outcomes based on KSS. Appleton et al. [10] highlighted the utility of rotating hinge prostheses in elderly patients with distal femoral fractures, lending further support to the role of GMRS in complex fracture scenarios where conventional arthroplasty may not be feasible.

Literature reports a wide range of infection rates with incidences varying between 2% and 14% [14,15, 26, 27, 28]. In this present study, we observed a relatively low infection rate of 2.87%, which s comparable to some of the other studies [28]. Yilmaz et al. [15], in their nationwide cohort study of 119 patients, reported a 5-year revision rate of 14% and a 5-year amputation rate of 8%. In our study, while we had no revisions, one patient (2.87%) underwent a hip disarticulation due to recurrence of aggressive osteosarcoma in the distal femur. Both studies highlight favourable long-term outcomes for patients undergoing limb-sparing surgeries using GMRS. The differences in complication rates may be attributed to the inclusion of both oncologic and non-oncologic cases in our cohort. However, not all studies report uniformly positive outcomes. Unwin et al. [7] noted higher rates of aseptic loosening and mechanical failure in earlier generations of custom prostheses. This discrepancy may reflect advancements in modular implant design and surgical technique since the 1990s. Wunder et al. [8] observed mixed results in functional recovery, particularly following extensive oncologic resections, a subset less prevalent in our study population. Our results also compare favourably with those of Fakler et al. [11], who studied distal femoral replacements for complex fractures in 14 patients and reported moderate outcomes. We report higher mean functional scores and a lower complication rate, likely attributable to the use of GMRS components and a standardized surgical protocol. Jamshidi et al. [16] reported a 92% survivorship at five

years in his series of 21 patients. He also reported a complication rate of 28.6%. Sambri et al. in a systematic review of 2,598 cases involving megaprosthetic reconstructions, reported a complication rate of 19.7% [31]. In our study, the complication rate was significantly lower at 14.28%, with successful management of complications such as patellar tendon rupture and deep infection. Our outcomes reinforce that the GMRS is a more reliable option compared to other reconstruction methods in complex knee pathologies involving massive peri- articular bone loss. The absence of aseptic loosening in our cohort further underscores the mechanical reliability of GMRS in carefully selected patients. The rate of aseptic loosening in tumor prostheses varies from 2% to 11% [14, 27, 29], with extensor mechanism disruption being the most common complication, emphasizing the technical challenges associated with these complex reconstructions. The strength of this study lies in the inclusion of patients with diverse and complex indications involving massive bone loss around the knee joint and demonstrating the versatility of GMRS in addressing a broad spectrum of challenging clinical scenarios. Although the retrospective, non-randomized design and absence of a control group remain limitations, the heterogeneity of indications reinforces the generalizability and practical applicability of our findings across a wide clinical spectrum. It is noteworthy that the majority of comparable studies, such as those by Bernthal et al. [4], Marczak et al. [25], Holm et al. [24] and Jamshidi et al. [16] are based on relatively small patient cohorts, yet the consistency of their findings with ours reinforces the external validity and clinical reliability of GMRS in managing complex knee reconstructions.

Conclusion:

Given the promising results of this study, the GMRS should be considered an effective solution for complex knee reconstructions, particularly in cases where standard TKA is unsuitable. This study demonstrates good functional outcomes, with significant improvement in movements, pain relief and independent ambulation. However, future research with larger cohorts, multi centric randomized controlled trials and longer follow ups are needed to evaluate long- term outcomes and survivorship of this option.

Conflict of interest: None of the authors have any potential conflict of interest.

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