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Functional Outcomes and Complications of Megaprosthetic Reconstruction in Limb-Salvage Surgery for Musculoskeletal Tumors: A Scoping Review

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Learning Point of the Article:

Megaprosthetic reconstruction in limb salvage surgery achieves meaningful functional recovery; however, complication rates remain substantial and are influenced by anatomical site, implant characteristics, and duration of follow-up.

Abstract

Introduction: Limb salvage surgery (LSS) has replaced amputation in most cases of primary malignant bone tumors, achieving comparable oncologic control while preserving limb function and quality of life. Among reconstruction techniques, megaprosthetic replacement offers immediate stability, modular flexibility, and early rehabilitation potential. However, variability in tumor site, prosthesis design, and post-operative care continues to influence functional outcomes and complication rates across regions.

Materials and Methods: A comprehensive scoping review of studies published between 2014 and 2025 was conducted using PubMed, Scopus, Google Scholar, and EBSCO databases. Nineteen studies involving more than 600 patients who underwent LSS with megaprosthetic reconstruction for primary or recurrent bone tumors were analysed. Extracted data included patient demographics, tumor type, prosthesis characteristics, functional outcomes (musculoskeletal tumor society [MSTS], Toronto extremity salvage score [TESS], range of motion [ROM], gait parameters, Karnofsky Performance Status [KPS], return to work), and complications such as infection, mechanical failure, and aseptic loosening.

Results: Functional recovery was favourable, with mean MSTS and TESS scores ranging from 66% to 89%. Distal femur reconstructions demonstrated the highest functional outcomes (>80%), while proximal femur and humerus reconstructions showed slightly reduced scores (66–73%) due to soft-tissue limitations and reduced mobility. Improvements in ROM, gait symmetry, and KPS indicated successful restoration of biomechanics and independence. Complications included deep infections (5–24%), aseptic loosening (6–15%), and mechanical failures (up to 12.5%), most commonly in expandable implants. Despite these, limb retention exceeded 88% at 5 years, and long-term implant survival remained encouraging across different centers. Socioeconomic disparities and limited access to rehabilitation were identified as key factors affecting recovery and patient satisfaction.

Conclusion: Megaprosthetic reconstruction remains a cornerstone of modern LSS, providing durable oncologic safety and functional restoration. Early physiotherapy, infection prevention, and careful prosthesis selection are vital for optimising outcomes. Future studies should include standardized reporting of functional and psychosocial parameters and integrate socioeconomic factors to ensure equitable, patient-centred recovery worldwide.

Keywords: Bone tumour, endoprosthesis, functional outcome, limb salvage surgery, megaprosthesis, reconstruction.

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Introduction

Limb salvage surgery (LSS) has become the preferred treatment for primary malignant bone tumors of the extremities, replacing amputation in nearly 90–95% of eligible cases while achieving comparable oncologic control [1,2]. This approach emphasizes wide tumor excision, preservation of limb function, and improved quality of life for patients. The majority of these tumors occur in load-bearing bones, with the distal femur accounting for approximately 37% of cases, followed by the proximal tibia (19%), proximal humerus, and proximal femur [3]. The principal tumor types treated with limb salvage procedures include osteosarcoma, Ewing's sarcoma, chondrosarcoma, and giant cell tumors. Advances in neoadjuvant chemotherapy, cross-sectional imaging, and reconstructive techniques have significantly improved the safety and functional success of limb-sparing surgery, leading to 5-year survival rates exceeding 60–70% in non-metastatic osteosarcoma patients [4].

Restoring limb biomechanics and function following tumor resection remains a key challenge. Various reconstructive strategies have been developed, including biological options such as allografts, autografts, arthrodesis, and rotationplasty. However, modular endoprosthetic reconstruction (megaprosthesis) has gained the widest acceptance due to its intraoperative adaptability, immediate structural stability, and facilitation of early mobilization [5,6]. These implants are particularly advantageous for metaphyseal and epiphyseal lesions where joint preservation is not feasible.

Functional outcomes following megaprosthetic reconstruction are generally favourable, with 70–85% of patients achieving good to excellent results. Functional recovery has been most commonly assessed using the musculoskeletal tumor society (MSTS) score and, in several recent studies, the Toronto extremity salvage score (TESS). Other complementary indicators – such as range of motion (ROM), gait analysis (e.g., 6 min walk test or gait deviation index [GDI]), pain reduction, Karnofsky Performance Status (KPS), and return to work capability have also been reported, providing a broader understanding of post-operative functional restoration. Despite these encouraging outcomes, residual limitations, including restricted joint motion, gait asymmetry, persistent pain, and reduced activity levels, may still impact overall quality of life.

Complications remain a major concern. Deep infections occur in approximately 10–20% of cases, while aseptic loosening, mechanical failures, and periprosthetic fractures continue to threaten long-term prosthesis survival and may necessitate revision surgery or, in severe instances, secondary amputation [7]. These complications are influenced by tumor site, prosthesis design, and soft-tissue reconstruction Quality.

Given the complexity of reconstruction and variability in outcomes across anatomical sites, understanding functional recovery patterns, complication profiles, and prosthesis longevity is crucial for optimizing patient outcomes. Therefore, this review aims to synthesize current evidence on the functional and non-functional outcomes of megaprosthetic reconstruction following LSS, with particular attention to site-specific challenges and complication rates.

Materials and Methods

This scoping review was conducted according to the Arksey and O'Malley scoping framework [8] and reported with reference to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement to enhance transparency in study identification and selection. The study selection process is illustrated in the PRISMA flow diagram (Fig. 1) [9]. A comprehensive search was performed across PubMed, Scopus, Google Scholar, and EBSCO databases for studies published between January 2014 and May 2025, guided by the population, intervention, comparison, outcome

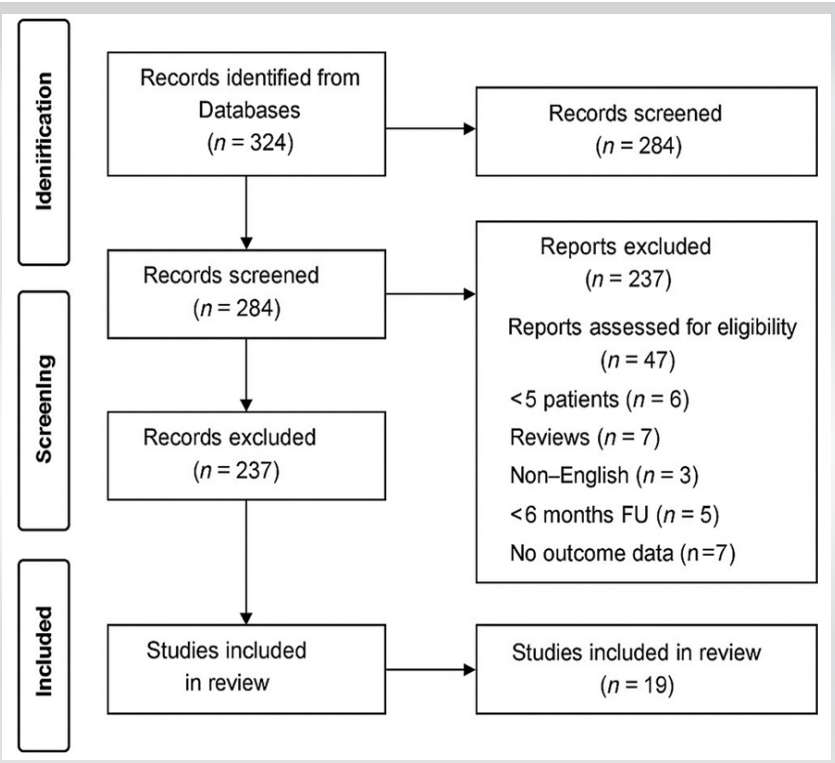

Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 flow diagram of study selection.

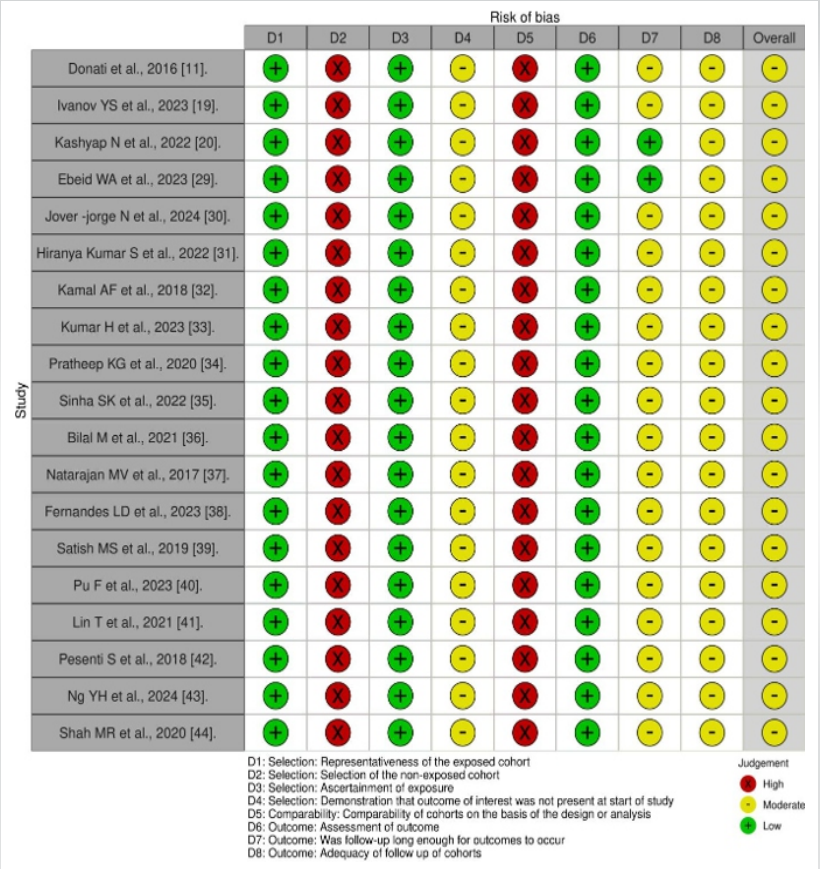

Figure 2: Risk of bias assessment of included non-randomized studies using the Newcastle Ottawa scale.

framework (Table 1). A structured combination of MeSH terms and keywords related to bone tumors, LSS, endoprosthetic or megaprosthetic reconstruction, and functional or complication outcomes was applied, with detailed search logic outlined in (Table 2). The initial search yielded 324 records, and after duplicate removal and screening, 47 full-text articles were assessed, of which 19 met the inclusion criteria. Eligible studies were English language publications (2014–2025), available in full text, focusing on LSS using modular or custom megaprosthetic reconstruction for primary or recurrent bone tumours, and reporting at least one functional outcome (e.g., MSTS, TESS, ROM, pain, or quality of life) and at least one complication outcome (infection, mechanical failure, aseptic loosening, or revision surgery). Excluded were studies with fewer than five patients, conference abstracts, reviews, non-English papers, non-extractable data, or follow-up shorter than 6 months.

Methodological quality and risk of bias of the included non-randomized observational studies were assessed using the Newcastle Ottawa scale (NOS) for cohort studies. The critical appraisal skills programme checklist [10] was used as a supportive framework to aid critical appraisal and interpretation of study findings. The assessment evaluated three key domains: Selection of study cohorts, comparability of cohorts based on study design or analysis, and adequacy of outcome assessment and follow-up. Risk of bias judgments for individual NOS domains were summarized and visualised using the risk of bias tool, employing a generic risk of bias framework. After the bias assessment, data were extracted using a structured template (Table 3) documenting study design, sample size, demographics, tumor type and site, prosthesis details, surgical margins, follow-up duration, functional outcomes, and complication profiles. Due to heterogeneity in study design, prosthesis models, and outcome reporting, results were synthesised through a qualitative narrative approach rather than meta-analysis. The review further analysed patterns in functional recovery, complication rates, prosthesis survivorship, and regional practice trends, while identifying gaps in evidence concerning long-term implant performance, rehabilitation protocols, and design innovation to inform future research directions.

Results

Study scope and patient demographics

This review included 19 studies published between 2014 and 2025, encompassing a total of 610 patients who underwent LSS with megaprosthetic reconstruction for primary or recurrent bone tumors. Patient ages ranged from 13 to 47 years, with several studies focusing on pediatric and adolescent groups receiving expandable prostheses. Geographically, India contributed eight studies, followed by China (three), Egypt (two), France (two), and one each from Spain, Bulgaria, Denmark, and Pakistan. Study designs comprised prospective cohorts, retrospective series, cross-

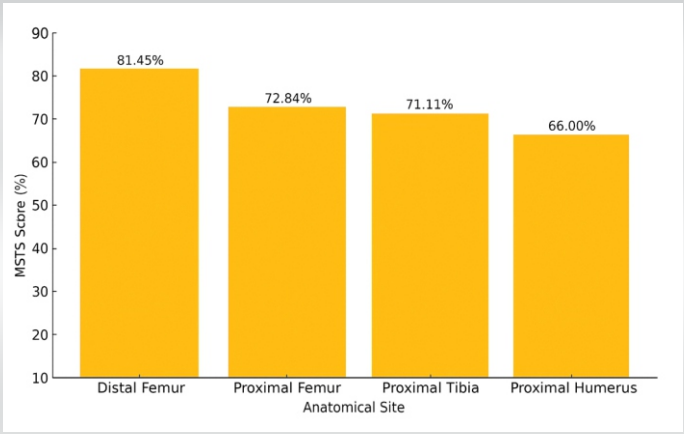

Figure 3: Mean musculoskeletal tumour society scores by anatomical site.

Table 1: The PICO framework guided search strategy and selection criteria	
Component	**Description**
Population	Patients undergoing limb salvage surgery for primary or recurrent bone tumours
Intervention	Metaprosthesis or megaprosthesis reconstruction using modular endoprosthesis
Comparison	Historical cohorts or alternative limb salvage techniques
Outcomes	Functional outcomes (MSTS, TESS, ROM, gait), psychological recovery, pain relief, return to work and complications
PICO: Population, intervention, comparison, outcome, MSTS: Musculoskeletal tumor society, TESS: Toronto extremity salvage score, ROM: Range of motion	

sectional, and case–control studies, with follow-up durations ranging from 6 months to more than 8 years.

Risk of bias assessment

Overall, the included studies demonstrated predominantly moderate risk of bias across NOS domains. Most studies showed low risk in selection representativeness and outcome assessment, reflecting well-defined cohorts and the use validated functional outcome measures. However, comparability between cohorts was frequently limited due to a retrospective study design and a lack of adjustment for confounding variables. In several studies, the absence of a clearly defined non-exposed comparator group contributed to higher risk ratings in selection-related domains. Follow-up duration and adequacy were generally moderate, with variability in reporting of loss to follow-up. A summary of the domain-specific risk of bias assessment is presented in Fig. 2.

Surgical techniques and prosthesis types

Across the included literature, both modular and custom megaprostheses were used, with common systems including MUTARS, RESTOR, GMRS, and silver-coated or cemented variants. Modular implants predominated in India, China, and Egypt because of their cost-effectiveness, intraoperative adaptability, and ease of revision, whereas custom implants were favoured in European centers for precise anatomical reconstruction in complex resections. Silver-coated prostheses demonstrated lower infection rates (7.9% vs. 16.7%) and improved revision-free survival [11,12], while cemented fixation allowed earlier weight bearing and faster mobilization. Modular systems also facilitated simpler revision procedures in cases of loosening or mechanical failure [13,14,15].

Functional outcomes

Functional recovery was favourable, influenced by rehabilitation intensity, early mobilisation, prosthesis design, and anatomical site [16]. The MSTS score was the predominant outcome tool, while three studies also used the TESS. Additional parameters such as ROM, gait and biomechanical analysis (6-min Walk Test, Timed Up and Go, GDI), pain scores (Visual Analog Scale), KPS, and return to work or activities of daily living measures were variably reported.

Across all cohorts, MSTS/TESS scores ranged from 66.6% to 89.7%, indicating good to excellent limb function. The distal femur remained the most frequently reconstructed site and consistently yielded mean MSTS scores exceeding 80%, attributed to better biomechanics, soft-tissue coverage, and structured physiotherapy [17]. Proximal femur and proximal humerus reconstructions showed lower functional scores (66–73%), reflecting abductor weakness and limited joint mobility [18,19] (Fig. 3). ROM data were reported in eight studies, with mean knee flexion ranging between 80° and 110° post-rehabilitation, extension lag of 5–20° in proximal tibial cases, and shoulder abduction between 70–90° after proximal humeral reconstruction. Biomechanical assessments were presented in three European studies, which demonstrated near-normal gait kinematics with GDI values of 86–89 compared to 94 in healthy controls and mildly prolonged 6MWT and TUG times. In Pu et al. (2023), KPS improved significantly from 50 preoperatively to 70–90 postoperatively, indicating restored independence. Early physiotherapy and weight bearing within 6–8 weeks were consistently associated with superior function, faster gait recovery, and higher satisfaction [20].

Non-functional outcomes

Non-functional results, including oncologic control, prosthesis

Table 2: Keywords	
Search domain	**Keywords and synonyms**
Bone tumours	Osteosarcoma, Ewing sarcoma, Chondrosarcoma, giant cell tumour, Bone neoplasm
Limb salvage surgery	Limb preserving surgery, endoprosthetic resection, megaprosthesis, modular implants
Functional outcomes	MSTS, TESS, mobility, gait, range of motion (ROM), rehabilitation
Quality of life	Psychological acceptance, pain relief, return of work, and daily activity resumption
MSTS: Musculoskeletal tumor society, TESS: Toronto extremity salvage score	

Table 3: Data extraction table [11, 19, 20, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43]

Author and year	Study design and location	Sample size	Demographics	Tumour type	Site	Indication	Type of prosthesis	Surgical margin	Follow-up duration	Functional outcome	Non-functional outcome	Complication	Limb survival	Prosthesis survival	Conclusion
Donati *et al*., 2016 [11].	Retrospective study, Italy	68 patients	Mean age 61.6 years, 31 M, 37 F.	Primary bone tumours (23)- OS ES, CS, malignant fibrous histiocytoma, GCT, metastatic bone tumours (45)	Proximal femur	Oncologic limb salvage surgery.	Silver coated hip hemiarthroplasty (55.9%) versus uncoated megaprosthesis (44.1%).	Wide resection	Mean 46.5 months	MSTS score comparable between silver coated and uncoated prosthesis; mobility, pain reduction and overall recovery showed no significant difference.	No signs of local or general silver toxicity reported.	Infection (11%); 7.9% silver coated, 16.7% uncoated), prosthesis degradation observed after 6–18 months.	Majority retained limb function, silver coated implants showed reduced early infection rate.	Silver degradation observed over time, reducing antimicrobial efficacy.	Silver coated prosthesis lower early infection rate but antimicrobial effects diminish over time due to wear; recommended for primary implantation in limb salvage surgery.
Ivanov and Tsenkov 2023 [19].	Retrospective analysis, bulgaria	14 patients	10 males, 4 females.	ES (7), OS (4), GCT (1), CS (1), CB (1)	Humerus, tibia, femur. most common: distal femur.	Primary malignant bone tumour.	Modular tumour prosthesis (mutars, mutars xpand).	Wide resection (AJCC system)	Mean 38.5 months. (8–96 months).	MSTS score: 70%	Improved quality of life, early rehabilitation, weight bearing possible.	Local recurrence (3), distant metastases (4), surgical wound necrosis (3), peripheral nerve paralysis (1), mechanical failure in expandable prosthesis (1).	Majority retained limb function, 2 patient deceased due to disease complication.	Aseptic loosening, mechanical failure.	Modular tumour endoprosthesis provide excellent functionality and improved quality in patients.
Kashyap *et al*., 2022 [20].	Retrospective cohort study, india.	28 patients	Mean age: 30.0±10.9 years (range 18–60); 22 males, 6 females.	GCT (53.6%), OS (25%), multiple myeloma (3.6%), chondromyxoid fibroma (3.6%)	Distal femur (57.1%), proximal femur (32.2%), proximal humerus (7.1%), proximal tibia (3.6%).	Limb salvage surgery for benign/malignant bone tumors.	Modular segmental-replacement system prosthesis.	Wide resection confirmed via MRI and biopsy.	Median: 80 months	Mean MSTS score: 25.0±4.3; proximal femur: 25.0±4.8, distal femur: 26.6±1.4, proximal tibia: 16.5±6.4.	Mean MSTSscore: 25.0±4.3; proximal femur: 25.0±4.8, distal femur: 26.6±1.4, proximal tibia: 16.5±6.4.	Leg length discrepancy (25%) delayed wound healing (7.1%), popliteal artery injury (7.1%), extension lag (10.7%), recurrence (7.1%).	83.7% relapse-free survival at median follow-up.	83.7% at 80 months.	Modular prosthesis ensures satisfactory tumour control and limb function; case selection is key.
Ebeid *et al*., 2023 [29].	Retrospective study, egypt	55 patients	30 M, 25 F, mean age: 19 years.	Proximal tibial osteosarcoma	Proximal tibia	Limb salvage surgery	Modular endoprosthesis.	Wide resection	Mean: 71.69 months	MSTS score: Mean 26.5±2.22; mean rom: 72.63±25.07; mean extension lag 15.09±15.38.	Psychological benefits of limb salvage surgery; improved early weight bearing.	Soft-tissue failure (7.3), aseptic loosening (14.5), structural failure (21.8%), periprosthetic infection (23.6%), local tumor progression (5.5%), lung metastasis (18.2%).	5-year: 88.2%; 10-year: 88.2%.	5-year: 88.2%; 10-year: 88.2%.	Modular endoprosthesis is a reliable limb salvage option; most complication are manageable.
Jover-Jorge *et al*., 2024 [30].	Case–control study, spain.	31 patients, 48 controls (healthy).	Mean age: 39.3 years (patients), 42.4 year (controls), 17 M, 14 F.	OS, CS, GCT, plasmacytoma, undifferentiated soft-tissue sarcome	Distal femur	Musculoskeletal tumours	Distal femur megaprosthesis (cemented, cementless, osseointegration system.	N/A	49.3 months	MSTS score: 22.2 (range 4–29).	SF-36 physical component significantly lower than controls; mental component comparable to control.	Knee extension weakness, reduced knee flexion rom, limb length discrepancy, aseptic loosening, infection, recurrence.	Majority retained limb function, 5 patients deceased due to disease complication.	Aseptic loosening, recurrent surgery requirements.	Knee extensor strength and ROM strongly influence functional recovery; rehabilitation should prioritise strength and mobility.
Kumar *et al*., 2022 [31].	Prospective study, india	64 patients	38 M, 26 F, age range - (14–54 years).	GCT (primary 28, recurrent 12, OS (stage iia: 6, iib:8), chondrosarcoma (10)	Distal femur (34), proximal tibia (30).	Musculoskeletal tumour	Modular tumour prosthesis (zenior system).	Wide excision with acceptable margin (enneking staging system).	5-year follow-up.	MSTS score: Distal femur (76.4%), proximal tibia (71.11%), overall (73.96%).	Majority returned to work, functional limb retention.	Surgical site infection (15.6%), skin necrosis (9.3%), aseptic loosening (4 patients), recurrence requiring amputation (1 patient).	Majority retained limb function; 1 patient required amputation due to recurrence.	Aspetic loosening	Modular tumour endoprosthesis provide good functional outcome around knee; long-term patient survival remain consideration.
Kamal *et al*., 2018 [32].	Prospective case series, india.	32 patients	17 M, 15 F, age range 13–64 years.	OS (14), metastatic bone disease (2), gct (13), chondro myxoid fibroma (1)	Distal femur (15), proximal tibia (13), proximal femur (4).	Oncologic limb salvage	Megaprosthesis reconstruction	Wide excision with acceptable margin (enneking staging system).	24 months	MSTS improvement from mean 5.3 (pre-op) to 25.2 (post-operative).	Quality of life improved, pain reduce.	Infection, knee dislocation, nerve injury, recurrence, periprosthetic fracture.	Majority retained limb function; 4 patient deceased.	Soft-tissue reconstruction and infection.	Megaprosthesis is effective but has complications; geographic barriers impact follow up care.
Kumar *et al*., 2023 [33].	Prospective study, India	32 patients	14 M, 28 F, mean age 31 years.	GCT (17, 53.1%), OS (9, 28.1%), secondary tumours (5, 15.6%), fibrous dysplasia (1, 3.2%)	Proximal femur	Oncologic limb salvage surgery.	Modular endoprosthesis	Wide excision with acceptable margin (enneking staging system).	5 years (2012–2019)	MSTS score: 72.84% overall, evaluating gait, walking, emotional well being, pain, function.	Improved quality of life, mobility recovery, pain reduction.	Infection (12.5%), dislocation (6.25%), aseptic loosening (6.25%), no amputations reported.	All patients retained limb function, no major loss.	Survivorship affected by soft-tissue attachment, infection, mechanical failures.	Modular endoprosthesis is an effective limb salvage option, improving function and quality of life.
Pratheep *et al*., 2020 [33].	Prospective study and retrospective study, India.	20 patients	14 M, 6 F, range 11–50 years.	OS (9), GCT (9), chondrosarcoma (1), solitary plasmacytoma (1)	Distal femur (12), proximal tibia (6), proximal femur (2).	Oncologic limb salvage	Custom-made endoprosthesis	Wide excision	Min. 6 months, maximum 5 years (mean 2.6 years)	MSTS score: Mean 66.55%; 6 patients excellent (>70%), 12 good (60–69%), 2 fair (50–59%).	Emotional acceptance lower due to prosthesis weight.	Nerve palsy (3), wound dehiscence (1), recurrence (1), prosthesis breakage (1), pulmonary metastasis (2).	19 patients retained limb function, 1 required amputation.	Affected by infection and mechanical failure.	Custom made endoprosthesis is effective for limb salvage, but outcomes are influenced by surgical expertise and rehabilitation.
Sinha *et al*., 2022 [34].	Prospective study, india	14 patients	10 M, 4 F, range 15–48 years, mean 35.8 years.	OS, CS, GCT, locally malignant tumour	Distal femur, proximal tibia, proximal femur, proximal humerus.	Oncologic limb salvage	Custom made metallic megaprosthesis.	Wide resection (enneking staging).	Minimum 1.5 years	MSTS score: 89.71±3.58; knee society score: 85.55±3.64; harris hip score: 90.5; oxford shoulder score: 41.67.	Improved emotional acceptance, pain reduction, strength maintenance.	Hip dislocation (1, superficial infection (1), no implant loosening, recurrence or amputation.	All patients retained functional limbs.	No failure; stable long-term results.	Endoprosthesis effectively preserves limb function with high emotional acceptance and minimal complications.
Bilal *et al*., 2021 [35].	Retrospective study, pakistan	43 patients	Mean age 26.5 years, 30 M, 13 F.	OS (27), CS (9), ES (5), plasmacytoma (1), diffuse large B-cell lymphoma (1)	Distal femur (18), proximal tibia (17), proximal femur (6), proximal humerus (2).	Oncologic limb salvage	Modular mega prosthesis	Wide resection (negative margins).	Mean 22.3 months	MSTS scores improved from 51.78 (pre-op) to 76.96 (post-operative); distal femur had highest msts (81.45).	Better quality of life, mobility recovery, correlation between site infection and msts scores.	Prosthesis joint infection (9%), recurrence (6.45%), metastasis (9.3%), mortality (6.97%).	Retained limb function in majority; 1 amputation due to infection.	Failure due to aseptic loosening, periprosthetic fracture, implant breakage.	Limb salvage surgery with mega prosthesis offers satisfactory functional outcomes but requires further study.
Natarajan *et al*., 2017 [36].	Retrospective study, india	6 patients (from a large cohort of 1198 osteosarcoma cases).	Mean age 24.2, 5 M, 1 F.	Metachronous osteosarcoma (conventional subtype)	Primary tumour in distal femur (3), proximal tibia (1), tibial diaphysis (1), proximal femur (1), distal radius (1).	Oncologic limb salvage	Custom-made endoprosthesis	Wide resection	Mean 2.45 years	MSTS score: Primary tumours 22.9, metachronous tumours 19.5 (lower at humerus and tibia).	Good functional recovery; poorer outcomes for proximal humerus and distal tibia cases.	Pulmonary metastasis (2), cerebral metastasis (1).	Majority retained limb function except 2 patients which got metastatic disease.	Stable result with follow-up; survival influenced early detection.	Metachronous osteosarcoma should be recognized in long-term survivors; limb salvage with custom prosthesis yields good results.
Fernandes *et al*., 2023 [37].	Cross-sectional study, denmark.	20 patients, 20 controls.	Mean age: 43 years (20–71).	Os, cs, gct	Proximal femur (9), distal femur (7), proximal tibia (4).	Work ability and physical activity post-majore bone resection.	Work ability and physical activity post-majore bone resection.	Wide resection	Mean 7 years	MSTS score: 70% (patients), 97% (control).	Lower work ability, difficult performing self selected activities.	Reduce work ability in relation to physical demands.	Patient maintained limb function but reported work related challenges.	Stable reout with follow-up, impact on long-term workability.	Patients had lower work ability and severe activity limitation depsite similar physical activity level, rehabilitation should include work ability assessments.
Satish *et al*., 2019 [38].	Cross-sectional study, India.	32 patients (15 revision ka, 17 amputees).	Age 15–60 years, mean age 29 years.	Os (75%), soft-tissue sarcoma (25%)	Distal femur (59.73), proximal tibia (40.63).	Revision limb salvage surgery versus above-knee amputation.	Custom mega prosthesis	Wide resection confirmed	6–18 months.	MSTS scores: Revision ka (80.44%), ak amputees (70.39%); ka had better emotional acceptance, support, and function).	Fear of recurrence higher in ka patines, amputees had better pain control.	Loosening, breakage, infection, amputation had better psychological acceptance.	LSS patients had improved body image but fear of recurrence.	Cmp challenges in long-term use.	Limb salvage surgery had better functional outcomes and body image, but increased fear of recurrence compared to amputation.
Pu *et al* ., 2023 [39].	Retrospective study, wuhan china.	18 patients	11 M, 7 F, age range 46–79 years.	Metastases from lung cancer (7), kidney cancer (4), breast cancer (2), thyroid cancer (2), cervical cancer (1), colon cancer (1), stomach cancer (1)	Femoral shaft	Limb salvage surgery for femoral shaft metastasis.	Customized modular prosthesis (ti6 al4 v alloy).	En bloc resection of diseased bone.	Mean: 25.28 months (range 12–62 months)).	MSTS scores improved significantly (pre-op: 22.17±1.75; post-operative: 28.75±2.13); isols scores also increased (pre-op: 21.36±1.06; post-operative: 28.19±1.72).	Pain reduction (VAS scores significantly decreased from 8.54 ± 1.02 to 2.45 ± 0.22); improved quality of life (karnofsky performance status increased from 61.83±5.38 to 78.87±1.72).	Two cases of aseptic prosthesis loosening; no local recurrence.	Patients retained limb function; survival rates at 1-year (72.22%) and 2-year (27.78%).	Stable results; two cases of loosening, but no reoperation needed.	En bloc resection and modular prosthesis implantation effectively reduce pain and improve function; limb salvage is a viable option for femoral shaft metastases.
Lin *et al* ., 2021 [40].	Retrospective study, China	53 patients	Mean age 20 years, 37 M, 16 F.	Osteosarcoma	Distal femur (50.9), proximal tibia (45.3), proximal femur (3.8).	Limb salvage surgery with segmental tumour endoprosthetic replacement.	Segmental tumour endoprosthetic replacement.	Wide resection	Mean age 46 months.	Mean MSTS score of 20.	Limb salvage preserved function, delayed recovery due to infection risk.	Periprosthetic infection (5.08), aseptic loosening (3), recurrence (2), metastasis-related death (2).	Majority retained limb function, 9 patient required amputation.	Two stage revision successful in most cases; combined prosthesis / cement revision strategy introduced.	Periprosthetic infection risk increases with prolonged surgery and high blood loss; 2 stage revision remains effective.
Pesenti *et al*., 2018 [41].	Retrospective study, aix-marseille university, france.	15 patients (6 megaprosthesis, 9 allografts) + 10 controls.	Mean age 25.2 years.	Distal femur osteosarcoma and ewing sarcoma	Distal femur	Limb salvage surgery	Megaprosthesis (fixed hinge knee replacement) versus allograft with epiphysis sparing (vascularized fibula).	Wide resection (2 cm).	Mean: 10.3 years	MSTS: megaprosthesis (79.4%), allograft (81.1%); no significant gait pattern difference between groups; gait. Megaprosthesis (86.4), allograft (84.3), controls (94).	No significant difference in global function; megaprosthesis may have concern for prosthesis wear due to quadriceps weakness.	Decreased knee flexion in megaprosthesis patinets during stance phase, quadriceps weakness affected gait.	Both techniques preserved acceptable knee function with adjusted gait mechanisms.	Megaprosthesis patients got unique gait adaptions that may influence long-term wear.	No major difference between megaprosthesis and allograft in gait function; gait modifications mainly caused by quadriceps weakness, not prosthesis limitations.
Ng *et al* ., 2024 [42].	Retrospective cross sectional study, malaysia.	65 patients	Mean age 35.93 years; 31 M, 25 F.	Os (46.4%), gct (19.6%), es (7.1%), whole femur (8.9%), humerus (12.5%)	Distal femur (30.4%), proximal femur (21.4%), proximal tibia (21.4%), whole femur (8.9%), humerus (12.5%).	Limb salvage surgery with endoprosthesis reconstructionscemented endoprosthesis.	Cemented endoprosthesis	Clear margin (82.1%), margin involved (17.9%).	Msts scores reported, with better results for clear margin cases.	MSTS scores reported, with better results for clear margin cases.	Psychological acceptance high in successful limb salvage cases.	Structural failure (16.1%), infection (16.1%), tumor progression (25%), soft-tissue failure (5.4%).	Amputation rate: 7.1% due to infection or local recurrence; comparable with global data	Comparable with global data; failure rate excluding tumour progression: 30.4%,	Endoprosthesis reconstruction results align with global data; careful patient selection is crucial for optimizing outcomes.
Shah *et al* ., 2020 [43].	Retrospective study, gujarat, india.	40 patients	28 M, 12 F, age range 9–68 years.	Osteosarcoma (59%), chondrosarcoma (15%), ewing's sarcoma (10%), secondary bone tumors (10%), aggressive gct (5%), spindle cell sarcoma (2.5%), synovial sarcoma (2.5%)	Proximal humerus (10%), proximal femur (15%), distal femur (45%), proximal tibia (30%).	Limb salvage surgery with megaprosthesis.	Cemented megaprosthesis replacement	Wide marginal excision (3 cm).	Mean: 3.2 years (range 2–6 years); 70% followed up for more than 3 years.	MSTS score: Knee (20), proximal femur (22), proximal humerus (15); 92.5% returned to original work.	Better psychosocial acceptance; prolene mesh improved functional outcome.	Superficial infection (2.5%), delayed infection (2.5%), flap necrosis (2.5%), tumor recurrence requiring amputation (5%).	92.5% tumor-free at final follow-up; one patient died post-surgery.	No implant-related complications or revisions; stable long-term outcomes.	Limb salvage surgery with megaprosthesis provides good tumor control and functional outcomes in selected cases; requires a specialized team-based approach.

ES: Ewing sarcoma, OS: Osteosarcoma, GCT: Giant cell tumour, CS: Chondrosarcoma, CB: Chondroblastoma, M: Male, F: Female, VAS: Visual Analog Scale

longevity, and psychosocial recovery, were encouraging. Local recurrence ranged from 6.45% to 9.3% [13,14], while metastatic spread occurred in 7–18.2% of patients [17,18]. Five-year limb retention rates exceeded 88% in nearly all cohorts, with several reporting stable 10-year survivorship [11,12]. For example, Ebeid et al. (2023) documented 82.1% wide surgical margins and only 7% secondary amputations due to recurrence or severe complications. Distal femur reconstructions achieved the best local control [14], whereas proximal humerus and pelvic reconstructions carried slightly higher recurrence risks [19]. Psychosocial and return to work outcomes were addressed in five studies. Fernandes et al. (2023) reported 70% return to employment with a mild reduction in work capacity compared to controls, while Satish et al. (2019) and Jover-Jorge et al. (2024) observed better emotional well-being, self-image, and social reintegration among limb salvage patients compared to amputees. Ebeid et al. (2023) and Ivanov et al. (2023) similarly reported high patient satisfaction and improved quality of life following structured rehabilitation [21].

Complications and survivorship

Complications influenced long-term outcomes, with deep infection being the most common (5.1–23.6%), particularly in Egyptian and Chinese cohorts, despite the use of silver coatings [11,13]. Aseptic loosening occurred in 6.25–14.5% of patients, primarily in Indian and Pakistani studies [14,15]. Mechanical failures – including prosthetic breakage, hinge malfunction, periprosthetic fracture, and expansion mechanism defects – were observed in 6.5–12.5% of cases, with higher incidence among skeletally immature patients undergoing expandable reconstructions due to repeated lengthening and growth stresses [22]. A bar chart demonstrating pooled mean incidence of major complications following megaprosthesis reconstruction, including infection, aseptic loosening, mechanical failure, local recurrence, and metastasis (Fig. 4). Despite these complications, implant survival remained robust, with 5-year limb retention consistently above 88% and multiple studies reporting durable functionality beyond 10 years [11,12].

Discussion

Recovery after LSS extends far beyond restoring bone and muscle – it represents the restoration of independence, identity, and quality of life. Across the 19 core studies (n > 600), patients frequently described regaining the ability to walk independently, return to work, and reclaim personal autonomy as defining milestones of recovery. Collectively, these outcomes reaffirm that megaprosthetic reconstruction is not merely a technical triumph but a means of restoring function and dignity. Long-term survivorship data have been equally encouraging, with several reports demonstrating that proximal femoral endoprostheses achieve more than 85% survival at 10 years, underscoring their durability in experienced oncologic centers [23].

Interpretation of these results, however, must be cautious given the predominance of retrospective designs, limited randomization, and heterogeneity in implant types and follow-up durations across studies. Functional outcomes, most commonly assessed through the MSTS and TESS, consistently demonstrated good to excellent recovery, with mean values ranging between 66% and 89%. These scores reflect an overall improvement in limb function, pain reduction, emotional acceptance, and independence in daily activities – highlighting that megaprosthetic reconstruction achieves both mechanical and functional recovery. Parallel gains in joint mobility and gait performance confirmed smoother biomechanical adaptation and efficient ambulation following structured rehabilitation. Improvements observed in performance indices such as the GDI and Timed Up and Go tests suggest that patients achieved near-normal walking symmetry and endurance. Similarly, higher KPS and increased return to work rates underscored the restoration of physical capacity, self-care ability, and social reintegration. Together, these multidimensional improvements confirm that LSS restores not only the integrity of the limb but also the patient's overall quality of life and independence.

Hardes et al. demonstrated that silver-coated prostheses reduce infection risk by nearly half, offering a valuable preventive strategy against one of the most devastating complications [24]. Nevertheless, mechanical failures – including hinge fractures, component fatigue, aseptic loosening, and expansion mechanism defects remain significant challenges, particularly among children and adolescents treated with expandable implants, where repeated lengthening increases mechanical stress and revision rates [25]. Early initiation of rehabilitation and progressive weight bearing after reconstruction have been repeatedly shown to enhance functional recovery, accelerate ambulation independence, and improve MSTS and TESS scores among limb salvage patients [26].

Beyond surgical technique, social and economic contexts profoundly influence long-term outcomes. Gronchi et al. (2021) emphasised that optimal sarcoma management should be centralised in multidisciplinary reference centers where surgeons, oncologists, physiotherapists, and psychologists collaborate to optimise oncologic control, functional recovery, and emotional adaptation [27]. Duijts et al. (2014) further noted that even after successful physical recovery, many cancer survivors face ongoing psychosocial barriers, including anxiety and challenges returning to work or social activities [28]. In resource-limited settings, modular systems are often preferred due to their affordability and versatility; however, restricted access to structured rehabilitation and socioeconomic constraints can impede functional recovery and quality of life outcomes. Future studies should incorporate socioeconomic indicators such as income, education, and rehabilitation access to present a more comprehensive picture of recovery trajectories.

From an oncologic standpoint, achieving wide surgical margins remains the cornerstone of durable limb preservation. Ebeid et al. reported that 82% of patients with histologically clear margins retained their limbs at 5 years, reaffirming the delicate balance between oncologic safety and functional preservation [29]. By systematically searching four major databases, we were able to map both outcomes and complications rates over 600 patients worldwide. This provides a broad and realistic picture of how megaprosthetic reconstruction perform across different anatomical sites and healthcare settings. Because the included studies varied significantly in their study design, prosthetic models and follow-up durations, a statistical meta analysis was unable to be conducted. Furthermore, our review is limited by available literature as most of the underlying studies are retrospective and single-center series. Progress in this field now depends on methodological refinement. Moving forward, the establishment of multi-center registries that incorporate standardised definitions, validated patient-reported outcome measures (PROM's), and socioeconomic variable is essential. This will enable better comparison and help guide global best practices.

Conclusion

This scoping review demonstrates that megaprosthetic LSS provides durable oncologic control and reliable functional restoration for patients with primary or recurrent bone tumours. Functional outcomes were consistently favourable, particularly in distal femur reconstructions, with strong long-term implant survival across studies. Although complications such as infection, aseptic loosening, and mechanical failure persist, modern modular and silver-coated prosthetic designs

combined with structured rehabilitation have markedly improved long-term results. Future progress will depend on multi-center collaboration, standardized outcome measures, and the integration of socioeconomic and rehabilitation factors into future research, ensuring that advances in implant technology translate into equitable, patient-centered improvements in mobility and quality of life.

Clinical Message

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Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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