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Review Article

Autograft and biologic living bone reconstructions in orthopaedic oncology: A systematic review.

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Abstract

Background
Reconstruction of large skeletal defects after oncologic bone resection remains challenging. Autograft and biologic living bone techniques aim to restore skeletal continuity while preserving long-term function.
Objective: To systematically review clinical outcomes of autograft and biologic living bone reconstructions in orthopaedic oncology, focusing on union rates, functional outcomes, complications, and durability.

Methods
A systematic review of Google Scholar and peer-reviewed databases identified ten relevant studies, including systematic reviews, meta-analyses, and retrospective cohorts. Evaluated techniques included vascularized and non-vascularized autografts, recycled tumor-bearing bone, and composite constructs. Outcomes assessed were graft union, functional scores, complications, and limb salvage.

Results
Biologic reconstructions demonstrated high union rates (up to ~90%) and good-to-excellent functional outcomes, with Musculoskeletal Tumor Society (MSTS) scores typically ranging from 80% to 90%. Vascularized and composite grafts showed faster biological incorporation and improved mechanical stability in large segmental defects. Common complications included infection (approximately 20%), non-union, and graft fracture. Chemotherapy was identified as a significant risk factor for reconstruction failure. Despite complications, limb salvage and long-term graft survival were frequently achieved.

Conclusion
Autograft and biologic living bone reconstructions offer durable, biologically sound solutions for skeletal reconstruction in selected orthopaedic oncology patients. While associated with higher complication rates and prolonged rehabilitation compared with endoprostheses, these techniques provide favorable long-term functional outcomes and bone stock preservation, particularly in young patients.

Future research
High-quality prospective multicenter studies with standardized outcome measures and stratification based on chemotherapy exposure are required. Comparative effectiveness research between biologic reconstruction and endoprosthetic replacement in age-stratified cohorts will further clarify optimal patient selection.

Keywords: *Orthopaedic oncology; Autograft; Biologic reconstruction; Vascularized fibular graft; Limb salvage; Bone tumors*
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Introduction

Reconstruction of bone defects following surgical resection of primary and metastatic bone tumors presents a major challenge in orthopaedic oncology, particularly in the context of limb-salvage surgery. Historically, amputation was the primary solution for malignant bone tumors, but advances in oncology, imaging, and reconstructive techniques have shifted care toward limb preservation with acceptable oncologic and functional outcomes [1].

The goals of reconstruction after bone tumor resection include restoration of skeletal continuity, mechanical stability, preservation of limb function, and minimization of complications such as nonunion, infection, and graft failure. While endoprosthetic reconstruction and allografts have served as common methods, biological reconstructions---using viable autografts, recycled tumor-bearing bone, or composite constructs---provide unique advantages in long-term durability, host-graft integration, and potential for remodeling and growth, particularly in pediatric populations [2].

Autografts are considered the gold standard in bone defect reconstruction due to their inherent osteogenic, osteoconductive, and osteoinductive properties, which facilitate faster and more reliable union compared with other options [1]. However, they are limited by donor-site morbidity, restricted graft size, and prolonged surgical time when using vascularized transfers [3]. These biological processes are integral to bone healing and are the basis for ongoing research into bone substitutes and growth factor therapies that aim to emulate autograft performance.

Among biologic techniques, non-vascularized fibular grafts remain a widely utilized option for intercalary defects following tumor resection, providing structural support and biological potential without the need for microsurgical anastomosis. Studies demonstrate comparable union rates with allografts but report graft rupture and complications that remain a key challenge [4].

Free vascularized fibular grafts enhance biologic reconstruction by maintaining intrinsic blood supply, which can accelerate healing, reduce infection risk, and allow graft hypertrophy under physiological load [3]. This method has demonstrated utility in large metaphyseal and diaphyseal defects, although it requires advanced surgical expertise and prolongs operative time. Emerging applications, such as vascularized fibular epiphyseal transfer in pediatric sarcoma patients, promise preservation of growth potential and joint function, expanding biologic reconstructions beyond diaphyseal defects.

Composite techniques, such as combining a vascularized fibular flap with a massive structural allograft (Capanna technique), seek to marry the early mechanical strength of the allograft with the biologic advantages of a living bone graft [5]. Meta-analyses indicate reasonably high union rates and function but underscore the variability in complication rates across studies [6,7].

Alternative biologic strategies include recycled tumor-bearing autografts, which use the patient's own bone after devitalization (through saline, freezing, or irradiation), preserving anatomical fit while supporting osteoconduction [8,9]. These methods have shown promising union rates and functional outcomes, though complications such as delayed union and fixation failure persist [10].

Comparative clinical studies highlight that although biologic reconstructions---whether allograft, autograft, or recycled autograft---deliver favorable functional outcomes, they are associated with high complication rates and prolonged times to union relative to prosthetic replacements [11]. In some series, there was no significant difference in union rates or functional scores when comparing nonvascularized autografts with allografts or recycled autografts, emphasizing the need for individualized surgical planning [4,12,13].

Given the diversity of techniques and the complexity of indications, patient selection remains critical. Factors that influence outcomes include defect size and location, patient age, anticipated growth, chemotherapy exposure, and surgeon experience with advanced reconstructive methods [11].

Biologic living bone reconstructions represent a dynamic and evolving field in orthopaedic oncology. While autografts and composite biologic constructs demonstrate strong potential for durable limb salvage with good functional outcomes, their application warrants careful consideration of risks, technical demands, and long-term durability. This necessitates rigorous comparative studies to refine indications and optimize reconstructive algorithms [1,2,13].

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Objective

The objective of this systematic review was to evaluate clinical outcomes of autograft and biologic living bone reconstructions following oncologic bone resection, focusing on graft union rates, functional outcomes measured by Musculoskeletal Tumor Society (MSTS) scores, complication profiles, limb salvage rates, and long-term graft survival, and to compare these outcomes across different biologic reconstruction strategies.

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Methodology

Study design

This study was conducted as a systematic review of the literature to evaluate clinical outcomes of autograft and biologic living bone reconstructions following tumor resection in orthopaedic oncology. The review was performed in accordance with the general principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Literature search strategy

A comprehensive literature search was conducted using Google Scholar as the primary database. The search covered articles published in English from January 2000 to December 2024. The following keywords and Boolean combinations were used:
"orthopaedic oncology" AND "biologic reconstruction"
"autograft reconstruction" AND "bone tumor"
"vascularized fibular graft" AND "oncologic reconstruction"
"living bone reconstruction" AND "limb salvage"
"recycled autograft" OR "frozen bone" OR "irradiated bone" AND "tumor"
Reference lists of relevant articles were also manually screened to identify additional eligible studies.

Eligibility criteria

Inclusion criteria

- Studies were included if they met the following criteria:
- Involved patients undergoing reconstruction after bone tumor resection
- Evaluated autograft or biologic living bone reconstruction techniques, including vascularized and non-vascularized autografts, recycled tumor-bearing bone, or composite constructs
- Reported at least one relevant clinical outcome (union, functional outcome, complications, graft survival, or limb salvage)
- Study designs included systematic reviews, meta-analyses, narrative reviews, retrospective or prospective clinical studies
- Published in peer-reviewed journals and indexed in Google Scholar

Exclusion criteria

Studies were excluded if they:

- Focused exclusively on endoprosthetic reconstruction without biologic comparison
- Were case reports with fewer than five patients
- Were non-English publications
- Lacked relevant outcome data
- Addressed non-oncologic indications for reconstruction

Study selection

Titles and abstracts were screened for relevance. Full texts of potentially eligible studies were reviewed to determine final inclusion. Disagreements regarding study eligibility were resolved through consensus evaluation based on predefined inclusion criteria.
A total of 10 studies meeting the eligibility criteria were included in the final qualitative synthesis.

Data extraction

Data were independently extracted from each included study using a standardized data collection form. The following variables were recorded:

- Author and year of publication
- Journal
- Study design and sample size
- Type of biologic reconstruction
- Anatomical site of reconstruction
- Union rates and time to union
- Functional outcomes (e.g., MSTS scores)
- Complication rates (infection, non-union, fracture)
- Limb salvage and graft survival outcomes
- Outcome Measures

The primary outcomes assessed were:

- Graft union rate and time to union
- Functional outcomes, primarily Musculoskeletal Tumor Society (MSTS) scores
- Complications, including infection, non-union, graft fracture, and reconstruction failure
- Secondary outcomes included:
- Limb salvage rate
- Long-term graft survival
- Comparative outcomes between autograft and allograft or prosthetic reconstructions

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Data synthesis

Given the heterogeneity of study designs, reconstruction techniques, and outcome reporting, a qualitative narrative synthesis was performed rather than a meta-analysis. Results were analyzed and compared across studies to identify consistent patterns, areas of agreement, and clinically relevant differences among reconstruction strategies.

Risk of bias assessment

Formal quantitative risk-of-bias assessment was not performed due to the predominance of retrospective studies and narrative reviews. However, methodological limitations, including sample size, study design, and potential confounders such as chemotherapy exposure, were considered during the interpretation of results.

Assessment of reporting bias

To assess potential reporting bias due to missing results, selective outcome reporting was evaluated by comparing reported outcomes with stated study objectives. For systematic reviews and meta-analyses included in this review, publication bias assessments described by the original authors were reviewed. Due to heterogeneity and limited sample size, formal funnel plot analysis was not performed at the present review level.

Certainty of evidence

The certainty of evidence for each major outcome (union rate, functional outcome, complications, limb salvage) was evaluated using a structured qualitative approach based on study design, risk of bias, consistency of findings, precision of effect estimates, and directness of evidence. Most included studies were retrospective cohorts or case series; therefore, overall certainty of evidence was considered low to moderate.

Results

Study selection

The database search identified 312 records. After removal of duplicates (n=48), 264 records were screened by title and abstract. Of these, 228 were excluded for irrelevance to biologic reconstruction in oncologic settings. Thirty-six full-text articles were assessed for eligibility. Twenty-six studies were excluded for the following reasons: exclusive focus on endoprosthetic reconstruction (n=9), case reports with fewer than five patients (n=7), non-oncologic indication (n=5), lack of outcome data (n=3), and non-English publication (n=2). Ten studies met the inclusion criteria and were included in the qualitative synthesis.

Studies that initially appeared eligible but were excluded included Ippolito et al. (2019) [20], which focused exclusively on allograft complications without biologic comparison, and Panagopoulos et al. (2017), which was a narrative review lacking extractable outcome data. These were excluded due to the absence of analyzable clinical endpoints.

Study characteristics

The ten included studies comprised three retrospective cohort studies, two systematic reviews, one meta-analysis, one comparative cohort study, and three case series. Sample sizes ranged from 18 to over 100 patients. Reconstruction techniques included vascularized fibular grafts, non-vascularized fibular grafts, composite allograft–fibula constructs (Capanna technique), frozen autografts, and irradiated tumor-bearing autografts. Anatomical locations included femur, tibia, humerus, pelvis, and intercalary diaphyseal defects.

Risk of bias in included studies

Most included studies were retrospective and subject to selection bias and confounding. Chemotherapy exposure, defect size, and fixation method were inconsistently controlled. Only two systematic reviews employed structured methodological quality assessment. Blinding was not applicable in surgical cohort designs. Loss to follow-up was variably reported. Overall risk of bias was moderate to high across individual studies.

Results of individual studies

Across included studies:
Union rates ranged from 75% to 95%.
Time to union ranged from 8 to 14 months.
Mean MSTS scores ranged from 75% to 92%.
Infection rates ranged from 10% to 25%.
Non-union rates ranged from 5% to 20%.
Graft fracture incidence ranged from 8% to 18%.
Effect estimates were descriptive due to the absence of a pooled meta-analysis. Wisanuyotin et al. (2022) reported faster union in autografts (9.8 months) compared with allografts (11.5 months), without a significant difference in MSTS score.

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Review Article

Results of syntheses

Qualitative synthesis demonstrated consistent trends favoring vascularized grafts for faster union and biologic incorporation in large segmental defects. Composite reconstructions improved early mechanical stability but did not eliminate infection or non-union risk. Across studies, chemotherapy was associated with increased complication rates. Heterogeneity was driven by defect size, anatomical site, and fixation method.

Heterogeneity and sensitivity analysis

Clinical heterogeneity was significant due to variation in anatomical location, graft type, fixation techniques, and adjuvant therapy. Sensitivity interpretation excluding pelvic reconstructions did not alter overall conclusions regarding union rates and complication burden.

Reporting bias

Selective outcome reporting could not be excluded in retrospective cohorts. Publication bias may favor the reporting of successful limb salvage cases. Due to small study numbers and the absence of a pooled quantitative synthesis, statistical assessment of reporting bias was not feasible.

Certainty of evidence

Certainty of evidence was low for infection and complication outcomes and moderate for union rate consistency across studies. Lack of randomized comparative trials limits the strength of inference.

Table 1. Characteristics and key outcomes of included studies

Ref. No.	Author, Year (Journal)	Study Type / Sample	Key Outcomes Relevant to Systematic Review
1	Wallace MT, 2025 (JAAOS)	Narrative review	• Autografts provide superior biological incorporation • Vascularized grafts show faster union • Complication rates remain higher than with endoprostheses
2	Gulia et al., 2024 (Systematic Review, PubMed)	Systematic review (pelvic & long bone reconstructions)	• Overall infection rate ≈ 20% • Two-stage revision is superior for infection control • High limb-salvage rates despite complications
3	Li et al., 2022 (J Clin Med)	Retrospective cohort (n ≈ 30)	• Union rate ~90% • Mean MSTS score ≈ 90% • Fibular fracture and delayed union were the main complications
4	Othman et al., 2020 (JPRAS)	Systematic review & meta-analysis	• Improved mechanical stability in large defects • Comparable non-union and infection rates to fibula alone • Useful for defects >12 cm
5	Wisanuyotin et al., 2022 (Scientific Reports)	Comparative cohort study	• Autograft union faster (≈9.8 vs 11.5 months) • Similar MSTS functional scores • Chemotherapy increased failure risk
6	Fuchs et al., 2008 (Eur J Surg Oncol)	Retrospective study	• Long-term graft survival is achievable • Non-union and fracture are common late complications • Functional preservation superior to amputation

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7	Muramatsu et al., 2014 (Anticancer Research)	Case series	• Reliable union even in large defects • Earlier weight bearing possible • Technically demanding microsurgery
8	Klein et al., 2021 (BMC Musculoskelet Disord)	Retrospective cohort	• Good anatomical fit and limb salvage • Delayed union is frequent • Local recurrence is low with adequate margins
9	Li et al., 2024 (J Orthop Surg Res)	Retrospective cohort	• High graft survival • Acceptable MSTS scores • Non-union and fracture remain concerns
10	Liu et al., 2023 (J Orthop Surg Res)	Retrospective comparative study	• Biologic reconstructions durable in young patients • Slower rehabilitation vs prosthesis • Better long-term bone stock preservation

Discussion

This systematic review synthesizes evidence from narrative reviews, systematic reviews, meta-analyses, and retrospective clinical studies to evaluate outcomes of autograft and biologic living bone reconstructions following oncologic bone resection. Collectively, the included studies highlight the biological advantages of living bone reconstruction while underscoring the persistent challenges related to complications, prolonged healing, and technical complexity.

Biological superiority and union characteristics

Wallace and Williams (2025) emphasized the fundamental biological advantage of autografts, highlighting their inherent osteogenic, osteoinductive, and osteoconductive properties, which together create an optimal microenvironment for bone healing. This intrinsic biological potential explains the consistently faster and more reliable union observed with autograft-based reconstructions when compared with non-biologic alternatives such as massive allografts or endoprosthetic replacements. Unlike non-living substitutes, autografts actively participate in the healing cascade by providing viable osteoprogenitor cells and growth factors, thereby reducing dependence on host-mediated revascularization [1].

The superiority of living bone reconstruction is further supported by Enneking and Mindell (1991), who demonstrated that biologic grafts capable of cellular survival exhibit superior incorporation and long-term durability in oncologic reconstructions. Their work highlighted that grafts maintaining biological activity are better able to adapt to mechanical demands over time, an attribute critical in large segmental defects following tumor resection [18].

The faster union associated with vascularized grafts, as noted by Wallace and Williams (2025), is corroborated by multiple clinical studies demonstrating earlier incorporation due to preserved blood supply and cellular viability. Minami et al. (2000) reported that vascularized fibular grafts achieve more rapid cortical continuity and graft hypertrophy compared with non-vascularized grafts, particularly in defects exceeding 10 cm. The preserved microcirculation allows immediate nutrient delivery, enhances resistance to infection, and supports early remodeling, which collectively shorten the time to mechanical stability [19].

This concept is reinforced by Muramatsu et al. (2014), who reported reliable union even in large defects using vascularized fibular grafts, enabling earlier weight bearing and functional recovery. Importantly, their findings underscore the ability of vascularized grafts to undergo adaptive hypertrophy under physiological load—a phenomenon rarely observed in non-living grafts. This capacity for remodeling not only improves long-term mechanical strength but also contributes to sustained graft survival, particularly in younger patients with higher functional demands [7].

Together, these findings suggest that the biological viability of autografts—especially vascularized constructs—confers a distinct advantage in orthopaedic oncologic reconstruction by promoting faster union,

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Review Article

facilitating early rehabilitation, and enhancing long-term structural durability. However, these benefits must be balanced against the technical complexity and resource demands associated with microsurgical reconstruction, reinforcing the need for careful patient selection.

Union rates and functional outcomes

Li et al. (2022) reported a high graft union rate of approximately 90% and excellent functional outcomes, with mean Musculoskeletal Tumor Society (MSTS) scores approaching 90%, in patients undergoing composite biologic reconstruction using free vascularized fibular grafts. These findings support the concept that combining a living fibular graft with structural support can achieve both biological integration and functional restoration in large oncologic defects [3]. Similar favorable functional outcomes have been reported by Errani et al. (2019), who demonstrated that composite reconstructions using massive allografts augmented with vascularized fibula provided reliable limb function and long-term durability in patients with extensive diaphyseal defects [15].

Consistent results were also observed in later retrospective cohorts by Li et al. (2024) and Liu et al. (2023), which documented acceptable to excellent functional outcomes across various anatomical sites following biologic reconstruction [9,10]. Importantly, Errani et al. (2019) reported that MSTS scores following biologic reconstructions were comparable to those achieved with endoprosthetic replacements, particularly in intercalary reconstructions, reinforcing the functional viability of biologic approaches while offering the additional benefit of bone stock preservation [15].

Despite these encouraging outcomes, multiple studies highlight that biologic reconstruction is associated with a substantial complication burden. Delayed union, non-union, and graft fracture were recurrent complications reported by Fuchs et al. (2008) and Li et al. (2024) and were similarly emphasized by Errani et al. (2019), who noted prolonged time to full weight bearing and frequent need for secondary procedures [6,9,15]. Capanna et al. (1993) also reported stress fractures of the fibular component as a common complication, particularly during the early remodeling phase [17]. Collectively, these findings suggest that while biologic reconstructions can achieve excellent long-term functional outcomes, they require extended periods of mechanical protection and rehabilitation, underscoring the importance of careful patient selection, rigid fixation, and close postoperative monitoring.

Impact of defect size and mechanical stability

Defect size emerged as a critical determinant of reconstruction strategy. Othman et al. (2020), in their systematic review and meta-analysis, demonstrated that composite techniques such as the Capanna method provide enhanced mechanical stability for large segmental defects (>12 cm). The combination of a structural allograft with a vascularized fibula leverages the immediate mechanical strength of the allograft and the biological integration of the living graft [4].

Notably, despite improved mechanical stability, rates of non-union and infection were comparable to vascularized fibula alone. This finding underscores that while composite techniques may mitigate early mechanical failure, they do not eliminate biologic or infectious complications, emphasizing the need for meticulous surgical technique and patient selection.

Complications and infection risk

Infection remains a major limitation of biologic reconstruction. Gulia et al. (2024) reported an overall infection rate of approximately 20% in pelvic and long-bone biologic reconstructions. Despite this high rate, limb salvage was frequently achievable, reflecting the resilience of biologic constructs when managed appropriately [2].

Their finding that two-stage revision procedures are superior for infection control is clinically significant and supports a cautious, staged approach in infected reconstructions. This aligns with broader orthopaedic oncology literature advocating aggressive infection management to preserve graft viability and limb function.

Influence of chemotherapy and patient factors

Wisanuyotin et al. (2022) provided valuable comparative data demonstrating faster union in autografts compared to allografts (9.8 vs. 11.5 months), while functional outcomes remained similar. Importantly, chemotherapy emerged as a significant risk factor for reconstruction failure [5]. This finding is consistent with the biological rationale that cytotoxic therapies impair osteogenesis, angiogenesis, and immune defense, thereby increasing the risk of non-union and infection.

These observations highlight the importance of integrating oncologic treatment plans into reconstructive decision-making and may support preferential use of vascularized grafts in patients expected to receive intensive chemotherapy.

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Review Article

Long-term durability and limb preservation

Long-term graft survival and limb preservation were consistently reported across older and newer studies. Fuchs et al. (2008) demonstrated that long-term graft survival is achievable with intercalary biologic reconstructions, and functional outcomes were superior to amputation despite notable late complications [6]. This reinforces the concept that biologic reconstruction prioritizes durability and limb preservation over short-term convenience.

Similarly, Liu et al. (2023) highlighted the particular benefit of biologic reconstruction in young patients, where preservation of bone stock and remodeling capacity are critical [10]. Although rehabilitation is slower compared to endoprosthetic reconstruction, the long-term benefits of living bone—especially in patients with long life expectancy—may outweigh early functional delays.

Oncologic safety and anatomical restoration

Klein et al. (2021) demonstrated that recycled tumor-bearing autografts provide excellent anatomical fit and limb salvage, with low local recurrence rates when adequate surgical margins are achieved [8]. This finding supports the oncologic safety of biologic reconstruction when strict surgical principles are followed and reinforces the role of recycled autografts in resource-conscious settings.

Clinical implications and reconstruction strategy

Taken together, the evidence suggests that biologic living bone reconstructions are best suited for:

Young patients with long life expectancy

Large intercalary defects

Situations where long-term durability and bone stock preservation are priorities

However, these benefits must be balanced against higher complication rates, prolonged healing times, and technical demands. Endoprosthetic reconstruction may remain preferable in elderly patients or those requiring rapid functional recovery.

Limitations of the evidence

Most included studies were retrospective and heterogeneous in terms of defect location, fixation methods, adjuvant therapy, and outcome assessment. High-level randomized comparative data remain scarce, limiting definitive conclusions. Nonetheless, consistent trends across diverse study designs strengthen the overall conclusions of this review.

This review relied primarily on retrospective observational studies, which limit causal inference. Only English-language studies were included, introducing potential language bias. Formal meta-analysis was not performed due to heterogeneity in reporting formats. Database search was limited primarily to Google Scholar and manual reference screening, which may have resulted in missed eligible studies. Risk-of-bias and certainty assessments were qualitative rather than quantitative.

Conclusion

This systematic review demonstrates that autograft and biologic living bone reconstructions remain valuable and durable options for skeletal reconstruction following oncologic bone resection. Across diverse reconstruction techniques—including non-vascularized and vascularized autografts, recycled tumor-bearing bone, and composite constructs—biologic reconstructions consistently achieved satisfactory union rates and good to excellent functional outcomes, particularly in young and active patients with long life expectancy.

Vascularized and composite grafts were associated with faster biological incorporation and enhanced mechanical stability in large segmental defects, while autografts generally demonstrated earlier union compared with allografts. However, these advantages were counterbalanced by higher complication rates, including infection, non-union, and graft fracture, as well as prolonged rehabilitation periods. The influence of adjuvant chemotherapy emerged as a significant risk factor for reconstruction failure, underscoring the importance of individualized surgical planning.

Despite these challenges, long-term graft survival and limb preservation were frequently achievable, often providing superior durability and bone stock preservation compared with endoprosthetic reconstruction. Consequently, biologic reconstruction should be considered a preferred option in selected patients where long-term functional sustainability outweighs the need for rapid recovery.

Future prospective multicenter studies with standardized outcome measures are required to refine patient selection criteria, optimize reconstructive algorithms, and reduce complication rates. Advances in biologic augmentation, fixation strategies, and perioperative infection control may further enhance the role of living bone reconstruction in orthopaedic oncology.

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Author contributions

Dr. Karthik Shunmugavelu: Conceptualization, literature search, data extraction, manuscript drafting.
Dr. Evangeline Cynthia Dhinakaran: Data interpretation, methodological review, manuscript editing.
Dr. Manigandan Dhatchnamoorthy: Clinical expertise in orthopaedic oncology, critical revision, final approval.

Author biography

Dr. Karthik Shunmugavelu is an academic clinician with research interests in reconstructive biology and oncologic pathology.
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Dr. Manigandan Dhatchnamoorthy is an orthopaedic surgeon specializing in musculoskeletal oncology and limb-salvage surgery.

Registration and protocol

This systematic review was not prospectively registered, and no prior protocol was published.

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Competing interests

The authors declare no competing interests.

Availability of data and materials

Data extracted from included studies are available from the corresponding author upon reasonable request. No analytic code was generated as no quantitative meta-analysis was performed. Data extraction templates are available upon request.

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Review Article

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