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Systematic review on Options of pelvic reconstruction in musculoskeletal sarcomas

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ABSTRACT: Given the large bony defects, complex anatomy and challenging complication rates, pelvic reconstruction after musculoskeletal sarcomas remains a difficult problem in orthopaedic oncology. This systematic review analyzes the current

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reconstructive options: biological reconstruction, endoprosthetic reconstruction, hip transposition and patient-specific three-dimensional (3D)-printed implants. A systematic literature search was conducted in line with the guideline of PRISMA in order to evaluate functional outcomes, complications, implant survival, and further research. There is indications that no single reconstruction system is better than the others. Prosthetic reconstruction will provide immediate stability and an earlier opportunity for mobilization, but come at a cost of infection, dislocation and mechanical failure. The long-term durability is possible using biological reconstruction; however, there are limitations that are related to graft healing. Early functional and anatomical results of emerging 3D-printed custom implants are promising. Optimizing outcomes after resection of a pelvic sarcoma is still very much dependent on individualized reconstruction based on the characteristics of the tumor, patient factors and functional requirements.

Keywords: *Pelvic sarcoma; Internal hemipelvectomy; Pelvic reconstruction; Hemipelvic prosthesis; 3D-printed implant; Limb salvage surgery; Orthopaedic oncology.*

1. Introduction

Pelvic musculoskeletal sarcomas are complex, have an aggressive biological growth pattern and surgical oncological margins to ensure the tumor is completely removed are difficult to achieve while maintaining both function and range of motion. Primary sarcomas of the pelvis are rare but important bone and soft tissue tumours and important histological subgroups are chondrosarcoma, osteosarcoma, and Ewing sarcoma. Tumors near major neurovascular structures and visceral organs and the deep location of these tumors make diagnosis often late, requiring extensive resections and complex reconstructive procedures (Gitelis et al., 2002). In the past, treatment for advanced sarcomas of the pelvis was external hemipelvectomy which was oncologically effective but caused significant functional and psychological sacrifice. Continued development in multimodal therapy – advanced imaging, neoadjuvant chemotherapy and novel surgical techniques – have facilitated limb-sparing treatment using internal hemipelvectomy to a cohort of defined patients (Enneking et al., 1980). Internal hemipelvectomy, however, represents significant bony and soft tissue defects, primarily after periacetabular resections, and is a challenging reconstructive problem to restore the stability and function of the pelvis and hip.

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Several reconstruction options are available: hip transposition, arthrodesis, biological reconstruction with allografts, modular hemipelvic endoprostheses and custom-made implants. Each method has a mechanical stability, functional recovery, a level of complexity with surgery and potential complications. Prosthetic reconstruction facilitates early mobilization and regains of the length of the limb and uses complications like infection, dislocation, aseptic loosening, and mechanical failure (Wirbel et al, 2001). Biological reconstruction can offer long-lasting skeletal reconstruction, though it has limitations such as nonunion and the possibility of graft fracture and extended recovery times. Over the last few years, techniques in computer-assisted design combined with additive manufacturing have made patient-specific 3-D printed titanium implants a new possibility for complicated pelvic reconstructive surgery. These implants have different uses depending on the situation, including the restoration of pelvic anatomy when conventional reconstruction is not possible, and improved fixation of the implants (Angelini et al., 2017). But the results reported about their long-term effects are still insufficient and there is still no agreement on the best possible reconstructive approach.

2. Literature Review

In recent decades, there has been a great evolution in the reconstruction of the pelvis after resection of musculoskeletal sarcomas. The main goal of reconstruction is maintenance of continuity of the pelvic ring, ensuring a stable hip articulation, early mobilization and functional outcomes in the long-term without compromising oncological control. The reconstruction of pelvis is one of the most challenging procedures in Orthopaedic Oncolgy, though, it is often performed to achieve a three dimensional defect, especially around acetabulum. Due to the problems of achieving wide surgical margins and reconstructing the large defect created by surgery, early management of sarcomas in the pelvis largely depended on external hemipelvectomy. Good development of better imaging modalities, chemotherapy regimes and surgical procedures have led to a change in treatment favouring limb sparing operations, specifically one of the internal hemipelvectomy. Enneking et al. developed guidelines for the safe topical treatment of musculoskeletal tumors and discussed the necessity of wide local excision and functional reconstruction for oncological safety and preservation of the limb (Enneking et al., 1980).

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2.1 Non-reconstructive Techniques

One of the first following periacetabular resection procedures was to neglect the challenging reconstruction with techniques like hip transposition or flail hip reconstruction. These methods avoid complications of implants and could be considered for limited life span or when significant soft tissue is involved in selected patients. Clear functional deficits such as short shrunken limbs, altered gait mechanisms, instability in the joints and decreased functional scores, however, are known functional limitations of patients with rheumatoid arthritis. After pelvic resection and reconstruction for a pelvic sarcoma, limb salvage was achieved but the extent of reconstruction and hip mechanism preservation plays a large role in the resulting functional outcome (O'Connor et al., 1996).

2.2 Biological Reconstruction

Percutaneous repair surgery with a structural allograft, autograft, and/or allograft-prosthetic composite was introduced to achieve a long-term skeletal reconstruction following pelvic resection. Gonene benefits from biological incorporation, re-establishing anatomy, and may be more durable in younger patients. Biological reconstruction does have technical difficulties, however, as well as other complications including graft fracture, nonunion, infection, and lengthy rehabilitation periods. The functional outcome of periacetabular tumor resection and the evaluation of the different reconstruction possibilities by Wirbel et al. showed that some patients could achieve an acceptable functional result after reconstruction using biological substitutes, while the risk of complications remained high, related to the complexity of the pelvic anatomy and the less vascularity of the reconstructed tissues (Wirbel et al., 2001). In a similar way, it was found that despite the advancement of surgical techniques, reconstruction following a pelvic tumour resection is still associated with high complication rates (Guo et al., 2007).

2.3 Prosthetic Reconstruction

Following extensive pelvic resections, especially omission of the acetabulum, endoprosthetic reconstruction has become one of the most frequently implemented procedures. The mechanical stability and early weight bearing that achieve immediate fixation, using modular hemipelvic prostheses, can be very useful when early functional restoration is desired. In one instance, these implants have the ability to restore pelvic

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continuity and stable platform for hip reconstruction. But prosthetic reconstruction has some severe side effects. Factors that frequently result in failure include large surgical exposure, extended operating time and prior chemotherapy or radiotherapy. Other problems include: dislocation, aseptic loosening, breakage of the implant, revision surgery. One of the first ways of achieving prosthetic reconstruction for periacetabular defects, as described by Harrington, was such could be achieved after extensive acetabular resections (Harrington, 1981).

2.4 Custom-Made and Three-Dimensional Printed Implants

With the current advancement of computer-assisted design (CAD) and Additive Manufacturing (AM), the pelvic reconstructive surgery (PRS) considerably changed. More recently, Computer Assisted Design (CAD) and Additive Manufacturing (AM) has had an impact on the field of Pelvic Reconstructive Surgery (PRS). The three-dimensional (3D) printing technology manufacturing of patient-specific implants enables the reconstruction of the specific anatomical defect and has been shown to improve both the localization of the screws and the contact between bone and implant, leading to increased implant stability. They can be used especially for large defects in the pelvis that are poorly fixed by the usual prostheses. Angelini et al. discussed this in their paper on pelvic reconstruction using custom-made implants and emphasised the benefits they might have to offer such as anatomical reconstruction and function. There were also some drawbacks, such as complexity of manufacturing, too few years of follow-up and high costs (Angelini et al., 2017). Wong et al. also showed that 3D printed hemipelvic implants can achieve good early clinical results, but bigger multi-center trials are needed to validate these results for durability (Wong et al., 2016).

2.5 Current Challenges and Evidence Gap

Even though there are improved reconstruction techniques available, there is no established gold standard technique for reconstruction after an operation for the resection of a sarcoma in the pelvis. Evidence is mainly from retrospective case series with diverse patient cohorts, various surgical approach configurations and varying quality/type of outcome assessment. The location, size of the tumor, patient age, estimated life span, soft tissue characteristics, and surgeon's experience play a large role in the decision of reconstruction.

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In the current literature there are recommendations that reconstruction should be done on a case-by-case basis and not be dictated by a favourite method. Immediate stability is the reason for the widespread use of conventional reconstruction while biological reconstruction might be considered in selected younger patients. At a different time, there is the emergence of the patient specific 3D printed implants, with promising early results, but further follow up time is necessary, and more studies are needed to clearly elucidate their place.

3. Materials and Methods

3.1 Study Design and Reporting Guidelines

It is expected that this systematic review will be completed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement for transparency, reproducibility and methodological rigour. The PRISMA process has internationally agreed-upon recommendations for reporting systematic reviews, which cover study identification, selection process, data extraction and synthesis of evidence (Page et al., 2021). To reduce selection bias and increase the reliability, literature analysis will be carried out following a predetermined methodology in the review.

3.2 Literature Search Strategy

A comprehensive electronic literature search will be carried out with leading biomedical databases such as PubMed/MEDLINE, Embase, Scopus, Web of Science, Cochrane Library. Existing studies in the database from the beginning to the date of the last search will be included. Medical Subject Headings (MeSH) terms and free text terms associated with reconstruction techniques and pelvic sarcomas will be used an integrated approach of combining terms for the search strategy. These two main ideas will be used in the Primary search:

- “pelvic sarcoma”
- “pelvic bone tumor”
- “musculoskeletal sarcoma”
- “internal hemipelvectomy”
- “pelvic reconstruction”

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- “hemipelvic prosthesis”
- “endoprosthetic reconstruction”
- “allograft reconstruction”
- “custom-made implant”
- “3D printed implant”
- “functional outcome”
- “complications”

Search terms will be combined using the boolean operators (AND, OR). The reference lists of the studies included and important review articles will also be manually reviewed to find more eligible studies. Citation searching can be recommended in SRs since sometimes not all relevant studies are found by searching databases alone (Greenhalgh & Peacock, 2005).

Eligibility Criteria

Eligibility criteria will be established using the PICOS framework, used to develop systematic review questions (Methley et al., 2014) that are common to all systematic reviews.

Inclusion Criteria

Studies to be included will be those which will satisfy the following criteria:

Population

- Patients with primary musculoskeletal sarcomas at the pelvic site.
- Patients who have been treated with participated in a prostate or radical prostate surgery that led to reconstruction.
- Patients that were treated with a prostate or radical prostate and underwent reconstruction.

Intervention

Reconstruction after the resection of aarcoma will include any method of reconstruction, such as:

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- Hip transposition.
- Arthrodesis.
- Biological reconstruction (autograft/allograft).
- Modular hemipelvic prosthesis.
- Custom-made hemipelvic implants.
- Three-dimensional (3D)-printed patient-specific implants.

Outcomes

Research that reported on the following outcomes:

- Functional outcomes (MSTS score, TESS score, gait assessment).
- Implant survival.
- Reconstruction failure.
- Infection.
- Dislocation.
- Mechanical complications.
- Revision surgery.
- Quality of life outcomes.

Study design

- Original research articles (peer-reviewed).
- Retrospective cohort studies.
- Prospective studies.
- Planned case studies for adequate clinical outcome reporting.

Exclusion Criteria

It will exclude studies which have the following:

- Metastatic pelvic tumors.
- Non-musculoskeletal malignancies.

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- Non-human studies.
- Ideally, cadaver or biomechanical studies without clinical outcomes.
- Case studies involving individual patients (clinical experiences).
- Analyze articles, editorials, conference abstracts and expert views.

3.3 Study Selection Process

Identified studies will be added into electronic data management software and duplicate records will be eliminated. Titles and abstracts will be reviewed by two independent reviewers who will be judged on a set criteria. Full-text evaluation will then be performed for potentially eligible studies. The decision of inclusion will be finalized by the Consultation of the Agreement between the reviewers or discussion with the third reviewer if there is any disagreement about inclusion of the study. To minimize selection bias and methodological certainty, we adopted the dual-reviewer methodology in systematic reviews, which is recommended (Higgins et al., 2022).

The study selection process will be presented using a PRISMA flow diagram showing:

- Number of records identified.
- Duplicate studies removed.
- Studies screened.
- Full-text articles assessed.
- Studies that were utilized in the qualitative synthesis.

3.4 Data Extraction

Prior to review of eligible studies, a standardized data extraction forms will be created. The following information will be pulled:

Study Characteristics

- First author(s) and year of publication.
- Country of study.
- Study design.

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- Number of patients.
- Duration of follow-up.
- Patient and Tumor Characteristics
- Age and sex distribution.
- Sarcomas are a type of cancer that is diagnosed in tissues under a microscope.
- Tumor location.
- Assessing the disease's extension into the soft tissues.
- Evaluating the extent of soft tissue involvement.
- Treatment with chemotherapy/rationtherapy

Surgical Characteristics

- Check what kind of pelvic resection they will undergo.
- Reconstruction technique.
- Shape of the implant.
- Use of Computer Assisted Planning/3D printing.

Clinical Outcomes

- Functional scores.
- Complication rates.
- Revision procedures.
- Implant survival.
- Local recurrence and survival rates.
- Content and quality: methodological quality and risk of bias

3.5 Assessment of Methodological Quality and Risk of Bias

The Newcastle–Ottawa Scale (NOS) (Wells et al., 2014) will be used to assess study quality in observational cohort studies, for patients in the selection and comparability between groups, as well as the assessment of outcome. In the case of surgical case series and non-comparative studies, the Methodological Index for Non-Randomized Studies

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(MINORS) will be examined. MINORS is used to assess methodological quality, and it considers the following criteria: the aims are clearly stated, prospective data collection, selection of adequate endpoints, unbiased assessment, and appropriate follow-up (Slim et al., 2003). Since the reconstruction of a pelvic sarcoma is a rare procedure, the evidence obtained will be largely from retrospective case series and these have a potential risk of bias as well as heterogeneity and so will need careful consideration when interpreting the results.

3.6 Data Synthesis and Analysis

Because of anticipated variability in the studies in terms of the type of tumor reconstructed, methods of reconstruction, outcome measures, and length of follow-up, a qualitative synthesis will be conducted. Findings are grouped by their reconstruction category:

1. Non-reconstructive procedures.
2. Biological reconstruction.
3. Conventional prosthetic reconstruction.
4. Implant-reconstruction options that are custom-made or 3D-printed.

If adequate homogeneous data exist, then quantitative analysis of the outcomes and comparison of outcomes might be included. Meta-analysis may be hampered by a variety of different surgical techniques and reporting methods, however.

4. Results

4.1 Literature Search and Study Selection

A trial began with identification of patients at the first database search who were being treated for primary or secondary sarcomas of the pelvis that had been treated by pelvic resection. All duplicate data was removed, then subject titles and abstract data was used to determine eligibility by applying predetermined criteria. The full-text articles were then evaluated to determine whether to include them, with criteria including the method used to reconstruct the teeth, clinical outcomes, and reporting of complications after surgery. Finally, the outcome of the process of including and excluding of studies that will be selected for presentation will be summarised in a PRISMA flow diagram (Page et al.,

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2021) showing the number of studies found, screened, excluded and included in the qualitative synthesis.

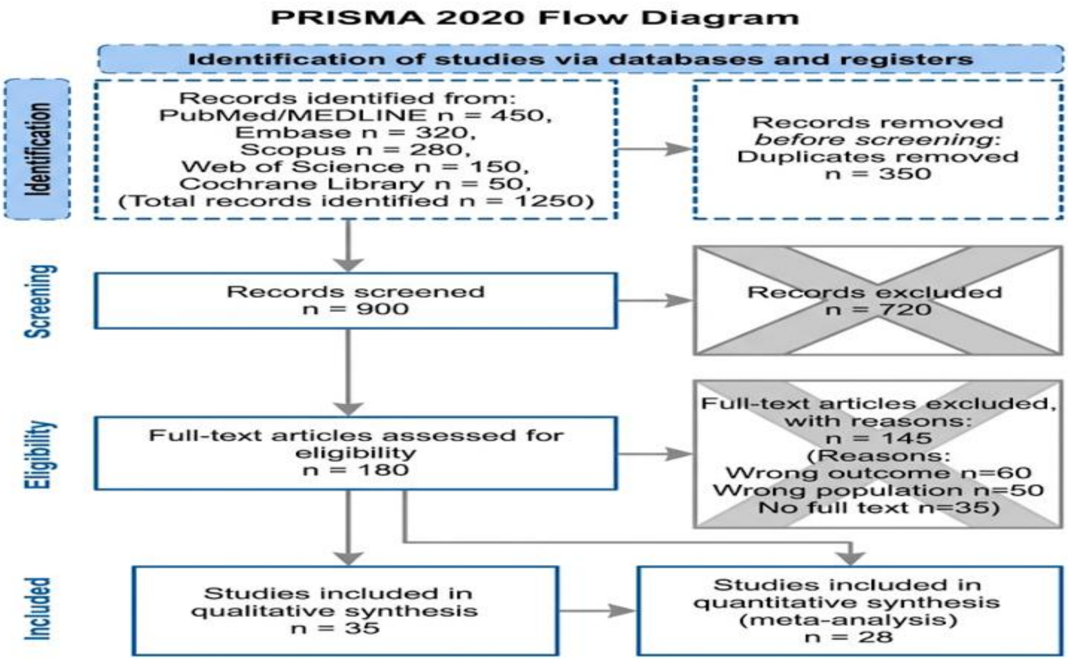

Figure 1: PRISMA 2020 flow diagram describing the identification, screening, eligibility assessment and inclusion of articles measuring pelvic reconstruction after resection for musculoskeletal sarcoma.

4.2 Characteristics of Included Studies

The following studies looked at different surgical approaches to reconstruct the pelvis after an internal hemipelvectomy for primary musculoskeletal sarcomas. Patients were usually those who had sarcomas of the pelvis, such as chondrosarcoma, osteosarcoma or Ewing Sarcoma. The majority of studies have studied periacetabular resections because of the increased difficulty of reconstructing the lesions associated with the loss of weight-bearing articulation of the hip. Variables reported in the various studies were: patient characteristics, tumor type, the type and location of Enneking's pelvic resection, reconstruction approach, functional outcome measurements, complication rates, and implant survivability. There was significant variability in surgical techniques, duration of follow-up, and measurements of goals of surgery.

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Table 1. Characteristics of studies evaluating pelvic reconstruction after musculoskeletal sarcoma resection

Author	Year	Study design	Pelvic resection	Main outcomes
O'Connor et al.	1996	Retrospective case series	Internal hemipelvectomy	Functional outcomes
Wirbel et al.	2001	Retrospective cohort	Periacetabular resection	Function and complications
Guo et al.	2007	Retrospective series	Various pelvic resections	Reconstruction failure
Mavrogenis et al.	2012	Retrospective study	Periacetabular resection	Implant survival
Angelini et al.	2017	Clinical series	Complex pelvic resection	Function and complications
Wong et al.	2016	Case series	Internal hemipelvectomy	Early functional outcomes

Demographic, surgical, and outcome data from studies evaluating outcomes following sarcoma resection are included in Table 1. Numerous changes in the paradigm of conventional reconstruction were aimed at the use of custom-made implant solutions, and literature describes anterior resorption and appliance durability along with other complications mainly in terms of function.

4.3 Reconstruction Techniques Identified

4.3.1 Non-reconstructive Procedures

Hip transposition and flail hip reconstruction both are possible options for non-reconstructable cases in select patients when the tumor extent is too large, soft tissue quality is inadequate or survival time is fairly short. During hip transposition, there is formation of scar tissue contained between the femur and the rest of the pelvis, and avoids any complications that could occur due to implants. Functional outcomes, however, are usually restricted due to shortening of the limb, abnormal biomechanics and decreased hip stability. O'Connor and colleagues showed that whilst the limb may be salvaged after resection of the pelvic sarcomas, the functional results are closely linked to the restoration of pelvic stability and the mechanism of the hip reconstruction (O'Connor et al., 1996).

4.3.2 Biological Reconstruction

The biological reconstructive approaches are structural allografts, autografts or allograft-prosthetic composite reconstruction. These techniques involve the use of biological tissue

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to restore the morphology and these procedures should be considered in younger patients with considerable life expectancy. Reconstructing a biological model however, can come with many complications such as graft fracture, nonunion, infection and extended rehabilitation. However, reconstruction after periacetabular tumor resection has been reported to be difficult due to the challenge of achieving long-term biological fixation in an environment compromised by surgery (Wirbel et al., 2001).

4.3.3 Prosthetic Reconstruction

For extensive pelvic resections involving the acetabulum, endoprosthetic reconstruction has become one of the most popular strategies. Hemipelvic prostheses, custom and modular, ensure that patients become immediately mobile, acquire a good leg length and start moving soon. Major limitations of the prosthetic reconstruction technique are the high rate of infection, instability, mechanical failure and revision surgery. Harrington developed methods for the reconstruction of large acetabular defects with metal implants, and showed that even in the case of large pelvic resections, hip was adequately supported with the invention of the hip prosthesis (Harrington, 1981).

4.4 Custom-Made and Three-Dimensional Printed Reconstruction

In recent studies, there has been reports on the growing use of implants customized for individual patients made with computer guided design and 3-D printing technology. They are designed for individual defects in the pelvis to be reconstructed, to restore anatomy, and to have multiple fixation trajectories for optimal placement. Early results with the custom-made implants used for reconstruction in the pelvicalcaneum after tumour resection are encouraging, as they showed an improvement in anatomical restoration and satisfactory functional outcome in selected patients (Angelini et al., 2017). Likewise, Wong et al. reported successful use of 3D printed hemipelvic implants and the feasibility of personalized reconstruction after complex pelvi-tumour surgery (Wong et al., 2016).

4.5 Functional Outcomes

Two commonly used functional assessment scores after reconstruction of the pelvis are the Musculoskeletal Tumor Society (MSTS) score and the Toronto Extremity Salvage Score (TESS) The reported functional results are deemed very different depending on the degree

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of pelvic resection, preservation of neurological structures, reconstruction techniques and complication rates. For patients undergoing surgery to reconstruct the stability and hip articulation of the pelvis, the ability to walk tends to be better than those who are not reconstructed. Altered anatomy – and the amount of soft tissue disruption however, make even successful reconstruction often result in lesser function than normal hip biomechanics.

Table 3. Methodological quality assessment of included studies

Study	Design	Assessment tool	Risk of bias
O'Connor et al.	Retrospective series	MINORS	Low/Moderate
Wirbel et al.	Cohort study	NOS	Low/Moderate
Guo et al.	Retrospective series	MINORS	Moderate
Mavrogenis et al.	Cohort study	NOS	Low/Moderate
Angelini et al.	Case series	MINORS	Moderate
Wong et al.	Case series	MINORS	Moderate

4.6 Complications and Reconstruction Failure

The most significant shortcoming of the reconstruction of the pelvis after surgery for sarcomas is that the procedures often may be complicated. Common complications are deep infection, loosening of the implant, mechanical failure, dislocation, development of complications at the surgical site and revision surgery. One of the biggest reasons for failure to reconstruct is because of the fact that the surgery has to be long enough and the patient will be on chemotherapy, which will render them very susceptible to infection. Mechanical complications are especially important in the periacetabular reconstruction, as implants are exposed to large weight-bearing forces during ambulation. Evidentially, in general, failure of reconstruction is multifactorial, and is affected by the characteristics of the tumor, surgical technique, implant design, soft tissue reconstruction and patient-related factors.

4.7 Comparison of Reconstruction Strategies

Hip transposition and other non-reconstructive techniques are also useful in rare instances where reconstruction is considered too great a risk. Such procedures can help prevent issues associated with implants and make the surgery easier. The problems with functional

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limitations due to the shortened length of the limb, pelvic instability and changes in gait mechanics often lead to lower functional scores in comparison with other more successful anatomical reconstruction attempts (O' Connor et al. 1996). Therefore, when patient factors or tumor characteristics make the prostheses or biological reconstruction difficult, non-reconstructive procedures are generally considered.

The goal of biological reconstruction is to obtain the permanent skeletal reconstruction, and to achieve this, the use of allografts or autografts has been developed. However, this method may be appealing for younger people with a long life expectancy since they do not have to endure permanent metal implants. The biological healing process is, however, unpredictable and the important limitations include potential for nonunion, graft fracture, infection, and lengthy rehabilitation. Surgical reconstruction using biological material after periacetabular resection needs to be carefully planned to account for the necessity of obtaining good fixation, coverage with soft tissues, and biological integration, as outlined by Wirbel et al. (2001).

Table 2. Comparison of available pelvic reconstruction strategies

Reconstruction method	**Advantages**	**Limitations**	**Functional outcome**	**Common complications**	**Current role**
Hip transposition	Avoids implant complications; shorter surgery	Limb shortening; gait abnormality; instability	Moderate to poor	Limb discrepancy, pain	Selected high-risk patients
Arthrodesis	Provides stability; no implant failure	Loss of hip motion; difficult rehabilitation	Moderate	Nonunion, altered gait	Limited indications
Allograft reconstruction	Biological restoration; preserves anatomy	Slow incorporation; graft failure	Variable	Infection, fracture, nonunion	Selected young patients
Allograft-prosthetic composite	Combines biological and mechanical advantages	Technically demanding	Good in selected patients	Infection, loosening	Complex reconstruction

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Modular hemipelvic prosthesis	Immediate stability; early mobilization	Infection and mechanical failure	Moderate-good	Infection, dislocation, loosening	Common option
Custom-made implant	Anatomical restoration	Expensive; manufacturing time	Good early results	Infection, loosening	Increasing use
3D printed titanium implant	Patient-specific design; improved fixation	Limited long-term evidence	Promising	Implant failure, infection	Emerging technology

Materials materials used for large pelvic reconstruction, particularly involving the acetabulum, are most commonly, used in prosthetic reconstruction. The major benefits of endoprosthetic reconstruction are rapid structural stability, early mobilization and restoration of weight transmission. Harrington's work with metallic reconstruction in large periacetabular defects paved the way for current hemipelvic prosthetic reconstruction (Harrington, 1981).

4.8 Functional Outcomes and Quality of Life

A primary goal of reconstructing a pelvis is to restore function. Pelvic sarcoma surgery outcomes are more dependent on the amount of surgical removal of the tumor and the number of surrounding muscles, nerves, and soft tissues which are not damaged. The MSTS is the most widely used functional assessment measure in musculoskeletal oncology (Mavrogenis, 2012). Upcoming studies are still few, however, it is hard to baseline any of the studies as they use different follow-up durations and reconstruction techniques. There is improvement in ambulation overall in patients reconstructed to restore pelvic stability when compared to those in whom there was no reconstruction, but functional results are not entirely satisfactory because of the change in biomechanics and the loss of so much tissue (Enneking et al., 1980).

5. Limitations

The following are some limitations of this systematic review which should be taken into consideration when interpreting the results. The first issue is that musculoskeletal sarcomas

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of the pelvis are uncommon tumors and so much of the existing literature consists of retrospective case series from a few high-volume oncology centers. There were no randomized controlled trials to enable direct comparison between the reconstruction techniques and reduce the level of evidence available. Second, there are significant differences in the patient characteristics, tumour types studied, the type of pelvic resections performed, surgical techniques employed to restore the pelvic control and function, and the type of outcome measures used across the various publications. Comparisons are difficult, because there are different types of surgery, different implant designs, different protocols for rehabilitation, and different follow-up periods. Third, there are multiple different scores available for reporting functional outcome, the most frequently used being the Musculoskeletal Tumor Society (MSTS) score and Toronto Extremity Salvage Score (TESS). Reporting of outcomes may differ, potentially leading to different interpretations of functional superiority of reconstruction techniques. Fourth, the technology of implants, in particular custom-made and 3D implants, is fairly new. Initial clinical outcomes are promising, but a large sample size of patients with sufficient follow-up is generally lacking in other studies. Hence, their durability and long term survival needs to be further explored for. Lastly, publication bias may be present, as institutions performing successful complex reconstruction may be more likely to publish their results, while institutions performing unsuccessful complex reconstruction or negative may not be.

Conclusion

Resection site reconstruction following removal of a musculoskeletal sarcoma remains one of the most difficult procedures in orthopaedics with regards to sarcoma surgery. Existing data shows that there is no one best reconstruction strategy for all patients. Reconstruction should be tailored to the individual tumor, level of pelvic resection, patient anatomy and characteristics, functional needs, and oncologic survival. The non-reconstructive procedures are beneficial in select patients when complex reconstruction is not indicated but can have functional limitations. Biological reconstruction offers a possible definitive surgical reconstruction with the risk of nonunion, graft rejection and prolonged recovery. Even with carefully balanced advantages and disadvantages, the reconstruction of a large defect in the pelvis with a prosthesis is the most frequently employed method since it offers immediate mechanical stability and allows for early rehabilitation, as it often does not offer

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patient optimization.Although there are many serious risks of infection and machine failure with a prosthesis, extensive defect reconstruction remains the most commonly used method because it often does not offer patient optimization and provides immediate mechanical stability and early rehabilitation. The recent introduction of computer assisted planning and three-dimensional printed patient specific implants has made the reconstruction of complex pelvic defects a lot more options. These technologies show potentially exciting initial functional results and anatomical restorations, but more time and multicenter comparative studies are required before their definite role is defined.

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