



E-ISSN: 2707-8353

P-ISSN: 2707-8345

Impact Factor (RJIF): 6.09

IJCRO 2025; 7(2): 203-207

www.orthocasereports.com

Received: 18-08-2025

Accepted: 21-09-2025

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Mechanical Failure of a Custom-Made 3D-Printed Pelvic Reconstruction Following Hemipelvectomy for Chondrosarcoma: A Case Report

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DOI: <https://www.doi.org/10.22271/27078345.2025.v7.i2d.285>

Abstract

Chondrosarcoma is a malignant bone tumor with a high risk of local recurrence and distant metastasis, particularly to the lungs. Its management poses significant surgical challenges, especially in cases with multiple recurrences and the need for complex reconstructions. These situations demand highly individualized approaches and are associated with a high risk of complications, particularly infection. Achieving both oncological control and functional restoration is essential. This case report describes a patient who underwent hemipelvectomy with reconstruction using patient-specific, custom-made prosthesis created through three-dimensional printing technology. During mid-term follow-up, the patient presented broken sacral screws and the required revision included a new custom-made prosthesis with spinopelvic fixation. The integration of advanced imaging and three-dimensional printing has marked a significant milestone in orthopedic oncology, enabling precise, anatomically matched implants. These porous, custom-designed prostheses improve biological integration and allow optimal load distribution, contributing to better functional outcomes and complication control, even in the setting of revision surgeries. The spinopelvic fixation for hemipelvectomy reconstructions and the advantages of the pelvic ring reconstruction are questions to answer in the near future in order to optimize these patients' treatment and functional outcomes.

Keywords: Chondrosarcoma; Hemipelvectomy; Pelvic Reconstruction; Custom-made Prostheses; 3D Printing in Orthopedic Oncology

Introduction

Chondrosarcomas are uncommon bone tumors arising from cartilage-producing cells and represent the second most frequent primary bone sarcoma after osteosarcoma ^[1]. Recent studies suggest a rising incidence, largely due to the incidental detection of atypical cartilaginous tumors ^[2]. They typically present around 51 years of age, with a slight male predominance, and most cases occur in individuals over 40. Conventional primary chondrosarcoma accounts for approximately 85% of all cases ^[3].

Chondrosarcomas most frequently arise within the osseous skeleton, though a small proportion may present as primary soft tissue masses. These tumors can develop in various locations throughout the body, with the majority occurring in the extremities (45%), followed by the axial skeleton (31%). The pelvis is a common site of origin, with approximately 20% arising from the pelvic bones ^[3]. Accurate diagnosis and staging are essential for guiding management, with biopsy and histological grading forming the basis of treatment planning. Preoperative grading can be challenging due to sampling errors and interobserver variability, particularly in pelvic lesions, and should be interpreted alongside imaging and clinical findings ^[4].

Imaging plays a crucial role in assessment. Magnetic resonance imaging (MRI) evaluates tumor extent, tissue involvement, and proximity to critical structures, while computed tomography (CT) is used when MRI is contraindicated. Chest CT assesses pulmonary metastases, and skeletal involvement can be evaluated using radionuclide bone scans or whole-body fluorodeoxyglucose positron emission tomography/CT (FDG PET/CT) ^[5]. Staging commonly relies on the Enneking system or the American Joint Committee on Cancer (AJCC) staging system, which consider tumor grade, size, anatomical location, and metastases ^[6].

Like other primary bone malignancies, chondrosarcomas located in the long bones are associated with a more favorable prognosis compared to those arising in the pelvis or axial

skeleton. Notably, grade I tumors of the appendicular skeleton are classified as atypical cartilaginous tumors (ACTs), intermediate lesions, due to their limited malignant potential. In contrast, the term "grade I chondrosarcoma" is reserved for low-grade cartilaginous tumors of the axial skeleton, which are associated with worse clinical outcomes compared to ACTs of the extremities. Surgical management of pelvic chondrosarcomas is challenging due to complex anatomy and weight-bearing demands. Advances in three-dimensional (3D) printing allow the creation of customized hemipelvis prostheses with patient-specific osteotomy guides and porous structures, enhancing osseointegration and functional restoration [7]. Additive manufacturing enables precise, rapid production of implants with controlled architecture, addressing limitations of conventional prostheses. These developments have expanded reconstructive options for large pelvic defects, particularly in cases requiring wide resections or complex reconstructions. The integration of computer-aided design, 3D printing, and advanced biomaterials offers tailored solutions to optimize both mechanical stability and biological integration in orthopedic oncology [8].

Case Report

A 47-year-old man presented with a two-month history of right-sided hip pain radiating to the anteromedial thigh. Imaging and biopsy revealed a low-grade chondrosarcoma (grade I) of the right acetabulum (Fig. 1). He underwent intralesional treatment with aggressive curettage followed by cemented total hip arthroplasty (Lubinus®) (Fig. 2).

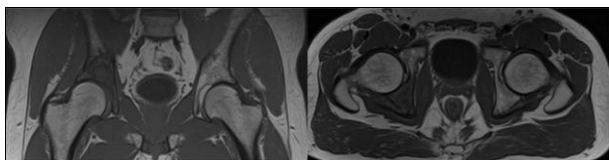


Fig 1: Osteolytic lesion of right acetabulum.



Fig 2: Cemented total hip arthroplasty after curettage, drilling and phenolization.

Histopathological analysis confirmed a grade I chondrosarcoma. During follow-up there was no other distant lesions. Two years after the initial surgery, imaging demonstrated a 22 mm lytic lesion with lobulated and slightly irregular margins, along with faint internal

septations. Additionally, a low-density, oval-shaped lesion measuring 7.6×3.1 cm in axial diameter and approximately 10 cm in longitudinal extension was identified within the obturator muscle. These findings were consistent with local recurrence of the chondrosarcoma involving the right ilium — pelvic zones I and II (periacetabular region) (Fig. 3).

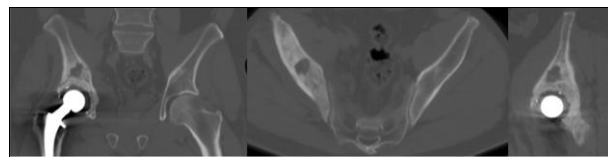


Fig 3: Local recurrence of the chondrosarcoma involving the right ilium—pelvic zones I and II (periacetabular region).

In this patient, given the complexity of the pelvic defect and the recurrence in the periacetabular region, although a low-grade in the biopsy there was a considerable risk for upgraded recurrent tumor. It was decided to proceed the wide resection and pelvic reconstruction in two stages. Initially, no reconstruction was performed after tumor excision, allowing for clinical evaluation and planning of delayed reconstruction (Fig. 4a). Two months later, a custom-made pelvic prosthesis was designed using 3D modeling techniques and produced in combination with a LUMiC® (Implantcast®) with dual mobility, tailored to the patient's specific pelvic anatomy and defect, anchored to the sacrum (Fig. 4b).



Fig 4a: Iliac excision with preservation of the pubic rami.



Fig 4b: A custom-made pelvic prosthesis was designed using 3D modeling techniques and produced in combination with a LUMiC® (Implantcast®) with dual mobility, tailored to the patient's specific pelvic anatomy and defect, anchored to the sacrum.

An *en bloc* resection of the right iliac bone (zones I and II) was performed while preserving the pubic rami. No reconstruction was done at that time (Fig. 4a). Two months later, pelvic reconstruction was carried out using the custom-made prosthesis anchored to the sacrum and integrating the LUMiC® reconstruction (Fig. 4b). Pathology report confirmed negative margin of the upgraded tumor to grade II chondrosarcoma (rpT2bR0). One year later, local recurrence was noted in the right pubic rami (Fig. 5)

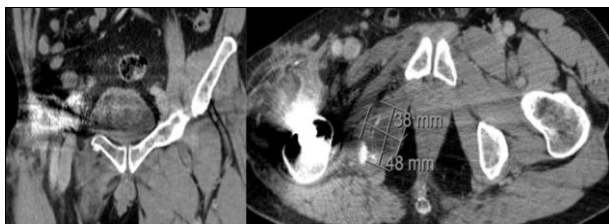


Fig 5: Chondrosarcoma recurrence in right pubic rami.

The patient underwent excision of the pubic rami, thereby completing a right hemipelvectomy (Fig. 6). Histology confirmed negative margins of a high-grade chondrosarcoma with further upgrade to grade III (rpT1R0). Postoperative recovery was successful, with effective rehabilitation, sustained functional activity, and no major complications. Patient returned to full activities.



Fig 6: After a second local recurrence at the pubic rami, the patient underwent excision of the pubic rami, thereby completing a right hemipelvectomy.

Two years after this procedure, the fully active patient started feeling pain with weight bearing that progressively limited him functionally. A mechanical failure of the screws fixed to the sacrum was identified (Fig. 7). A revision surgery was carried out: first, the sacral broken screws and the acetabular component fixed to the sacrum were removed and replaced with a new custom-made 3D printed implant. Second, a posterior spinal instrumentation of L4-L5-S1 (left) was performed at the same time, with a cross-link, to ensure adequate spinopelvic fixation and stability (Fig. 8). A Trevira® tube was used for soft tissue reinforcement. Local antibiotic pearls were also used (Stimulan®).

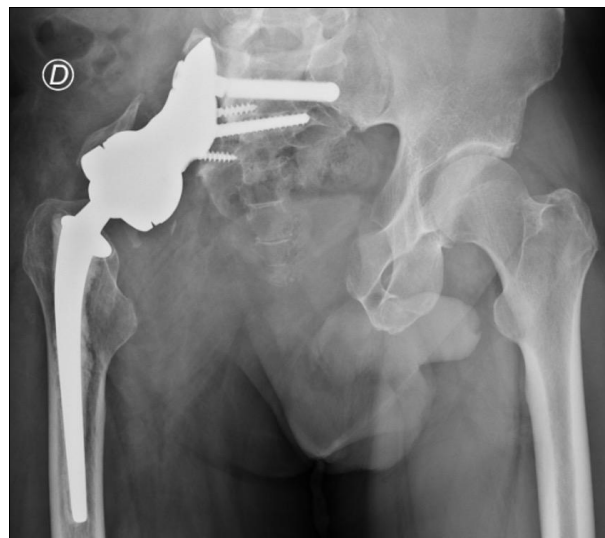


Fig 7: Mechanical failure of the screws fixed to the sacrum.



Fig 8: Posterior spinal instrumentation of L4-L5-S1 (left) was added, with a cross-link, to ensure spinopelvic fixation and stability.

Following the most recent surgical intervention, the patient showed a favorable clinical course, with stable reconstruction. The patient completed rehabilitation for muscles reinforcement and proprioception improvement on uneven floor, showed progressive functional recovery walking without support, and he is fully active at 12 months of follow-up. To date, there is no evidence of disease recurrence or other complications, particularly despite the high risk of infection. Oncological and long-term monitoring remain ongoing.

Discussion

Management of chondrosarcoma must be individualized, guided by tumor location, histological grade, involvement of critical structures, and metastatic status, alongside patient-specific factors. A multidisciplinary approach is essential. Surgery remains the primary treatment for conventional chondrosarcoma due to resistance to chemotherapy and radiotherapy, attributed to low mitotic activity, slow proliferation, and limited vascularity [9].

The surgical goal for non-metastatic pelvic chondrosarcomas is achieving negative margins while

preserving critical neurovascular structures such as the sciatic nerve, femoral vessels, and hip joint. Limb-salvage surgery is generally feasible if at least two of these structures can be retained [10]. Tumors limited to the iliac wing (Enneking Type I) or pubic rami (Type III) may be managed with wide resection alone, whereas periacetabular (Type II) resections require more complex reconstruction. Available reconstructive strategies include modular endoprostheses and allograft–prosthetic composites. Among these, the inverted "ice-cream cone" prosthesis, anchored to the ilium, offer better functional outcomes and lower complication rates compared to earlier techniques [10].

Pelvic chondrosarcomas — particularly those in the periacetabular region (Enneking zones I and II) — pose significant surgical challenges due to complex anatomy and the mechanical demands of the pelvis. In this case, a low-grade chondrosarcoma initially treated with aggressive curettage and cemented total hip arthroplasty recurred locally after two years, highlighting the difficulty of achieving durable oncologic control with intralesional approaches. Even low-grade pelvic chondrosarcomas require negative margins for effective local control. This patient experienced two local recurrences, each with tumor grade progression (first to grade II, then to grade III), despite successful resections with negative margins. Following completion hemipelvectomy, mechanical failure of the sacral fixation of the custom-made prosthesis occurred, demonstrating the importance of spinopelvic fixation, particularly in active patients.

The use of custom-made, 3D-printed pelvic prostheses, combined with dual mobility acetabular components, proved an effective option in this scenario. Based on 3D imaging planning, this approach allows for anatomically tailored implants, optimizing bone fixation and reducing mechanical complications. Recent patient series reported satisfactory functional outcomes measured by Musculoskeletal Tumor Society score, although complication rates remain substantial (~30–38%) in short- to mid-term follow-up [11].

This case clearly demonstrates that custom-made, 3D-printed prostheses provide a significant advantage in reconstructing complex pelvic defects, enabling precise anatomical restoration and improved mechanical stability, which are crucial for optimizing patient outcomes in challenging oncological scenarios. The integration of advanced image processing and three-dimensional (3D) printing technologies has marked a significant milestone in patient-specific reconstruction within orthopedic oncology. The porous architecture of 3D-printed implants demonstrates excellent biocompatibility, promoting the integration of both bone and soft tissue. Furthermore, the accurate anatomical conformity, porous bone–implant interface, and efficient load transfer contribute to improved limb function and a manageable complication profile [11].

It is important to add the spinopelvic fixation to the reconstruction of hemipelvis, especially for active patients. In this case, spinopelvic fixation was required following mechanical failure of the initial sacral fixation screws. It provides enhanced stability in extensive pelvic reconstructions, particularly in younger, active patients, as supported by recent clinical protocols [12]. Presently, experts discuss when to add the spinopelvic fixation and the best technic and evaluate the impact of pelvic reconstructions with or without closed ring in order to analyze if it adds stability and define indications. Furthermore, literature

shows that navigation and patient-specific planning improved negative margins impacting local control and disease-specific survival particularly for chondrosarcomas, thus assisting the technically difficult pelvic resections [13].

For this major reconstructions, infection, local recurrence and mechanical complications remain significant challenges, even in low-grade disease. Therefore, close clinical and radiological surveillance, alongside multidisciplinary management, is essential for timely intervention and long-term success.

This case presents several distinctive challenges, including multiple local recurrences and mechanical failure of the pelvic reconstruction, which underscore the inherent complexity of managing pelvic chondrosarcomas. Resection with negative margins impacts local control even for low-grade pelvic chondrosarcoma. These events highlight the importance of weighing the high surgical risks against the potential oncological and functional benefits. In the end, this report reinforces the need for individualized reconstructive strategies within the context of a highly experienced multidisciplinary team of referral centers, aiming to optimize both disease control and long-term patient function.

Ultimately, this approach underscores the critical role of tailored surgical planning, integration of advanced technologies, and rigorous follow-up in the management of pelvic chondrosarcomas. Despite the high complication risks, personalized 3D-printed reconstructions offer functional restoration and oncological control in complex scenarios.

Conclusion

Pelvic reconstruction after tumor resection carries high risk of infection, dislocation, and mechanical failure, and should be individualized in referral centers. In this case, the patient experienced upgraded local recurrence despite wide resection with negative margins. Later, after the totalization of the hemipelvectomy, mechanical failure of the reconstruction occurred, highlighting the importance of spinopelvic fixation for stability in sacrum-anchored prostheses, particularly in young, active patients.

Conflict of Interest

Not available

Financial Support

Not available

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How to Cite This Article

Nelas J, Cordeiro F, Vieira da Silva G, Carrapatoso M, Oliveira V, Cardoso P. Mechanical Failure of a Custom-Made 3D-Printed Pelvic Reconstruction Following Hemipelvectomy for Chondrosarcoma: A Case Report. *International Journal of Case Reports in Orthopaedics* 2025; 7(2): 203-207.

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