

Preoperative 3D printing-assisted plate precontouring for complex acetabular fractures: a case series

Sebastián Oyanedel

Universidad de La Frontera

Fernando Inostroza

Hospital Doctor Hernán Henríquez Aravena

José Ordóñez

Universidad de La Frontera

Francisco Poo

Hospital Doctor Hernán Henríquez Aravena

Felipe Caroca

fcarocam@gmail.com

Universidad de La Frontera

Research Article

Keywords: Acetabular fracture, Three-dimensional printing, Preoperative planning, Plate precontouring, Quadrilateral plate, Orthopaedic trauma

Posted Date: September 30th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10770665/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Background

Acetabular fractures remain a major surgical challenge due to their complex three-dimensional anatomy and the technical difficulty of achieving stable fixation. Fracture patterns involving the quadrilateral plate require demanding implant contouring to restore pelvic anatomy and provide adequate medial support. Three-dimensional (3D) printing has emerged as a surgical planning adjunct; however, its direct technical role in patient-specific plate precontouring remains underreported. This study aimed to describe the clinical application and feasibility of patient-specific 3D-printed pelvic models for preoperative anatomical plate precontouring in complex acetabular fractures.

Methods

A retrospective case series of nine adult patients with unilateral acetabular fractures treated surgically between January 2024 and April 2025 was performed. High-resolution CT scans were used to generate patient-specific, 1:1 scale 3D-printed pelvic models using fused deposition modeling. These models were used for fracture analysis, surgical planning, and anatomical precontouring of fixation plates prior to surgery. The primary outcome was technical feasibility, defined as successful intraoperative use of precontoured plates without major recontouring. Secondary variables included precontouring time, operative time, reduction quality, and complications.

Results

Patient-specific 3D models were successfully generated and anatomical plate precontouring was completed preoperatively in all nine cases. Precontoured plates were applied as definitive implants in all patients without major additional intraoperative recontouring. The most frequent fracture pattern was anterior column with posterior hemitransverse. Postoperative reduction quality, assessed by the Matta grading system, was anatomical (≤ 1 mm residual displacement) in 6/9 patients and poor (> 3 mm) in 3/9. Postoperative complications occurred in three patients; no intraoperative events related to implant mismatch were observed.

Conclusions

Patient-specific 3D-printed pelvic models enable reliable preoperative plate precontouring in complex acetabular fractures, reducing intraoperative adjustments and simplifying the definitive fixation phase. Prospective comparative studies are needed to quantify the impact on operative time, fixation stability, and clinical outcomes.

Background

Acetabular fractures are associated with high morbidity and mortality and represent a major challenge for orthopedic trauma teams due to the complex pelvic anatomy and the technical difficulty of surgical approaches [1, 2]. Their incidence is relatively low, estimated at approximately 3 cases per 100,000 inhabitants per year, which limits the exposure and experience of many surgical teams compared with other types of fractures, even in high-volume trauma centers [3]. These injuries typically occur in the setting of high-energy trauma, and patients often present in critical condition with associated multisystem injuries [4].

In this context, imaging studies play a key role in lesion characterization and preoperative planning, with plain radiography and computed tomography being the most commonly used modalities [5].

Over the past decade, three-dimensional (3D) printing has been increasingly incorporated into acetabular fracture surgery [6–8]. Most reports highlight its role in improving anatomical understanding, surgical planning, and operative efficiency. Patient-specific pelvic models generated from computed tomography data allow detailed visualization of fracture morphology and enable preoperative simulation of reduction and fixation strategies.

Beyond visualization, 3D printing offers the opportunity to transfer one of the most technically demanding aspects of acetabular surgery—anatomical plate contouring—from the operating room to the preoperative setting. Accurate precontouring based on patient-specific pelvic anatomy may facilitate intraoperative fixation, particularly in fractures requiring extended plate adaptation along the pelvic brim and medial wall [9].

The purpose of this study is to describe the clinical application and technical feasibility of patient-specific 3D-printed pelvic models for preoperative anatomical plate precontouring in the surgical management of complex acetabular fractures.

Methods

A descriptive, retrospective case series was conducted at a public tertiary referral hospital. The study protocol was approved by the institutional ethics committee, and all procedures were performed in accordance with current ethical standards. All patients provided written informed consent for the use of their imaging and clinical data for research purposes.

Patients were recruited from those referred to our institution as the regional public referral center for the management of complex acetabular fractures.

Nine patients with acetabular fractures surgically treated between January 2024 and April 2025 were included. Fractures were classified according to the Judet–Letournel classification [10].

Inclusion criteria were: patients aged 18 years or older, unilateral acetabular fracture of less than two weeks' duration, availability of a preoperative non-contrast pelvic computed tomography (CT) scan, and signed informed consent.

Exclusion criteria were: pre-existing hip osteoarthritis, prior hip or acetabular osteosynthesis material or prosthetic implants, pathological bone fractures, or patients deemed unfit for surgery due to severe general medical conditions.

Generation and fabrication of 3D anatomical models

Non-contrast pelvic CT images were processed using the open-source software 3D Slicer to segment the relevant bony anatomy. Subsequently, Meshmixer software was used to refine the three-dimensional mesh and to generate a mirrored model of the contralateral healthy hemipelvis when required.

The three-dimensional models (Fig. 1A–B) were exported in STL format and fabricated at a 1:1 scale using fused deposition modeling (FDM) 3D printing technology (Fig. 2). After printing, the models were cleaned and prepared for use in surgical planning and anatomical plate precontouring.

Surgical planning and plate precontouring

During the preoperative period, the printed models were used for detailed surgical planning, including analysis of fracture patterns, identification of displaced fragments, and definition of the reduction and fixation strategy.

Anatomical precontouring of conventional osteosynthesis plates (Matta® system) was performed directly on the 3D models, following the patient-specific pelvic curvature (Fig. 3A–C). The time required for precontouring was systematically recorded by a surgeon experienced in hip and pelvic trauma surgery. The plates were subsequently sterilized and used as definitive implants during surgery.

Surgical management and analyzed variables

Surgical procedures were performed using approaches selected according to fracture pattern and the treating team's discretion. The precontoured plates were applied once definitive fracture reduction had been achieved.

Demographic variables, mechanism of injury, fracture pattern, surgical approach, precontouring time, total operative time, postoperative complications, and quality of fracture reduction were recorded. Postoperative reduction quality was assessed on plain radiographs according to the Matta grading system: anatomical (≤ 1 mm residual displacement), imperfect (2–3 mm), or poor (> 3 mm).

The primary outcome was technical feasibility, defined as the ability to use the precontoured plate as a definitive implant without major intraoperative recontouring or implant abandonment. Major recontouring

was defined as the need to substantially re-bend or re-twist the plate after sterilization—altering its precontoured geometry—or to abandon it in favor of an alternative implant. Secondary variables included precontouring time, operative time, quality of reduction, and adverse events.

Data analysis

A descriptive analysis was performed. Continuous variables are presented as median with range, and categorical variables as absolute frequencies and percentages. No inferential statistical analyses were performed due to the descriptive design and limited sample size.

Use of artificial intelligence tools

During the preparation of this work, the authors used ChatGPT (OpenAI) to assist with language editing, text organization, and improvement of clarity and academic style, and AI2 Asta (Allen Institute for AI) to support literature exploration and organization during the bibliographic review process. After using these tools, the authors reviewed and edited all content as needed and take full responsibility for the integrity, originality, and accuracy of the published article.

Results

A total of nine patients with unilateral acetabular fractures managed surgically with 3D printing-assisted preoperative plate precontouring were included. The mean age was 50.8 ± 18.7 years (median 59, range 25–72). The cohort included seven male and two female patients. Injury mechanisms were predominantly falls from height and traffic accidents, with one motorcycle-related collision. Demographic and perioperative data are summarized in Table 1.

Table 1
Demographic, fracture characteristics, and perioperative data of patients treated with 3D printing-assisted plate precontouring.

Variable	Result
Number of patients	9
Median age, years (range)	59 (25–72)
Injury mechanism	Falls from height (n = 4) Traffic accidents (n = 4) Motorcycle collision (n = 1)
Most frequent fracture pattern	Anterior column with posterior hemitransverse (4/9)
Other fracture patterns	Posterior wall (n = 3) Both-column with protrusio (n = 1) Unclassifiable (n = 1)
Surgical approach	Anterior intrapelvic (n = 5) Posterior only (n = 3) Combined (n = 1)
Precontouring time, min (range)	32 (8–45)
Operative time, min (range)	210 (65–310)
Postoperative complications	3/9 · 2 wound-related infections · 1 hemorrhagic shock*
Postoperative reduction quality (Matta grading)	Anatomical (≤ 1 mm): 6/9 – Poor (> 3 mm): 3/9
* Hemorrhagic shock not related to the surgical procedure.	
Values are presented as median (range) or mean $\pm$ SD. Fracture patterns classified according to Letournel–Judet. Technical feasibility was defined as successful intraoperative use of precontoured plates without major recontouring.	
Abbreviations: 3D, three-dimensional; min, minutes; SD, standard deviation.	

Regarding fracture patterns, the most frequent configuration was anterior column with posterior hemitransverse fractures. Other patterns included posterior wall-related injuries, both-column fracture with protrusio, and one unclassifiable fracture pattern. Several patients presented with associated injuries, including femoral neck fracture, distal radius fracture, and polytrauma features.

Patient-specific 3D-printed pelvic models were successfully generated and used for preoperative anatomical plate precontouring in all cases. Precontoured plates were applied as definitive implants without the need for major additional intraoperative recontouring.

Postoperative reduction quality, assessed on CT (Fig. 4A–B) using the Matta grading system, was anatomical (≤ 1 mm residual displacement) in six patients (6/9) and poor (> 3 mm) in three patients (3/9). No case was classified as imperfect.

Surgical management used an anterior intrapelvic approach component (Stoppa) in 5/9 cases, while posterior-only approaches were used in 3/9 and a combined approach in 1/9. Surgical approaches and operative times are detailed in Table 1.

Postoperative complications were documented in 3/9 patients. Two cases developed wound-related infection/complications requiring additional management (including surgical debridement in one case), and one patient experienced postoperative hemorrhagic shock requiring transfusion, which was not related to the surgical procedure. No intraoperative events related to inability to apply the precontoured plates or major implant mismatch were reported.

Discussion

In this series, patient-specific 3D-printed pelvic models enabled accurate preoperative plate precontouring in complex acetabular fractures. The models reproduced individual pelvic anatomy at 1:1 scale, allowing detailed fracture analysis and progressive plate bending before surgery, so that near-anatomically adapted implants were available at the time of definitive fixation.

Acetabular fractures involving the quadrilateral plate remain among the most technically demanding injuries in orthopaedic trauma. In these fracture patterns, the principal difficulty often lies not only in achieving fracture reduction, but in obtaining precise and stable adaptation of fixation plates along the internal pelvic surface [11]. Accurate contouring is critical to provide effective medial buttress support and to maintain construct stability, yet it is traditionally performed intraoperatively in a deep and anatomically constrained surgical field.

The use of patient-specific 3D-printed models allows continuous and progressive precontouring of fixation plates along the pelvic anatomy, from the sacroiliac region through the innominate line to the anterior column. This preoperative preparation reduces the need for repeated intraoperative adjustments, limits prolonged implant manipulation, and decreases the uncertainty associated with freehand plate contouring [1, 3, 5]. As a result, it facilitates the fixation process once fracture reduction has been achieved, which represents one of the most critical steps where operative time is often lost and construct stability may be compromised in complex acetabular fractures.

From a technical perspective, the greatest value of this strategy lies in the possibility of planning and executing complex implant contouring in advance. In quadrilateral plate fractures, fixation success

largely depends on achieving an implant that accurately follows the internal pelvic curvature, providing effective medial support without intra-articular violation. In our practice, precontouring based on 3D-printed models simplified the intraoperative fixation stage once reduction was achieved, which is often the most demanding phase of these procedures.

Postoperative reduction quality was anatomical in 6/9 patients and poor in 3/9, with no imperfect result. Cases with poor outcomes corresponded to fractures of greater morphological complexity or with a longer interval between injury and surgery, suggesting that reduction quality depends on factors inherent to each case rather than on the preoperative planning strategy alone.

This approach appears particularly useful in fracture patterns requiring extended plate adaptation along the pelvic brim and medial wall. Having anatomically preadapted implants available intraoperatively reduced the need for repeated adjustments within the surgical field and improved control of implant positioning and fixation sequence. Although this study was not designed to quantitatively assess operative time, fluoroscopy use, or blood loss, the consistent perception of the surgical team was that this technique contributed to a more predictable and controlled intraoperative workflow in highly complex cases.

The usefulness of 3D printing extends to medical education. The pelvis, being a region with complex anatomy, presents challenges from a teaching perspective. In this context, several studies have reported that the use of 3D-printed models improves anatomical understanding and allows better visualization of lesion characteristics prior to surgery, particularly among trainees in the different areas of traumatology [12].

These results align with published series showing that 3D printing improves anatomical understanding and supports surgical planning in acetabular fracture management [1, 7, 12]. Unlike most of those reports, which focus primarily on visualization, our experience highlights its role as a direct tool for plate precontouring.

The main limitations of this work are the small number of cases, the retrospective design, and the lack of a control group, which prevent conclusions about differences in operative time, reduction quality, or clinical outcomes. The series also reflects a single center's experience, limiting generalizability. Despite this, it documents a reproducible technical application of 3D printing in one of the most demanding subsets of acetabular fractures.

Conclusions

3D-printed pelvic models are a reliable tool for preoperative plate precontouring in complex acetabular fractures. This approach allows complex implant adaptation outside the operating room, reducing intraoperative adjustments and simplifying the fixation phase once reduction has been achieved. Prospective comparative studies with larger samples are needed to quantify the impact on operative time, fixation quality, and clinical outcomes.

Abbreviations

3D
Three-dimensional
CT
Computed tomography
FDM
Fused deposition modeling
STL
Standard tessellation language

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Ethics Committee of Hospital Hernán Henríquez Aravena (Temuco, Chile). All procedures were performed in accordance with the ethical standards of the institutional committee and with the 1964 Helsinki Declaration and its later amendments. All patients provided written informed consent prior to their inclusion in the study.

Consent for publication

Written informed consent for publication of clinical data, imaging, and related figures was obtained from all patients included in this study.

Competing interests

The authors declare that they have no competing interests.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author Contribution

S.O and F.C contributed to conceptualization. S.O., F.C., and F.I contributed to methodology. S.O., F.I., and F.C. contributed to investigation. S.O and J.O contributed to data curation. S.O. performed formal analysis. F.C., F.I., and F.P. provided resources. F.P. contributed to software. F.C. contributed to supervision. S.O. and J.O. contributed to visualization. S.O. wrote the original draft. S.O., F.C., F.I., F.P., and

J.O. contributed to review and editing. S.O. and F.C. contributed to project administration. All authors read and approved the final manuscript.

Acknowledgements

The authors would like to thank the Orthopaedics and Traumatology Department and the operating room staff of Hospital Hernán Henríquez Aravena for their support in the management of these complex cases. We also acknowledge the technical support provided in the 3D printing process and the assistance of the clinical and academic teams involved in patient care and data collection. The authors further acknowledge the academic and institutional support of Universidad de La Frontera (Temuco, Chile), whose research environment contributed to the development of this work.

Data Availability

The datasets generated and/or analysed during the current study are not publicly available due to the presence of sensitive personal health information but are available from the corresponding author on reasonable request.

References

1. Lee AKX, Lin TL, Hsu CJ, Fong YC, Chen HT, Tsai CH. Three-Dimensional Printing and Fracture Mapping in Pelvic and Acetabular Fractures: A Systematic Review and Meta-Analysis. *J Clin Med*. 2022;11(18):5258. 10.3390/jcm11185258.
2. Trikha V, Cabrera VG, Bansal D, Mittal H, Sharma S. Epidemiological assessment of acetabular fractures in a level one trauma centre: A 7-Year observational study. *J Clin Orthop Trauma*. 2020;11(6):1104–9. 10.1016/j.jcot.2020.09.009.
3. Boudissa M, Francony F, Kerschbaumer G, Ruatti S, Milaire M, Merloz P, et al. Epidemiology and treatment of acetabular fractures in a level-1 trauma centre: Retrospective study of 414 patients over 10 years. *Orthop Traumatol Surg Res*. 2017;103(3):335–9. 10.1016/j.otsr.2017.01.004.
4. Cimerman M, Kristan A, Jug M, Tomažević M. Fractures of the acetabulum: from yesterday to tomorrow. *Int Orthop*. 2021;45(4):1057–64. 10.1007/s00264-020-04806-4.
5. Cimerman M, Kristan A. Preoperative planning in pelvic and acetabular surgery: The value of advanced computerised planning modules. *Injury*. 2007;38(4):442–9. 10.1016/j.injury.2007.01.033.
6. Zeng C, Xing W, Wu Z, Huang H, Huang W. A combination of three-dimensional printing and computer-assisted virtual surgical procedure for preoperative planning of acetabular fracture reduction. *Injury*. 2016;47(10):2223–7. 10.1016/j.injury.2016.03.015.
7. Chana Rodríguez F, Pérez Mañanes R, Narbona Cárcelos FJ, Gil Martínez P. Utilidad de la impresión 3D para el tratamiento quirúrgico de las fracturas acetabulares. Beca proyecto de investigación SECOT 2014. *Rev Esp Cir Ortopédica Traumatol*. 2018;62(4):231–9. 10.1016/j.recot.2018.02.007.

8. Cao J, Zhu H, Gao C. A Systematic Review and Meta-Analysis of 3D Printing Technology for the Treatment of Acetabular Fractures. *BioMed Res Int*. 2021;2021:1–15. 10.1155/2021/5018791.
9. Upex P, Jouffroy P, Riouallon G. Application of 3D printing for treating fractures of both columns of the acetabulum: Benefit of pre-contouring plates on the mirrored healthy pelvis. *Orthop Traumatol Surg Res*. 2017;103(3):331–4. 10.1016/j.otsr.2016.11.021.
10. Butler BA, Lawton CD, Hashmi SZ, Stover MD. The Relevance of the Judet and Letournel Acetabular Fracture Classification System in the Modern Era: A Review. *J Orthop Trauma*. 2019;33(2):S3–7. 10.1097/BOT.0000000000001401.
11. Mauffrey C, Stacey S, York PJ, Ziran BH, Archdeacon MT. Radiographic Evaluation of Acetabular Fractures: Review and Update on Methodology. *JAAOS - J Am Acad Orthop Surg*. 2018;26(3):83. 10.5435/JAAOS-D-15-00666.
12. Onggo JD, Fong FJY, Munro YL, Yam MGJ. Applications of 3D printing in orthopedics: A scoping review. In Review; 2023. Available from: <https://www.researchsquare.com/article/rs-3403913/v1>. 10.21203/rs.3.rs-3403913/v1

Figures

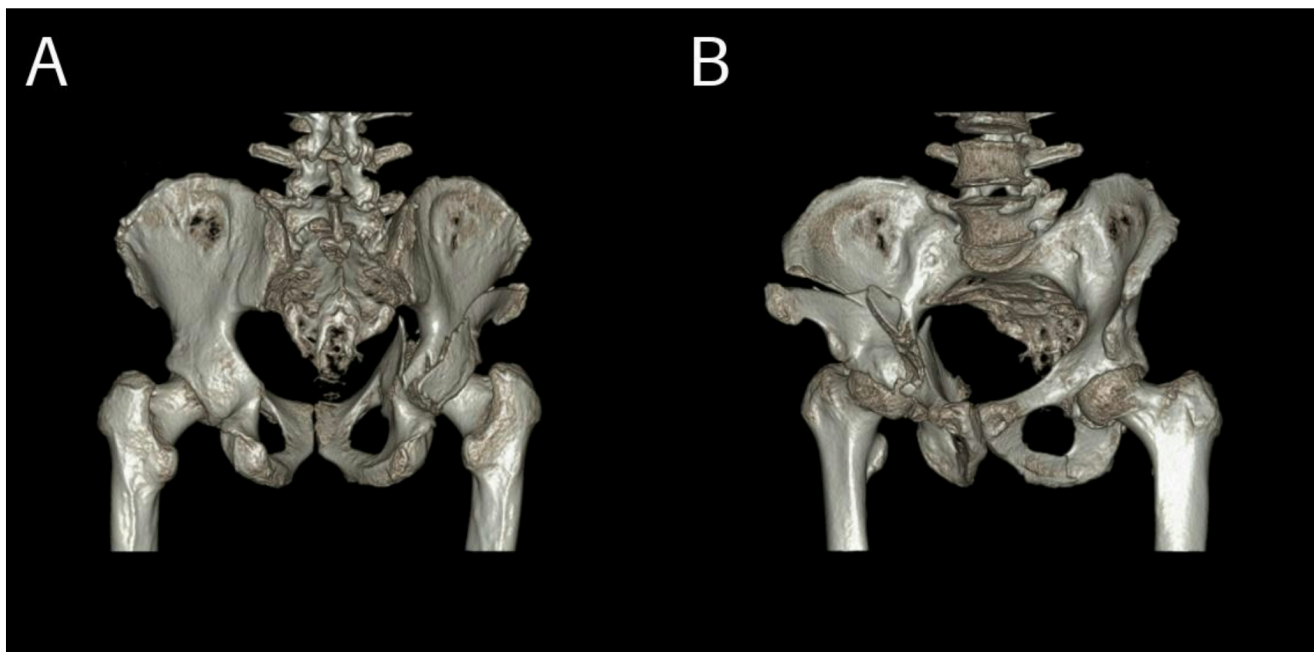


Figure 1

Preoperative CT reconstruction of a representative anterior column with posterior hemitransverse fracture. (A) Anteroposterior view. (B) Oblique view.



Figure 2

Patient-specific 3D-printed pelvic models generated from preoperative CT data. Left: fractured hemipelvis. Right: mirrored contralateral model used as anatomical reference.

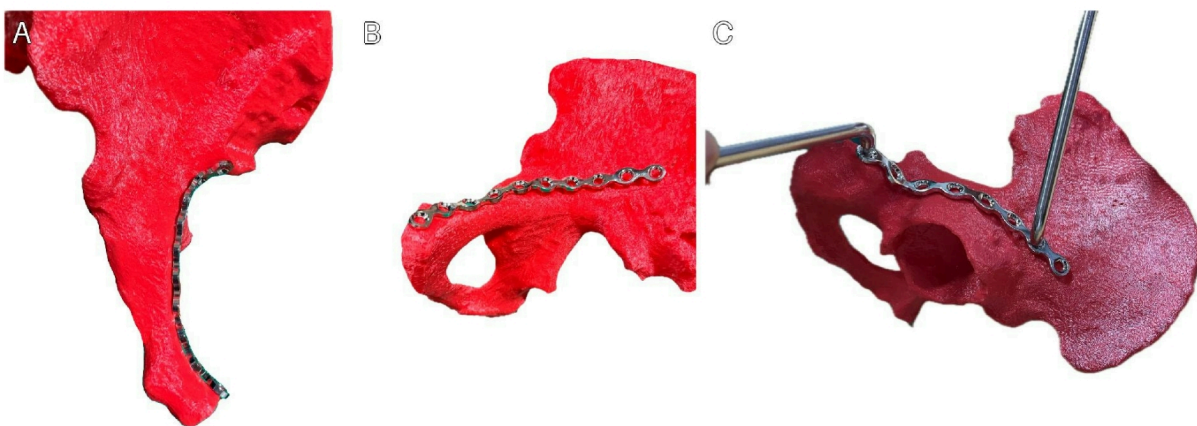


Figure 3

Preoperative anatomical plate precontouring on the 3D-printed pelvic model. (A) Contouring along internal pelvic surface. (B) Final congruence along pelvic brim. (C) Progressive contouring with bending instruments.

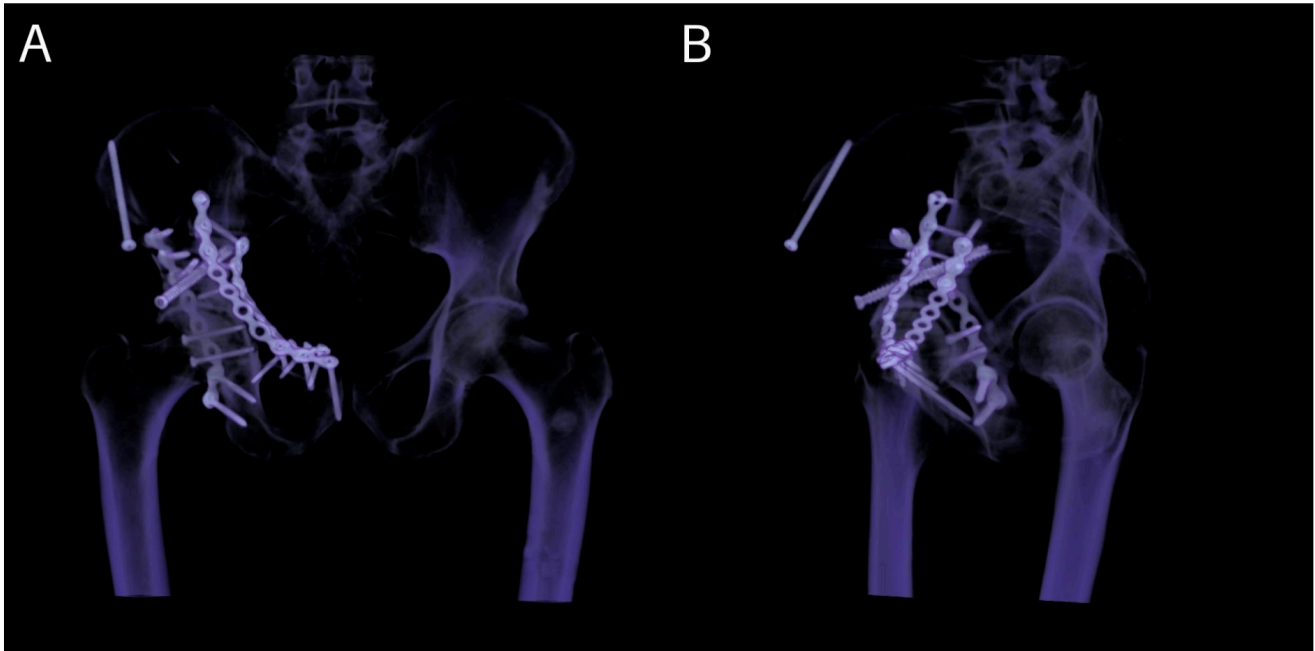


Figure 4

Postoperative imaging demonstrating definitive fixation with precontoured plates. (A) Anteroposterior view. (B) Oblique view, showing restoration of articular alignment.