

Title: Minimally Invasive Percutaneous Screw Fixation for Metastatic Pelvic Lesions: Clinical Outcomes, Biomechanical Modeling, and AI-Assisted Innovation

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INTRODUCTION: Metastatic lesions in the pelvis, particularly in periacetabular region, are challenging to manage due to complex anatomy and patient frailty. We evaluated a minimally invasive percutaneous screw fixation technique through clinical, biomechanical, and AI-assisted lenses.

METHODS: We retrospectively reviewed 120 patients treated with percutaneous fixation, assessing pain and function (VAS, ECOG, CPAFS), and radiographic healing after treatment. Finite element analysis (FEA) simulated stress distribution and construct stability across metastatic acetabular classification (MAC) types before and after Tripod fixation. In a prospective cohort (n=12), AI-assisted planning with 3D-printed guides was used to optimize screw trajectories using preoperative CAT and deep neural networks.

RESULTS: In the retrospective cohort, patients showed significant, lasting improvements in pain and function ($p < 0.001$), with a 85.1% bone healing rate in patients with pathological fractures, and low complication rates. FEA revealed that the Tripod fixation reduced stress and displacement, particularly in MAC IIIa/IIIb lesions. AI-guided placement achieved 72% trajectory accuracy and 100% screw containment, a shorter operative time (73 vs. 137 min) as compared to the free-handed approach.

DISCUSSION AND CONCLUSION: Percutaneous screw fixation is safe and effective for metastatic pelvic lesions. FEA validated biomechanical stability. AI-assisted planning and 3D-printed surgical guides improved precision and efficiency, especially for less experienced surgeons. Additional strategies may be needed for MAC IV lesions. Our results support broader adoption of minimally invasive, technology-enhanced approaches in orthopedic oncology.

Figure 1

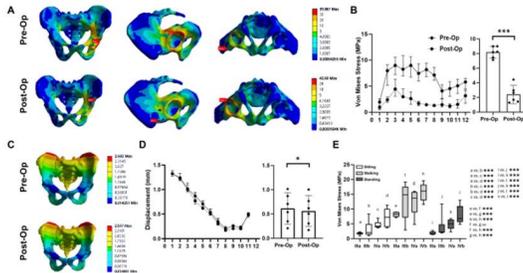


Figure 2

