

Early Detection of Acetabular Component Fixation Using Tomosynthesis and Its Association with Preoperative Bone Mineral Density in Cementless Total Hip Arthroplasty.

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INTRODUCTION: The long-term survival of cementless total hip arthroplasty (THA) depends on secure biological fixation between implant and host bone. Stable osseointegration prevents micromotion, fibrous tissue invasion, and loosening, whereas failure of early fixation can result in pain, bone loss, and revision surgery. Although animal studies show bone ingrowth within weeks, the timing and clinical detection of early fixation in humans remain unclear. Radiographs lack resolution and computed tomography, though more sensitive, has higher radiation, cost, and artifact. Tomosynthesis provides high-resolution images with less radiation and artifact, offering a promising method to evaluate the bone-implant interface. Detecting early fixation may help identify patients at risk of fibrous fixation and guide early management. Bone mineral density (BMD) is another important factor: low BMD increases micromotion, while higher BMD may support early osseointegration. Although linked to long-term outcomes, its role in early fixation is less defined. This study aimed to determine whether tomosynthesis can detect early acetabular fixation after cementless THA and examine the association between preoperative BMD and early osseointegration.

METHODS: This retrospective study included 130 hips in 113 patients (23 males, 25 hips; 90 females, 105 hips; mean age, 64.5 years; range, 27–85) who underwent cementless robotic-assisted total hip arthroplasty (THA) between December 2020 and December 2022 at a single institution. All procedures were performed with the MAKO robotic system, ensuring reproducible component positioning and consistent surgical technique. A single acetabular design (Trident II Tritanium, Stryker) was implanted in all cases via a posterolateral approach in the lateral decubitus position, minimizing variability from implant design or surgical method. Preoperative bone quality was evaluated using dual-energy X-ray absorptiometry (DXA; Prodigy, GE Healthcare). Bone mineral density (BMD) was measured in cancellous bone medial to the subchondral layer within DeLee and Charnley zones 1–3, independent of reaming plans to avoid surgical bias. Postoperative digital tomosynthesis (Sonial Vision G4, Shimadzu, Kyoto, Japan) was performed at 1, 2, 3, and 6 months. Biological fixation was defined as absence of radiolucent lines with trabecular continuity across the bone-implant interface. Two orthopaedic surgeons independently reviewed all images, with consensus for discrepancies. For analysis, patients were grouped by fixation status at 3 months, the earliest reliable time for evaluating trabecular ingrowth. BMD values were compared using the Mann-Whitney U test. ROC analysis was used to assess predictive ability and define cutoff thresholds. Categorical variables such as sex and screw usage were analysed with chi-square tests. Multivariate logistic regression identified independent predictors, adjusting for age, sex, and screw usage. Statistical significance was set at $p < 0.05$, and analyses were conducted with JMP version 14.0 (SAS Institute, Cary, NC, USA).

RESULTS SECTION: Fixation was first detected at 1 month in zone 3 (3.8%). Rates increased to 21.5% at 3 months and 32.3% at 6 months, with overall fixation (any zone) of 28.5% and 40.0%, respectively. The fixation group showed significantly higher preoperative BMD in all three zones (all $p < 0.001$). ROC analysis demonstrated good predictive ability (AUC: 0.807–0.916), with optimal cutoff values of 1.561 g/cm² (zone 1), 1.595 g/cm² (zone 2), and 1.285 g/cm² (zone 3). Logistic regression identified higher BMD in zone 3 (OR 15.9, $p = 0.002$) and male sex (OR 3.0, $p = 0.036$) as independent predictors of fixation at 3 months.

DISCUSSION: This study shows that tomosynthesis can detect trabecular continuity indicating acetabular fixation as early as 1 month, earlier than previously reported. Fixation was most frequent in DeLee and Charnley zone 3, likely due to consistent compressive loading during gait that promotes ingrowth. Higher preoperative BMD correlated strongly with fixation, supporting bone quality as a key determinant of early osseointegration. ROC analysis confirmed good predictive power, particularly in zone 2, though zone 3 remained the most relevant predictor in multivariate analysis. Tomosynthesis combines high resolution with lower radiation and minimal metal artifact, making it more suitable than radiographs or CT for serial monitoring. Its ability to detect fixation within the first month suggests clinical utility for evaluating patients with unexplained pain or suspected early loosening. Early recognition of poor fixation could prompt targeted interventions such as osteoporosis treatment, load modification, or closer follow-up. Limitations include the retrospective design, 6-month follow-up, radiographic rather than histologic assessment, and restriction to a single implant and approach. Despite these, the findings provide preliminary evidence that tomosynthesis and preoperative BMD assessment are valuable tools for predicting and monitoring early acetabular osseointegration in cementless THA.

SIGNIFICANCE/CLINICAL RELEVANCE: Tomosynthesis is a valuable modality for detecting early acetabular fixation after THA. Higher preoperative BMD, especially in zone 3, predicts early osseointegration, highlighting the importance of bone quality assessment in surgical planning.

IMAGES AND TABLES:

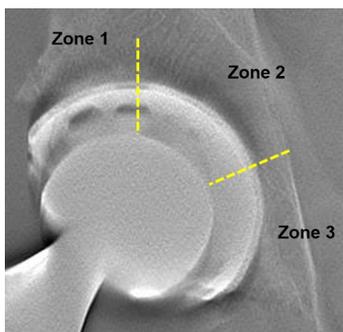


Figure 1. Evaluation of Biological Fixation of the Acetabular Component

This figure shows an image of the trabecular bone ingrowth into the porous surface of the implant in zone 1.

Table 1. ROC Curve Analysis for Predicting Biological Fixation at 3 months Postoperatively

Zone	AUC	Cutoff BMD (g/cm ²)	Sensitivity	Specificity
Zone 1	0.807	1.561	0.929	0.595
Zone 2	0.916	1.595	1.000	0.857
Zone 3	0.819	1.285	0.679	0.824

ROC, Receiver Operating Characteristic; AUC, Area Under the Curve; BMD, Bone Mineral Density.