

## **Clinical Utility of Three-Dimensional CT in Acetabular Fractures: A Prospective Study of Fracture Classification, Surgical Approach Selection, and Reporting Efficiency**

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**Conflicts of Interest:** Nil

### **Abstract**

**Background:** Accurate characterization of acetabular fractures is essential for optimal surgical planning owing to the complex three-dimensional anatomy of the pelvis. Although multidetector computed tomography is the imaging modality of choice, the additional value of three-dimensional volume-rendered reconstructions over conventional two-dimensional multiplanar reformations remains an area of ongoing clinical interest.

**Purpose:** To evaluate the role of three-dimensional computed tomography reconstructions in acetabular fracture classification, reporting efficiency, surgical planning, and postoperative radiological assessment.

**Materials and Methods:** In this prospective analytical observational study, 52 adult patients with acetabular fractures underwent multidetector computed tomography using a Multislice scanner with two-dimensional multiplanar and three-dimensional volume-rendered reconstructions. Fractures were independently assessed using two-dimensional and three-dimensional datasets in alternating order. Classification was performed using three systems: Judet–Letournel, Orthopedic Trauma Association/ Arbeitsgemeinschaft für Osteosynthesefragen, and Harris systems. Reporting time for each modality was recorded. Imaging-based surgical approach recommendations were correlated with

the actual operative management, and postoperative reduction was graded using Matta's radiographic criteria.

**Results:** Anterior column fractures were the most common subtype (32.7%). Elementary fractures accounted for 73.1% of cases, while associated fractures comprised 26.9%. The mean interpretation time was significantly lower using three-dimensional reconstructions ( $35.58 \pm 5.26$  seconds) compared with two-dimensional images ( $65.42 \pm 8.72$  seconds), demonstrating a mean reduction of 29.08 seconds ( $p < 0.001$ ). Imaging-guided surgical recommendations showed high concordance with the operative approach, with 88.2% agreement in anterior and posterior groups. Postoperative evaluation based on Matta's criteria revealed anatomical reduction in 45.8%, satisfactory reduction in 45.8%, and poor reduction in 8.3% of cases.

**Conclusion:** Three-dimensional computed tomography reconstructions significantly enhance reporting efficiency and improve fracture classification and preoperative planning in acetabular fractures. By providing superior spatial visualization of complex fracture patterns, three-dimensional imaging facilitates surgical decision-making and strengthens radiologist–surgeon communication, thereby contributing to optimized clinical outcomes.

**Keywords:** Acetabular fracture; Three-dimensional computed tomography; Volume-rendered reconstruction; Judet–Letournel classification; Orthopedic Trauma Association classification; Harris classification; Surgical planning; Reporting efficiency; Matta criteria; Pelvic trauma.

## Introduction

Acetabular fractures are complex injuries most commonly resulting from high-velocity trauma such as road traffic accidents, and less frequently from low-

energy mechanisms in elderly individuals with osteoporotic bone<sup>1</sup>. These fractures present significant challenges owing to the intricate three-dimensional anatomy of the pelvis and the biomechanical importance of the acetabulum as a primary weight-bearing structure. Accurate delineation of fracture patterns is essential for appropriate surgical planning, restoration of joint congruity, and prevention of long-term complications such as hip instability and post-traumatic osteoarthritis<sup>2</sup>. Historically, evaluation of acetabular fractures relied on plain radiography, including anteroposterior and oblique pelvic views described by Judet and Letournel<sup>1</sup>. However, due to overlapping osseous structures and the complex orientation of the acetabulum, conventional radiographs often provide limited information regarding fracture extent, displacement, intra-articular fragments, and associated pelvic injuries<sup>3</sup>.

With the advent of multidetector computed tomography, imaging of acetabular trauma has significantly improved. Axial sections with multiplanar reformations allow detailed assessment of fracture lines, column and wall involvement, marginal impaction, femoral head subluxation or dislocation, and extension into the pelvic ring<sup>3,4</sup>. Computed tomography is currently regarded as the imaging modality of choice in acetabular fractures and plays a crucial role in fracture classification and operative planning.

Among various classification systems, the Judet–Letournel system remains the most widely accepted for guiding surgical management<sup>1</sup>. The Orthopedic Trauma Association/Arbeitsgemeinschaft für Osteosynthesefragen classification provides a comprehensive framework for research and documentation, while the Harris classification offers a computed tomography-based approach for categorizing

fracture patterns<sup>4</sup>. Accurate classification facilitates standardized communication between radiologists and orthopedic surgeons and aids in determining the optimal surgical approach.

Despite the utility of two-dimensional multiplanar reformatted images, interpretation of complex acetabular fractures may be time-consuming and requires mental reconstruction of spatial relationships. Three-dimensional volume-rendered reconstructions provide a comprehensive overview of fracture morphology and may enhance visualization of column disruption, wall fractures, and fracture orientation<sup>3</sup>. Enhanced spatial understanding may improve reporting efficiency and strengthen radiologist–surgeon communication, particularly in complex or associated fracture patterns.

Although three-dimensional reconstructions are readily available with modern scanners, their incremental benefit over conventional multiplanar images in routine clinical practice remains a subject of interest. Limited prospective data are available comparing reporting efficiency, fracture classification utility, and surgical concordance between two-dimensional and three-dimensional computed tomography datasets. Furthermore, the role of three-dimensional imaging in postoperative assessment using radiological reduction criteria has not been extensively evaluated.

Therefore, the present study was undertaken to evaluate the role of three-dimensional computed tomography reconstructions in acetabular fracture classification, reporting efficiency, surgical planning, and postoperative assessment using established classification systems and Matta's radiographic reduction criteria.

The present prospective study was designed to systematically evaluate the incremental value of three-dimensional computed tomography reconstructions over

conventional multiplanar reformations in acetabular fracture classification, reporting efficiency, surgical approach selection, and postoperative reduction assessment.

## Materials and Methods

This prospective analytical observational study was conducted in the Department of Radiodiagnosis at a tertiary care teaching hospital over a period OF 24 months, following institutional ethical clearance. Written informed consent was obtained from all participants or their legal guardians where applicable.

## Study Population

A total of 52 consecutive adult patients diagnosed with acetabular fractures on computed tomography were included in the study.

## Inclusion Criteria

Adult patients ( $\geq 18$  years)

Acute acetabular fracture confirmed on computed tomography

Availability of complete imaging dataset including multiplanar and three-dimensional reconstructions

Patients who underwent definitive management with available operative details and postoperative radiographs.

## Exclusion Criteria

Pathological fractures

Previous pelvic surgery

Inadequate imaging quality

Incomplete clinical, operative, or follow-up data.

## Imaging Protocol

All examinations were performed using a multi-slice multidetector computed tomography scanner (Siemens Somatom Perspective). Thin-section axial images were acquired using a standard bone reconstruction algorithm.

Multiplanar reformations in coronal and sagittal planes were generated from axial source images.

Three-dimensional volume-rendered reconstructions were created using dedicated workstation software to enable comprehensive visualization of fracture morphology, column involvement, and spatial orientation.

### **Image Interpretation and Classification**

Each case was independently evaluated using:

Two-dimensional multiplanar reformatted images

Three-dimensional volume-rendered reconstructions

To minimize recall bias, datasets were reviewed in alternating order, and two-dimensional and three-dimensional images of the same patient were not interpreted consecutively.

### **Fractures were classified according to:**

Judet–Letournel classification

Orthopedic Trauma Association/Arbeitsgemeinschaft für Osteosynthesefragen classification

Harris classification

The following imaging parameters were documented:

Fracture type and pattern

Column and wall involvement

Presence of intra-articular fragments

Fracture displacement

Femoral head subluxation or dislocation

Associated pelvic ring injuries

### **Assessment of Reporting Efficiency**

Interpretation time for each modality was recorded in seconds. Timing commenced upon image display and concluded after fracture classification and documentation were completed. Mean reporting times for two-dimensional and three-dimensional datasets were calculated and compared.

### **Surgical Correlation**

Based on imaging findings, a surgical approach recommendation was documented for each case. These recommendations were subsequently correlated with the actual operative approach performed. Concordance between imaging-based recommendation and surgical management was calculated.

### **Postoperative Radiological Assessment**

Postoperative radiographs were evaluated using Matta's radiographic criteria for fracture reduction. Reduction quality was categorized as:

Anatomical (0–1 mm residual displacement)

Satisfactory (2–3 mm residual displacement)

Poor (>3 mm residual displacement)

### **Statistical Analysis**

Data were entered in Microsoft Excel and analyzed using SPSS version 22 (IBM SPSS Statistics, Somers, NY, USA). Continuous variables were summarized as mean  $\pm$  standard deviation or median with interquartile range where appropriate, and categorical variables were expressed as frequencies and percentages.

Comparison between two-dimensional and three-dimensional datasets with respect to reporting time and fracture assessment parameters was performed using paired t-test or Wilcoxon signed rank test as appropriate. A p-value of less than 0.05 was considered statistically significant.

### **Results**

A total of 52 patients with acetabular fractures were included in the study.

### **Demographic Profile**

The age of patients ranged from 19 to 84 years, with a mean age of  $43.88 \pm 19.55$  years. The highest incidence was observed in the 21–30 year age group (30.8%). There was a marked male predominance (75%), with

road traffic accidents accounting for 63.5% of cases. Right-sided fractures were slightly more common (54%) than left-sided injuries (46%).

### Fracture Characteristics

Elementary fracture patterns constituted 73.1% of cases, while associated fracture patterns accounted for 26.9%. According to the Judet–Letournel classification, anterior column fractures were the most common subtype (32.7%), followed by posterior wall fractures (17.3%) and anterior wall fractures (13.5%). Complex patterns including transverse, T-type, both-column, and associated combinations comprised the remainder.

Obturator ring involvement was present in 54% of cases. Superior fracture extension was absent in 76.9%, while extension to the anterior inferior iliac spine was seen in 13.5% and to the iliac crest in 9.6%. Inferior pubic ramus involvement was observed in 60% of patients.

Intra-articular fragments were identified in 27% of cases. Femoral head displacement was absent in 71.2%, while posterior dislocation was noted in 11.5%, posterior subluxation in 7.7%, anterior subluxation in 5.8%, and medial or superior subluxation in isolated cases. Fracture displacement greater than 2 mm was present in 92% of patients.

OTA/AO classification demonstrated predominance of Group A3 fractures (46.1%), while Harris classification most frequently corresponded to Category 1 injuries (42.3%).

### Surgical Correlation

Of the 52 patients, 48 underwent operative management. Based on preoperative imaging assessment, an anterior approach was recommended in 47.9%, posterior approach in 35.4%, and combined approach in 16.7%.

Operative management included anterior ilioinguinal approach in 29.2%, modified Stoppa’s approach in

14.6%, combined anterior approaches in 25%, and posterior Kocher–Langenbeck approach in 31.3%. Imaging-based surgical recommendations demonstrated high concordance with the operative approach.

### Postoperative Reduction

Among the 48 operated patients, postoperative reduction assessed using Matta’s radiographic criteria revealed anatomical reduction in 45.8%, satisfactory reduction in 45.8%, and poor reduction in 8.3% of cases. Thus, anatomical or satisfactory reduction was achieved in 91.6% of surgically treated patients.

### Reporting Efficiency

The mean reporting time for two-dimensional CT images was  $65.42 \pm 8.72$  seconds, compared with  $35.58 \pm 5.26$  seconds for three-dimensional reconstructions. The mean reduction in interpretation time was 29.85 seconds, which was statistically significant ( $t = 29.08, p < 0.001$ ).

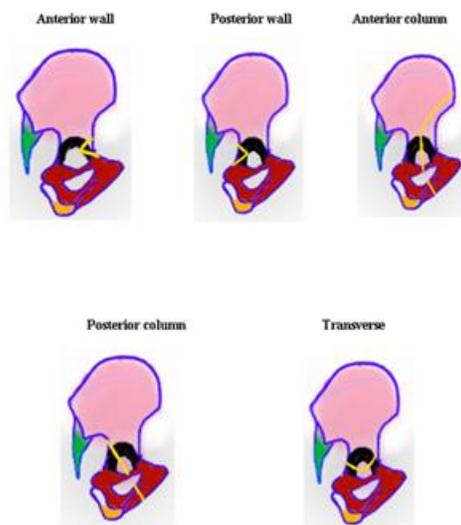


Figure 1: Schematic diagrams of elementary or simple fractures of the acetabulum according to the Judet and Letournel classification.

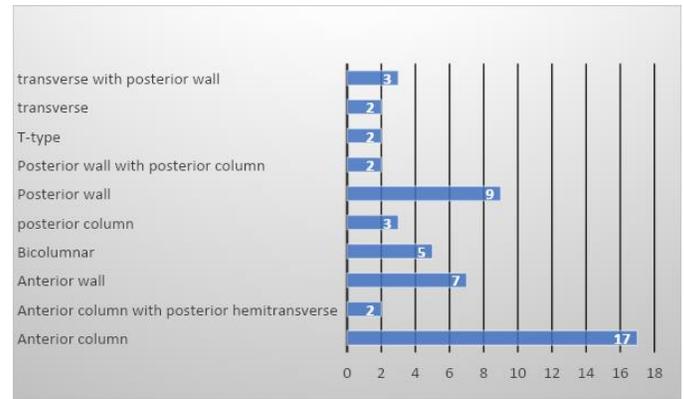
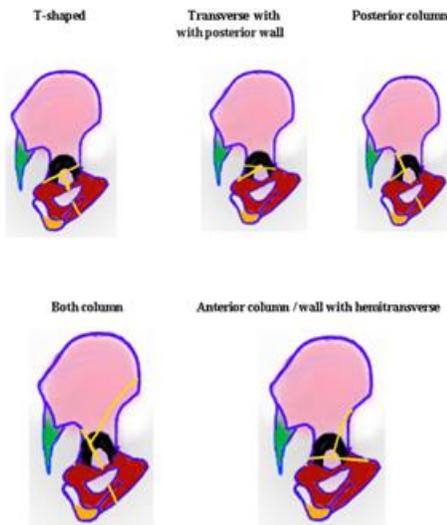


Figure 3: Bar diagram showing the types of acetabular fractures based on Judet and Letournel classification.

Figure 2: Schematic diagrams of associated or complex fractures of the acetabulum according to the Judet and Letournel classification.

Table 1: Surgical approach recommended based on the imaging findings.

Surgical approach recommended	Count	Percentage
Posterior approach	17	35.4 %
Anterior approach	23	47.9 %
Combined	8	16.7 %
Total	48	100 %

Table 2: Surgical approach followed to fix the acetabular fracture.

Surgical approach followed	Count	Percentage
Anterior ilioinguinal approach	14	29.2 %
Anterior Stoppa’s approach	7	14.6 %
Combined	12	25 %
Posterior Kocher Langenbeck approach	15	31.3 %
Total	48	100 %

Table 3: Post-operative reduction criteria based on Matta’s criteria

Postoperative reduction	Count	Percentage
Anatomic ( $\leq 1$ mm)	22	45.8 %
Poor ( $\geq 3$ mm)	4	8.3 %
Satisfactory ( $>1$ to $< 3$ mm)	22	43.5 %
Total	48	100 %

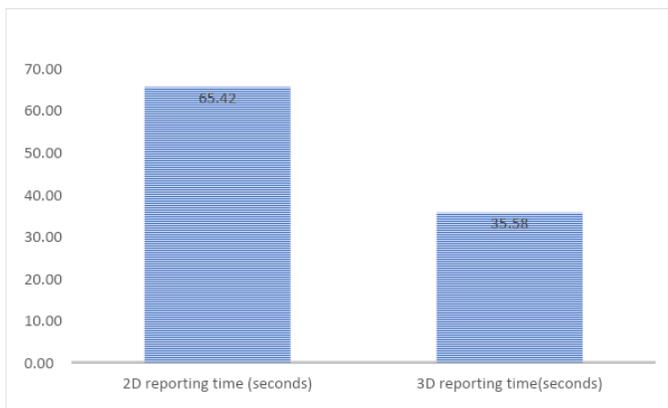


Figure 4: Bar chart showing mean time taken to report using 2D-CT versus 3D-CT images among the subjects.

### Discussion

Accurate characterization of acetabular fractures remains essential for optimal surgical planning, given the complex three-dimensional geometry of the pelvis and the biomechanical significance of the hip joint. The present prospective study evaluated the incremental value of three-dimensional computed tomography reconstructions over conventional multiplanar reformations in fracture classification, reporting efficiency, surgical planning, and postoperative outcome assessment.

The demographic profile of the present cohort demonstrated a predominance of young adult males with road traffic accidents as the leading mechanism of injury. This distribution is consistent with established epidemiological trends in acetabular trauma, where high-energy mechanisms account for the majority of cases. The predominance of anterior column fractures in our study contrasts with certain Western series reporting posterior wall fractures as the most common subtype, possibly reflecting regional variations in trauma patterns and injury mechanisms.

Three-dimensional reconstruction provided enhanced visualization of fracture morphology, particularly in cases involving obturator ring disruption, superior

extension, and complex associated fracture patterns. Although multiplanar reformations allow detailed evaluation of fracture lines, interpretation requires mental reconstruction of spatial relationships. Three-dimensional imaging reduces this cognitive burden by offering an integrated spatial overview, thereby facilitating rapid comprehension of column involvement and fragment orientation.

The most clinically significant finding of this study was the substantial reduction in reporting time when three-dimensional reconstructions were utilized. The mean interpretation time decreased, representing nearly a 45% improvement compared with two-dimensional assessment. This statistically significant reduction underscores the practical advantage of three-dimensional visualization in routine trauma workflow. In high-volume emergency settings, cumulative time savings may translate into improved reporting efficiency and expedited surgical planning.

Surgical approach selection demonstrated strong concordance with preoperative imaging recommendations. The high agreement rate indicates that computed tomography, particularly when supplemented with three-dimensional reconstructions, provides reliable anatomical information for operative strategy determination. Enhanced depiction of column involvement and wall fractures likely contributed to accurate selection of anterior, posterior, or combined approaches.

Postoperative reduction outcomes further support the clinical utility of meticulous preoperative imaging. Anatomical or satisfactory reduction was achieved in over 90% of operated cases according to Matta's criteria. While fracture reduction is multifactorial and dependent on surgical expertise, precise preoperative mapping of

fracture morphology likely contributed to favorable alignment outcomes.

The findings of this study align with emerging literature suggesting that three-dimensional computed tomography improves fracture visualization and surgical communication. However, unlike descriptive imaging studies, the present study quantitatively demonstrates measurable improvement in reporting efficiency along with surgical and radiographic outcome correlation.

### Limitations

Certain limitations must be acknowledged. The study was conducted at a single tertiary center with a moderate sample size. Long-term functional outcomes were not evaluated. Additionally, although reporting time was significantly reduced, the impact on overall operative duration and clinical recovery was not formally measured.

### Clinical Implications

Integration of three-dimensional reconstruction into routine evaluation of acetabular fractures enhances spatial understanding, improves workflow efficiency, and supports surgical decision-making. In complex fracture patterns, three-dimensional imaging serves as a valuable adjunct to multiplanar assessment.

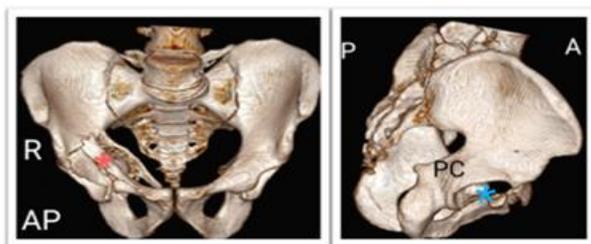
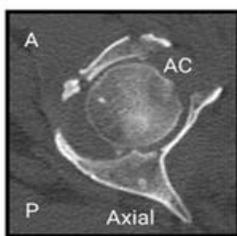


Figure 5: Anterior column acetabular fracture in a 47-year-old patient. (a) Axial image reveals fracture of the anterior column of the acetabulum. Antero-posterior (b) and lateral (c) 3D surface-rendered CT images of the acetabulum show a fracture of the anterior column that extends to the acetabular roof with separation of the anterior column (asterisk) from the sciatic buttress.

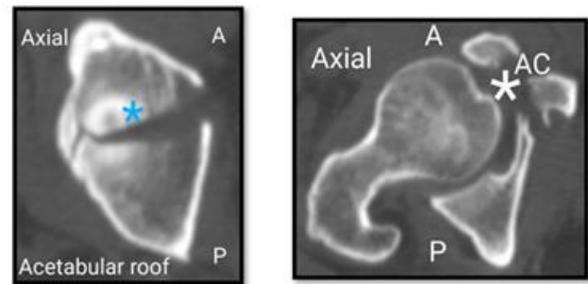


Figure 6: Anterior column acetabular fracture in a 30-year-old patient. (a and b) Axial images depicting the anterior column fracture (AC denoted by asterisk in b image) involving acetabular roof (asterisk in image b). 3D surface-rendered CT image (c) of the acetabulum show a fracture of the anterior column (asterisk) that extends from the iliac wing (blue arrow) through the superior portion of the acetabulum, with separation of the anterior column (asterisk) from the sciatic buttress.

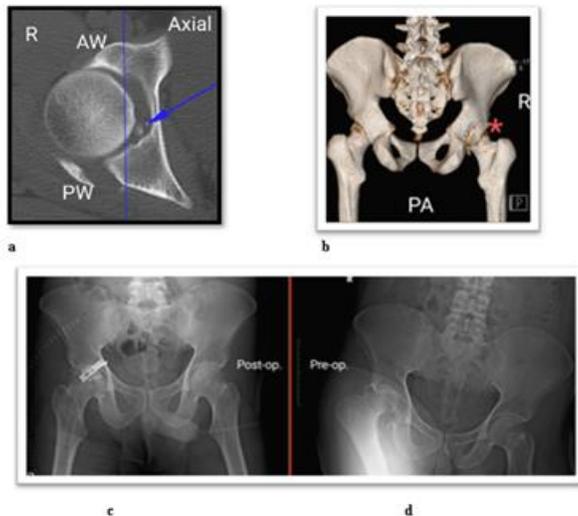


Figure 7: Posterior wall acetabular fracture in a 33-year-old male patient. (b) PA orientated 3D surface-rendered CT image of the acetabulum shows a posterior wall fracture (asterisk) and an intact quadrilateral plate. (b) Axial image shows the posterior wall fracture. A free intra-articular fragment is also seen (blue arrow). Pre-operative and post-operative images of the same patient. Post-operative reduction based on Matta's criteria was 0.8 mm (Anatomical reduction).

### Conclusion

Three-dimensional computed tomography reconstructions provide significant incremental value in the evaluation of acetabular fractures. In the present study, three-dimensional imaging demonstrated a statistically significant reduction in reporting time while maintaining high concordance with surgical approach selection and favorable postoperative reduction outcomes.

By enhancing spatial visualization of fracture morphology, particularly in complex and associated fracture patterns, three-dimensional reconstruction facilitates accurate classification, supports operative planning, and strengthens radiologist–surgeon communication. Although multiplanar reformations

remain essential for detailed assessment, integration of three-dimensional visualization into routine trauma imaging improves workflow efficiency without compromising diagnostic accuracy.

Routine incorporation of three-dimensional computed tomography in acetabular fracture evaluation is therefore recommended as a practical and clinically valuable adjunct in modern musculoskeletal trauma imaging.

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