



The obturator oblique and iliac oblique/outlet views predict most accurately the adequate position of an anterior column acetabular screw

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Abstract

Objective Percutaneous fixation of the acetabulum is a treatment option for select acetabular fractures. Intra-operative fluoroscopy is required, and despite various described imaging strategies, it is debatable as to which combination of fluoroscopic views provides the most accurate and reliable assessment of screw position.

Materials and methods Using five synthetic pelvic models, an experimental setup was created in which the anterior acetabular columns were instrumented with screws in five distinct trajectories. Five fluoroscopic images were obtained of each model (Pelvic Inlet, Obturator Oblique, Iliac Oblique, Obturator Oblique/Outlet, and Iliac Oblique/Outlet). The images were presented to 32 pelvic and acetabular orthopaedic surgeons, who were asked to draw two conclusions regarding screw position: (1) whether the screw was intra-articular and (2) whether the screw was intraosseous in its distal course through the bony corridor.

Results In the assessment of screw position relative to the hip joint, accuracy of surgeon's response ranged from 52% (iliac oblique/outlet) to 88% (obturator oblique), with surgeon confidence in the interpretation ranging from 60% (pelvic inlet) to 93% (obturator oblique) ($P < 0.0001$). In the assessment of intraosseous position of the screw, accuracy of surgeon's response ranged from 40% (obturator oblique/outlet) to 79% (iliac oblique/outlet), with surgeon confidence in the interpretation ranging from 66% (iliac oblique) to 88% (pelvic inlet) ($P < 0.0001$).

Conclusions The obturator oblique and obturator oblique/outlet views afforded the most accurate and reliable assessment of penetration into the hip joint, and intraosseous position of the screw was most accurately assessed with pelvic inlet and iliac oblique/outlet views.

Evidence Clinical Question

Keywords Fracture · Acetabulum · Radiographic magnification · Internal fixation · Percutaneous fixation · Acetabular anterior column

Introduction

Acetabular fractures are challenging injuries, frequently associated with high morbidity and prolonged physical disability [1]. Open reduction and internal fixation remains the gold standard of treatment for the large majority since the aim is to achieve anatomical reduction and absolute stability [2, 3]. Alternatively, for a minority of fractures that fulfill indication criteria, intramedullary screw fixation of the acetabular columns is an excellent surgical option, offering the advantage of percutaneous placement, minimizing the morbidity associated with open approaches [4–16].

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The bony corridor of the anterior column extends from the gluteus medius pillar of the ilium, over the acetabular dome, across the superior pubic rami, and to the pubic symphysis, and represents one such path for intramedullary screw placement (Fig. 1). The intramedullary bony corridor is a relatively narrow structure, and a thorough understanding of clinical and radiographic anatomy of the pelvis and acetabulum is required for safe screw placement [17]. Screw malposition risks penetration of the hip joint and/or injury to surrounding structures. While some centers treating acetabular fractures have the ability to use 3D fluoroscopy or intra-operative CT scanners, the majority of orthopaedic trauma surgeons globally do not have access to such intra-operative imaging modalities. The ability to obtain and interpret reproducible, high-quality intra-operative biplanar fluoroscopic images is critical. When placing anterior column screws, biplanar fluoroscopy is used to confirm two primary components of the implant position. First, the surgeon must determine that the screw is extra-articular with respect to the hip joint. Secondly, the surgeon must confirm that the screw is intraosseous in its path through the superior ramus portion of the bony corridor. The fluoroscopic projections considered standard for intra-operative evaluation of screw position in the anterior acetabular column are the obturator oblique and pelvic inlet views [18]. Other combinations of fluoroscopic projections have been described including those reported by Cunningham et al. [19].

The authors advocate the use of iliac oblique/outlet and obturator oblique/outlet views with the patient positioned laterally. Although several techniques are described, the combination of intra-operative fluoroscopic projections that provides most accurate evaluation of anterior column instrumentation remains debatable. Our hypothesis was that the combination of the obturator oblique and the iliac oblique/outlet would represent the most reliable and accurate combination of fluoroscopic views for the evaluation of screw position in the anterior column of the acetabulum.

Materials and methods

Five identical and intact synthetic adult human pelvis models (National Ossos, Jaú, São Paulo, Brazil) were used for this study. The bony corridor of the anterior column of each pelvic model was instrumented with a screw (3.5 mm in diameter and 90 mm in length) (Hexagon, Itapira, São Paulo, Brazil) in an antegrade fashion in five distinct trajectories. In the first model (P1), the screw was positioned in an ideal trajectory (extra-articular and intraosseous) (Fig. 2a, b), and in the four others (P2–P5), the screw was purposely mispositioned. In the second assembly (P2), the screw position was intra-articular and extraosseous distally, exiting anteriorly from the pubic ramus (Fig. 2c). In the third assembly (P3), the screw was extra-articular and extraosseous distally, exiting the pubic ramus posteriorly in an intrapelvic fashion (Fig. 2d). In the fourth assembly (P4), the screw was extra-articular and extraosseous distally, exiting superior to the pubic ramus (Fig. 2e, f). In the fifth assembly (P5), the screw was extra-articular and extraosseous distally, exiting inferiorly to the pubic ramus, inside the obturator foramen (Fig. 2g, h).

The plastic models were then rigidly positioned on an operative table, and fluoroscopic images were obtained using a mobile fluoroscopy unit (Everview 7500 GE Hualun Medical System, Beijing, China) (Fig. 3). From each pelvic model, five fluoroscopic projections preferentially used for anterior column fixation were obtained: pelvic inlet, obturator oblique, iliac oblique, obturator oblique/outlet, and iliac oblique/outlet views.

The 25 images generated by the five models imaged in the five projections were randomized and presented individually in digital format to 32 orthopaedic trauma surgeons specialized in the treatment of pelvic and acetabular fractures (Fig. 4). The participant surgeons' were blinded with regard to which pelvic model was being evaluated. For each image presented to the surgeon, he or she was asked two questions: (1) if the screw was in an extra-

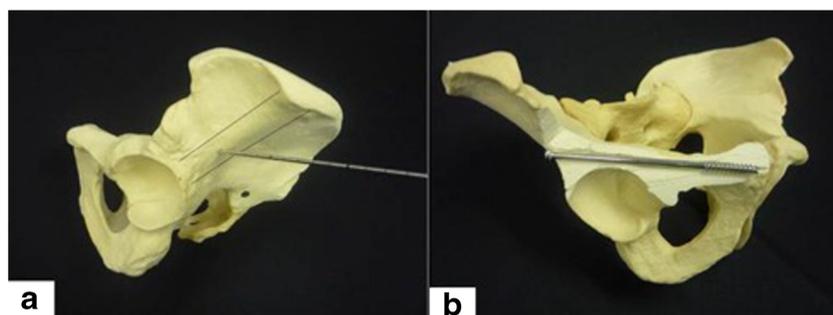
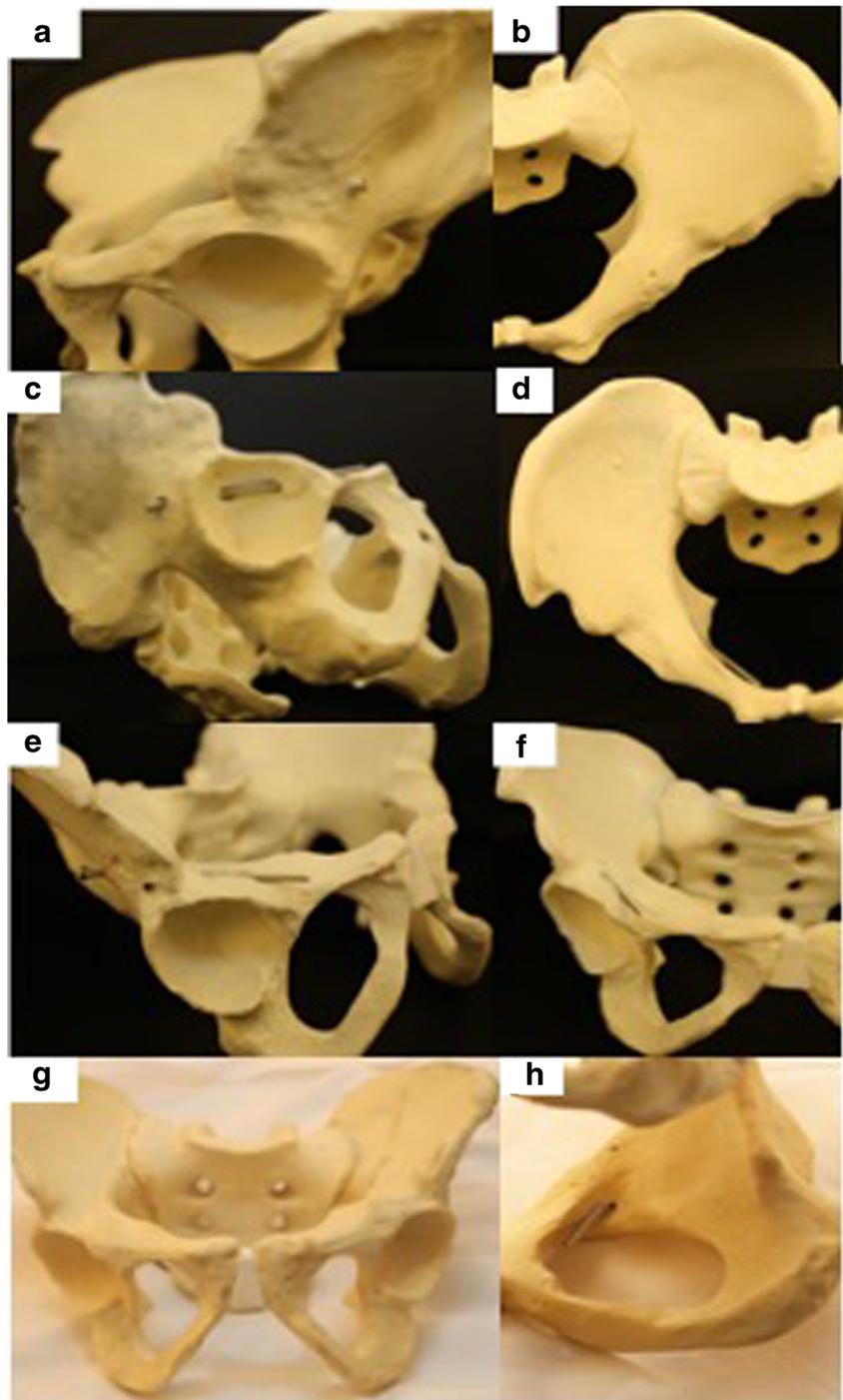


Fig. 1 **a** The starting point for insertion of the antegrade anterior column/superior ramus screw is located slightly superior to the acetabulum in the pillar of the gluteus medius, a thickening of the bone that extends from the acetabulum to the iliac crest. **b** Cut-away pelvic model demonstrating the

bony corridor of the anterior column of the acetabulum with a screw positioned in an ideal trajectory for fixation (Adapted from YI et al., 2014)

Fig. 2 Pelvic models demonstrating the five experimental screw trajectories (P1–P5) within the anterior acetabular column. **a, b** Ideal screw trajectory contained within the bony corridor of the anterior acetabulum (P1). **c** Intra-articular screw trajectory (P2). **d** Extraosseus trajectory with screw exiting posteriorly (P3). **e, f** Extraosseus trajectory with screw exiting superiorly (P4). **g, h** Extraosseus trajectory with screw exiting inferiorly in obturator foramen (P5)



articular position and (2) if the screw was an intraosseous position throughout its course. Three possible answers were presented for each question: (1) Yes (e.g., I am certain that the screw is extra-articular/intraosseous), (2) No (e.g., I am certain that the screw is intra-articular or extraosseous), or (3) I do not know. The responses were recorded in a database, and the results were expressed in percentage values of answers “I know” (answers 1 and 2,

indicating certainty in surgeons’ interpretation) and “I do not know” (answer 3, indicating uncertainty). In the latter case, the responses were stratified as correct (e.g., when the answer correctly described the screw position in the model) or incorrect (e.g., when the answer incorrectly described the screw position in the model).

The sample size was calculated using Epi Info 7 (version 7.1.3. - www.cdc.gov) assuming expected frequency of 8%,



Fig. 3 Demonstration of experimental setup with a pelvic model fixed to a positioner in order to obtain reproducible projections from a mobile fluoroscopy unit (Everview 7500 GE Hualun Medical System, Beijing, China)

confidence limits of 5%, design effect and clusters equal to 1, and with confidence level of 80%. The categorical data were expressed in number and percentage and were evaluated by Pearson's chi-square test (χ^2), with statistical significance set at $P < 0.05$. The statistical analysis was performed using GraphPad Prism (version 5.00 for Windows "Home - graphpad.com", [s.d]).

Results

From 32 orthopaedic trauma surgeons each evaluating 25 images, we obtained 160 responses for each pelvic view.

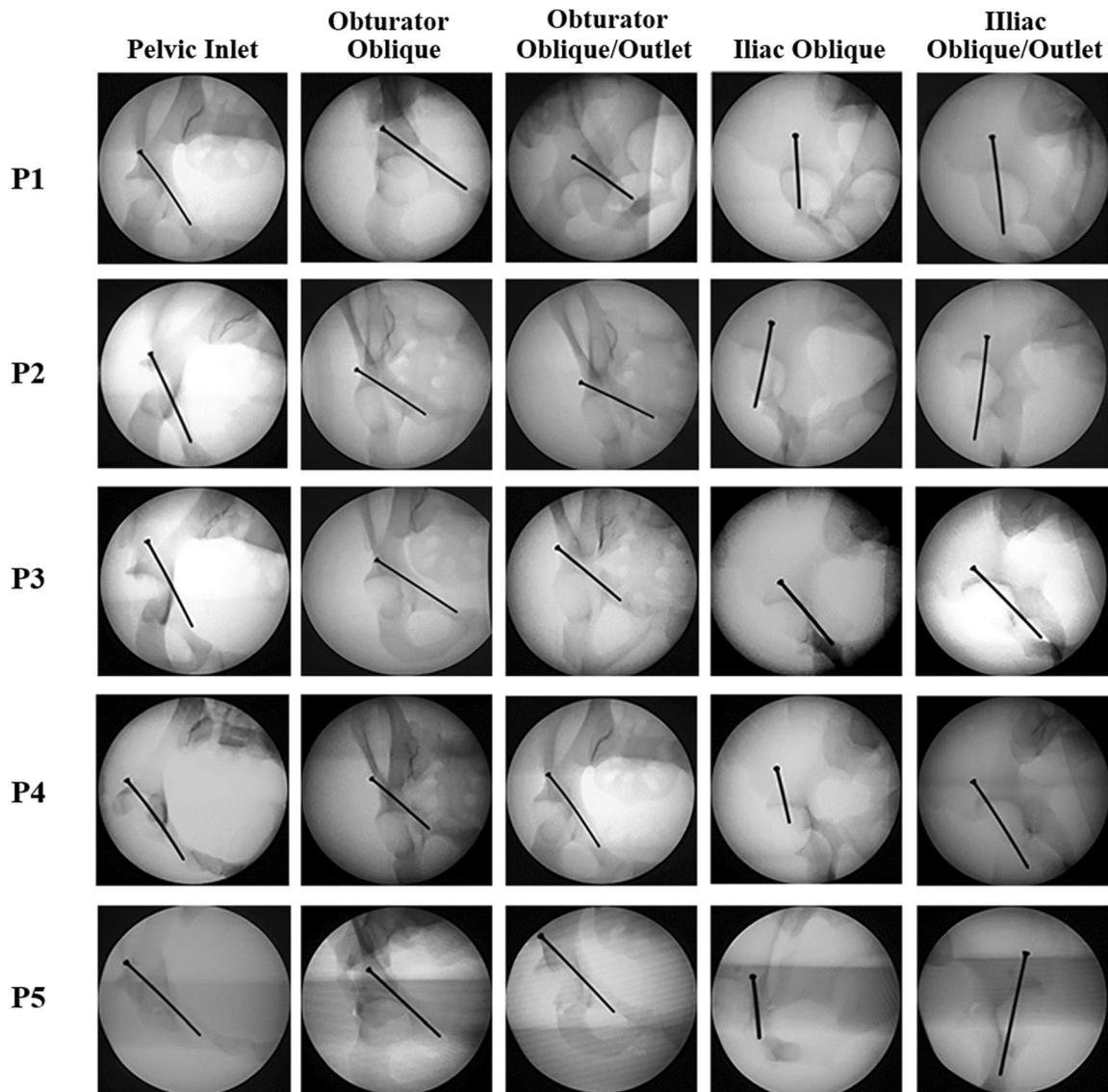
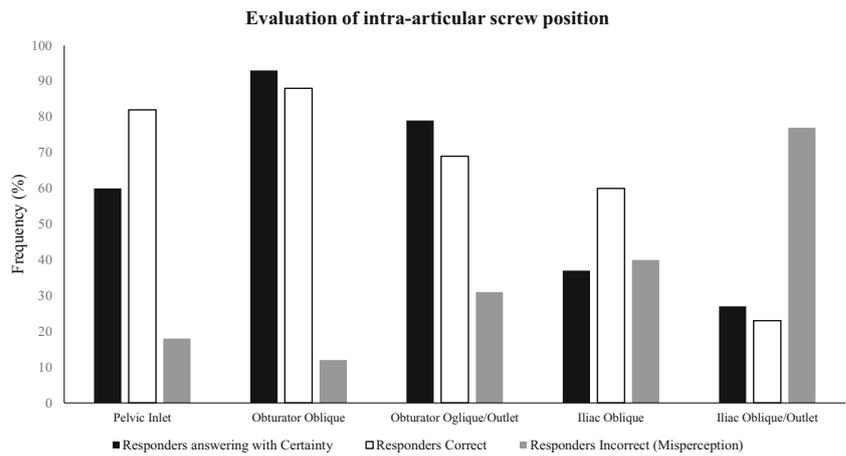


Fig. 4 Final fluoroscopic images obtained from the five pelvic models (corresponding to rows P1–P5) imaged with five fluoroscopic projections (corresponding to columns labeled inlet, obturator oblique, obturator

oblique/outlet, iliac oblique, and iliac oblique/outlet). These 25 images were presented in random order to the surgeon participants

Fig. 5 Intra-articular screw position. Analysis of responses (expressed in percentile; y-axis) based on fluoroscopic projection (x-axis). Bars in each cluster represent (from left to right), percentage of responders who answered with certainty (answers 1 and 2), percentage of these responses that were correct, and percentage of these responses that were incorrect. There are significant differences among the groups ($P < 0.0001$, assessed by the χ^2)



The results with regard to screw position relative to the hip joint (e.g., whether or not the screw penetrated the hip joint) are shown in Fig. 5. In summary, on the pelvic inlet view, 60% ($n = 96$) were sure about the screw position; 82% ($n = 79$) were correct. On the obturator oblique view, 93% ($n = 147$) were sure about the screw position; 88% ($n = 129$) were correct. On the obturator oblique/outlet view, 79% ($n = 127$) were sure about the screw position; 69% ($n = 88$) were correct. On the iliac oblique view, 37% ($n = 60$) were sure about the screw position; 60% ($n = 36$) were correct. On the iliac oblique/outlet view, 27% ($n = 44$) stated that they were sure about the screw position; 23% ($n = 10$) were correct. Significant differences were detected in the responders’ distribution of intra-articular screw position ($P < 0.0001$).

The predictive values (positive predictive value (PPV) and negative predictive value (NPV)), sensitivity, and specificity of screw position (intra-articular and intraosseous positioning) are summarized in Tables 1 and 2, respectively.

The results with regard to intraosseous screw position (e.g., whether or not the screw was contained within the bony corridor) are presented in Fig. 6. In summary, on the pelvic inlet view, 88% ($n = 142$) were sure about the screw position; 73% ($n = 104$) were correct. On the

obturator oblique view, 79% ($n = 127$) were sure about the screw position; 39% ($n = 49$) were correct. On the obturator oblique/outlet view, 78% ($n = 125$) were sure about the screw position; 40% ($n = 50$) were correct. On the iliac oblique view, 66% ($n = 105$) were sure about the screw position; 69% ($n = 72$) were correct. On the iliac oblique/outlet view, 83% ($n = 133$) were sure about the screw position; 79% ($n = 105$) were correct. Significant differences were detected in the responders’ distribution of intraosseous screw position ($P < 0.0001$).

Discussion

The greatest technical difficulty involved with anterior column screw fixation of the acetabulum is radiographic evaluation of the screw position in the narrow bony safety corridor [20]. Accurate placement of the screw is necessary to avoid joint penetration or to damage surrounding structures. The obturator nerve and vessels are at risk if the screw is mispositioned posteriorly and/or inferiorly, while the femoral vessels are at risk if the trajectory is extraosseous anteriorly and/or superiorly [17]. With the patient in the supine position, several authors have recommended the use of obturator oblique/outlet and pelvic

Table 1 Intra-articular screw position relative to the hip joint

	Pelvic inlet view (%)	O/O view (%)	O/O-outlet view (%)	I/O view (%)	I/O-outlet view (%)
Sensitivity	75	98	93	37	19
Specificity	69	36	40	61	45
PPV	82	88	69	60	52
NPV	60	77	79	38	15

Pelvic inlet view, O/O obturator oblique view, O/O-outlet obturator oblique-outlet view, I/O iliac oblique view, I/O-outlet iliac oblique-outlet view, PPV positive predictive value, NPV negative predictive value

Table 2 Intraosseous screw position (inside bony corridor)

	Pelvic inlet view (%)	O/O view (%)	O/O-outlet view (%)	I/O view (%)	I/O-outlet view (%)
Sensitivity	99	68	68	70	92
Specificity	31	11	13	42	39
PPV	73	39	40	69	79
NPV	94	30	31	44	67

Pelvic inlet view, *O/O* obturator oblique view, *O/O-outlet* obturator oblique-outlet view, *I/O* iliac oblique view, *I/O-outlet* iliac oblique-outlet view. *PPV* positive predictive value, *NPV* negative predictive value

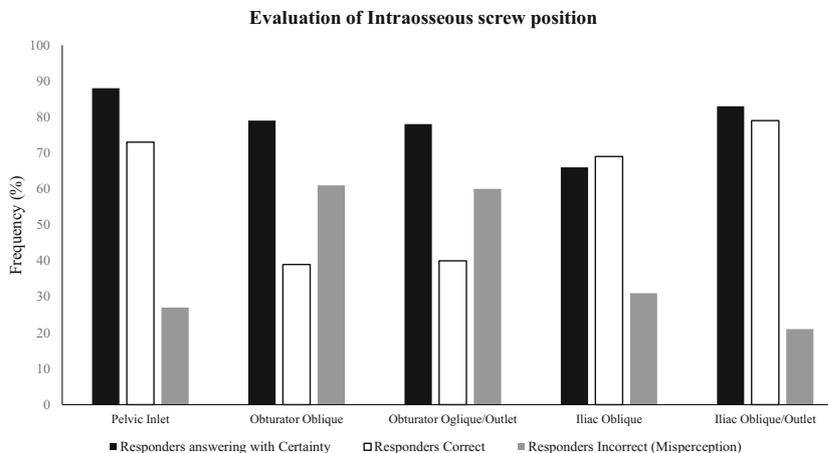
inlet views to evaluate screw position [12, 15, 21, 22]. With the patient in the lateral decubitus position, Cunningham et al. proposed the use of the iliac oblique/outlet and obturator oblique/outlet views to replace the traditional pelvic inlet view. These orthogonal views allow for C-arm adjustments in a single plane and allow for better definition of the starting point on the lateral ilium [19]. Regardless of the imaging strategy used intra-operatively, two primary aspects of the screw position must be evaluated: (1) if the screw is outside of the hip joint and (2) whether or not the screw is intraosseous in its course through the superior pubic ramus (Fig. 7). In the present study, we aimed to determine which fluoroscopic projections provided the surgeon with the most accurate evaluation of anterior column screw position and to highlight the projections which may lead to misperception of the screws' position.

With regard to evaluation of intra-articular penetration of the screw, surgeons were most likely to accurately and confidently identify screw position inside or outside of the hip joint using the obturator oblique (88% accuracy and 8% doubt) and obturator oblique/outlet views (69% accuracy and 21% doubt), which is consistent with previous reports in the literature [6, 11, 21]. The pelvic inlet view should be discouraged when evaluating intra-articular

involvement of the screw. On this view, 40% of surgeons were uncertain if the screw penetrated the hip joint or not. As demonstrated by Norris et al., the pelvic inlet view, when interpreted in isolation, will superimpose the screw trajectory in the anterior column over the hip joint, appearing as if the screw transverses it [23]. For the same reason, the iliac oblique and iliac oblique/outlet views will make the screw appear to penetrate the hip joint regardless of its actual position above or below the acetabular dome. Likewise, there was a high degree of uncertainty (63%) of responses associated with the iliac oblique view and iliac oblique/outlet view (73%), in addition to a high rate of misperception (40% for iliac oblique view and 77% for iliac oblique/outlet view) for respondents who answered with confidence.

The pelvic inlet and the iliac oblique/outlet projections allowed surgeons to most accurately evaluate intraosseous or extraosseous position of the screw within the bony corridor. Both views were associated with a low percentage of doubt among responders (12% pelvic inlet, 17% iliac oblique/outlet) and a greater accuracy when surgeons felt confident in his or her assessment (73% correct with pelvic inlet, 79% correct iliac oblique/outlet). The iliac oblique/outlet view demonstrates the femoral head superimposed on the pubic ramus providing the surgeon

Fig. 6 Analysis of responses (expressed in percentile; y-axis) based on fluoroscopic projection (x-axis). Bars in each cluster represent (from left to right) percentage of responders who answered with certainty (answers 1 and 2), percentage of these responses that were correct, and percentage of these responses that were incorrect. There are significant differences among the groups ($P < 0.0001$, assessed by the χ^2)



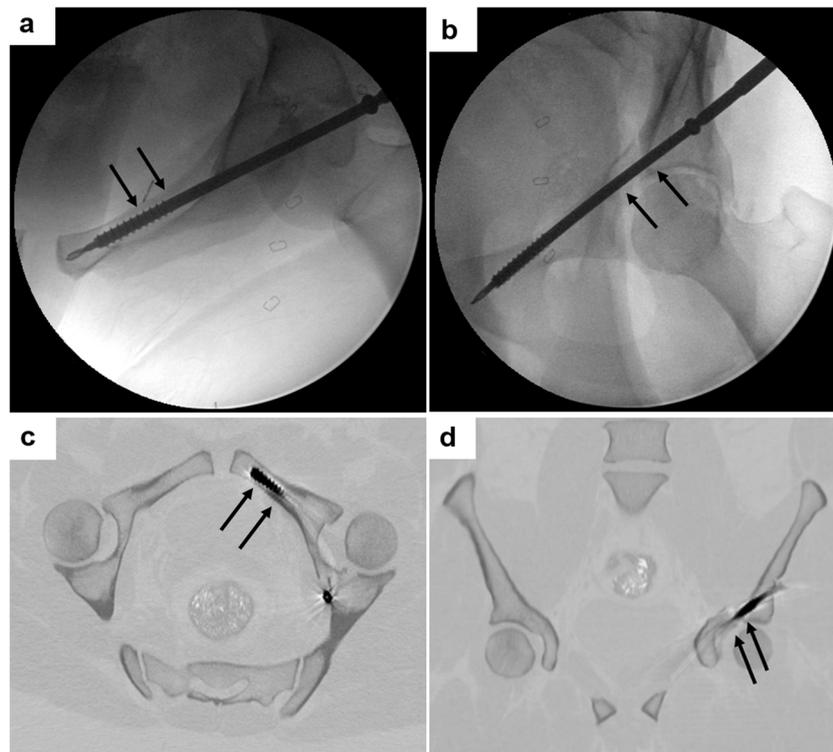


Fig. 7 Clinical case demonstrating standard fluoroscopic imaging principles for anterior column screw placement with post-operative computed tomography scan. **a** Intra-operative pelvic inlet fluoroscopic view demonstrating satisfactory screw position with screw positioned anterior to the posterior cortical border of the left superior pubic ramus (arrows). **b** Intra-operative obturator oblique view demonstrating satisfactory screw position above the hip joint articular surface (arrows).

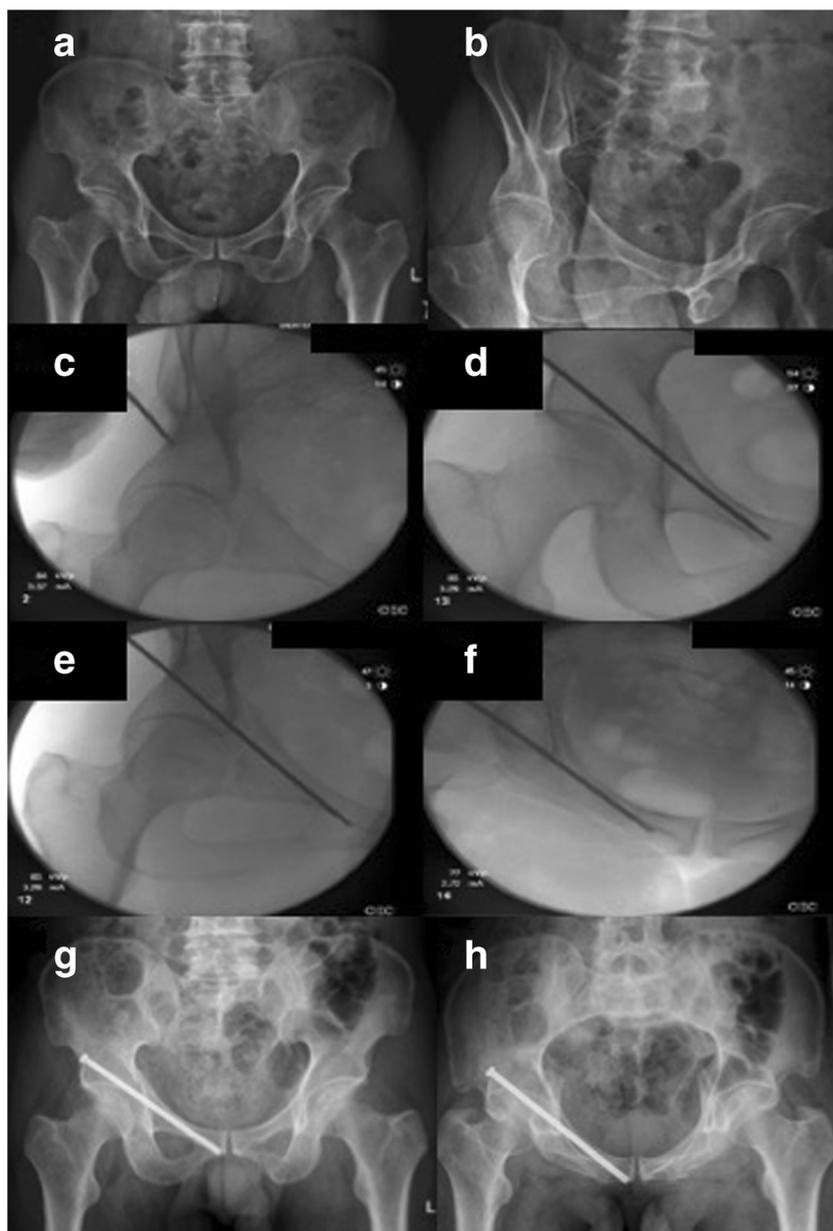
c Post-operative computed tomography scan in the axial plane, oriented perpendicularly to the S1 body, confirming intraosseous screw position (arrows correlate to intra-operative inlet view which demonstrate the posterior cortical margin of the superior pubic ramus). **d** Post-operative computed tomography scan in the coronal reconstructed plane confirming extra-articular screw position (arrows demonstrating upper portion of acetabular joint surface)

with a view that may seem difficult to interpret. However, on a laterally positioned patient, this projection is a useful alternative to the pelvic inlet, which is generally easier to obtain on a supine patient [19]. As an example, this practical tip can be used when the patient is positioned in a lateral decubitus position for reasons pertinent to an open surgical approach to the acetabulum but also requires an anterior column screw. The obturator oblique view, interestingly, proved to be associated with a high rate of misperception among surgeons (39% accuracy), despite a high degree of certainty among responders (79%). The obturator oblique and obturator oblique/outlet views are used to evaluate the cranial (upper) and caudal (lower) safety corridor of the anterior column [11], and based on our results, are not safe to assess the direction of the screw in or out of the pelvis, especially considering the high rate of misperception of screw position.

We acknowledge that our study has several limitations. One such limitation is the translation of our study from pelvic saw-bones to real case scenarios. Although pelvic models are accurate representations of the human pelvis,

anatomical variations are not present and the effect of soft tissues on the image quality and radiographic penetration is mitigated. Secondly, fracture and traumatic deformities were not represented in the models which can result in obvious differences in the surgeons' interpretation of fluoroscopic images. Moreover, the screw trajectories used in the experiment represent only five of a multitude of positions that may be encountered clinically, and these five trajectories may be more or less apparent than those encountered clinically. Despite these limitations, developing and improving surgeons' strategies for intra-operative evaluation of screw position has many benefits in clinical practice [24, 25]. We believe that for the adequately experienced and trained pelvic and acetabular surgeon, judicious use of the described technique for select fracture patterns provides an excellent treatment option for anterior column fixation, avoiding extensile exposures and potentially allowing immediate mobilization and weight bearing (Fig. 8). The design of the experiment and its results illustrate the key imaging principles required for the surgeon to understand safe anterior acetabular column

Fig. 8 **a, b** Demonstrate AP and obturator oblique radiographs of a minimally displaced right transverse acetabular fracture in a 48-year-old male after a fall. **c** Demonstrates intra-operative fluoroscopy demonstrating starting point on outer table of gluteus medius pillar of ilium. **d** Demonstrates intra-operative AP image of guidewire advancing across the anterior acetabular column. Note apparent close proximity to joint, which after correcting the image to obturator oblique view (**e**), demonstrates satisfactory position above the hip joint with additional space needed when screw is cannulated over the guidewire. **f** demonstrating pelvic inlet view confirming intraosseous position, anterior to posterior cortex of right superior pubic ramus. **g, h** Demonstrating post-operative AP and pelvic inlet radiographs with satisfactory fracture alignment and positioning of the 6.5-mm cannulated screw. The procedure was done completely percutaneously, and the patient was allowed to mobilize with full weight bearing as tolerated with no restrictions post-operatively



instrumentation. With a better understanding of which projections afford the greatest accuracy in evaluation of screw trajectory and which projections can lead to misperceptions, screw malposition may be reduced, radiation exposure diminished, and duration of the procedure optimized. It is our hope that for institutions that do not have access to intra-operative 3D fluoroscopy or CT imaging, our results contribute to patients' safety and improved outcomes following percutaneous anterior column fixation.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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