SCIENTIFIC ARTICLE

Obturator Oblique and Pubic Ramus Inlet Views Can Better Guide the Insertion of an Anterior Column Acetabular Screw

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Objective: The objective of the present paper was to investigate the value of obturator oblique and pubic ramus inlet views in guiding anterior column acetabular screw insertion.

Methods: We collected pelvic CT scans at the diagnostic imaging center of our hospital between 2017 and 2019. Virtual three-dimensional (3D) models of the pelvis were created based on the CT scans. Then the transparency was adjusted to 30%. Two identical copies of the 3D model data were made. 3D model replications were divided into a control group and an experimental group. In the control group, the screw was inserted into the anterior acetabular column using obturator-outlet and iliac-inlet views. In the experimental group, the screw was guided under obturator oblique and pubic ramus inlet views. Based on whether the screw penetrated the hip joint and/or exited the pubic ramus, models were divided into three grades. Grade I: the screw travels completely within the anterior column bone corridor; Grade II: the screw exits the superior pubic ramus, but the length of the screw outside the channel does not exceed 1/2 of the anterior column; Grade III: the screw exits the superior pubic ramus and the length of the screw outside the corridor exceeds 1/2 of the anterior column. We compared the screw placement quality of the two groups and analyzed differences between genders. In addition, the distance between the screws and the acetabulum was recorded and compared among the two groups.

Results: A total of 110 hemipelves were selected, including those of 80 men and 30 women, with an average age of 46.76 $\pm$ 14.26 years. In the control group, the screw quality of 64 models (58.2%) was Grade I. In the experimental group, 94 models (85.5%) had Grade I screw placement quality. Grade II screw placement quality accounted for 18.2% of the control group and 7.3% of the experimental group. In the control and the experimental groups, there were 26 and 8 cases with Grade III screw placement quality, respectively. The quality of screw placement in the experimental group was significantly better than that in control group, and the difference between the two groups was statistically significant ($P < 0.01$). The distance between the screw and the acetabulum in the control group and experimental group was 0.92 $\pm$ 0.49 mm and 2.78 $\pm$ 1.15 mm, respectively. The difference between the two groups was statistically significant.

Conclusion: Anterior column acetabular screws can be inserted successfully and more accurately using the obturator oblique and pubic ramus inlet views.

Key words: Acetabulum; Anatomy; Cross-sectional; Fracture fixation; Internal

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Introduction

Pelvic and acetabular fractures are challenging injuries for orthopaedic trauma surgeons[1, 2]. To achieve anatomical reduction and firm fixation, open reduction and internal fixation is the gold standard treatment for most pelvic and acetabular fractures. Fractures of the pubic ramus and anterior column of the acetabulum often require an ilioinguinal or Stoppa approach for reduction and stabilization[3]. Due to the existence of important structures such as the bladder, the femoral nerve, and the femoral artery, it is difficult to expose the fracture site and the attempt can cause secondary damage. Routt *et al.*[2] and Starr *et al.*[4] reported on the use of percutaneous screw internal fixation of the columns of the acetabulum, and then fluoroscopy-guided percutaneous acetabular anterior column screw insertion started being used as a means of minimally invasive fixation of the acetabular anterior column. In recent 20 years, with the advancement of minimally invasive surgical techniques, minimally invasive techniques have been increasingly applied in the treatment of pelvic and acetabular fractures. Therefore, more researchers have focused on how to perform percutaneous fixation of pelvic and acetabular fractures more accurately. Some researchers have devoted themselves to determining the width and length of the corridors of the anterior column and the suprapubic branch of the acetabulum[5–7]. Dr Tang and his team found that the narrowest diameter of the anterior column corridor for men and women is 8.59 ± 1.89 mm and 5.86 ± 1.45 mm, respectively[5]. Tang's team also established fluoroscopy views and a standardized procedure for percutaneous magic screw insertion for acetabulum fractures[8]. Chen *et al.* demonstrated that the anterior column of men will accommodate a 6.5-mm lag screw very well, but it will not fit for all women[6]. Others have focused on establishing more optimized fluoroscopy views to guide the percutaneous screw insertion for pelvic and acetabular fractures[9, 10]. However, there is still no unified view on which fluoroscopy method is best for accurately guiding the anterior column acetabular screw. In addition, current fluoroscopy methods have disadvantages, such as that the C-arm needs to be adjusted repeatedly, resulting in long fluoroscopy time.

Traditional acetabular anterior column percutaneous screw placement methods include retrograde and antegrade insertion. Retrograde insertion is guided by the iliac-inlet and obturator-outlet view during the operation. The position of the pubic tuberosity is superficial and easy to palpate and can be used as a screw entry point for the anterior column of the acetabulum. Therefore, retrograde insertion is more suitable for percutaneous minimally invasive treatment[11]. The main function of the obturator-outlet position is to ensure that the screw does not penetrate the acetabulum or exit the anterior column superiorly, and the iliac-inlet view is used to ensure that the anterior column screw guide wire does not exit the superior pubic ramus either anteriorly, toward the femoral neurovascular structures, or posteriorly, toward the bladder[2]. The anatomical structure of the bony corridor of the superior pubic ramus and the anterior column of the acetabulum is complex, and the cross-section changes among triangles, quadrilaterals, and circles. Therefore, it is challenging to insert the screw safely without it passing out of the pubic ramus or penetrating the acetabulum. Our postoperative CT examination of patients suggests that the patients in which the obturator-outlet and the iliac-inlet views were used to guide the screw placement had a high rate of screws exiting the pubic ramus, and the screws were not completely adjacent to the subchondral bone of the acetabulum. In the intraoperative fluoroscopy, we found that the screw corridor under the obturator oblique view was more comprehensive; that is, the obturator oblique view truly revealed the lateral view of the anterior column. We hypothesize that the obturator oblique view is better than the traditional obturator-outlet view-guided screw placement. Based on the existing surgical procedures, we always adjust the various fluoroscopy views of the pelvis to ensure that the screw is in the bony channel and that it neither penetrates the pubic ramus nor enters the hip joint (Fig. 1). The purpose of this study is, first, to evaluate the practicality of obturator oblique and pubic ramus inlet views guiding anterior column acetabular screw insertion. Second, we aim to compare the effects and differences between the new fluoroscopy view combination and the traditional fluoroscopy views guiding screw placement. Third, we explore the potential mechanism by which a new combination of fluoroscopy views can better guide screw placement. Based on our findings, in future procedures, we will be able to accurately insert screws percutaneously using these combinations of fluoroscopy views, which will substantially shorten the fluoroscopy time. In recent 5 years, increasing numbers of studies have been carried out using three-dimensional (3D) models of the pelvis. Collecting CT data is convenient, and the 3D structure of bone obtained by high-resolution CT scans is reliable[12, 13]. For this reason, we use 3D pelvis image simulation of screw placement to verify the pros and cons of the two methods of screw insertion.

Methods

Materials

We conducted a retrospective search for CT data from patients with pelvic injuries between 2017 and 2019. The inclusion criteria were: (i) the patient was aged 18–60 years; (ii) the CT scan slice thickness was less than 1 mm; and (iii) the inspection site was the pelvis. The exclusion criteria were: (i) the patient had deformities, fractures, or tumors around the pelvis; and (ii) the 3D mask quality was not satisfactory. We collected 110 hemipelvic CT scans (Siemens Sensation 64 Scanner; Siemens, Erlangen, Germany) at the diagnostic imaging center of our hospital between 2017 and 2019. All included CT data underwent processing as described below.

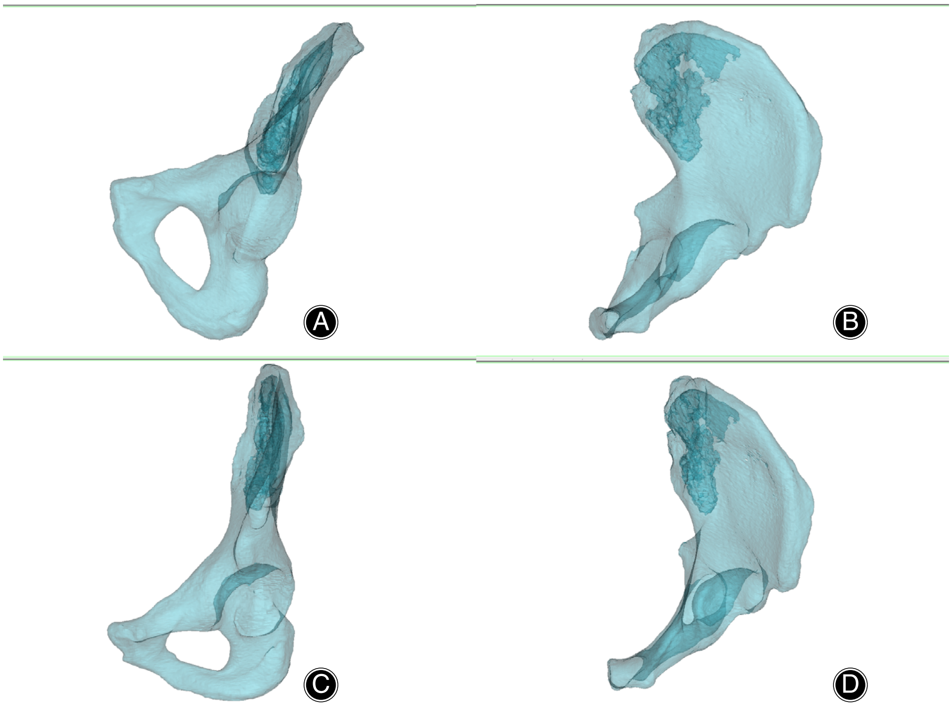

Fig. 1 Fluoroscopy views of anterior column screw insertion. (A) Obturator-outlet view: It is obtained by rotating the anterior–posterior view approximately 45° toward the head and then rotating it 45° toward the affected side. (B) Iliac-inlet view: It is obtained by rotating the anterior–posterior view approximately 45° toward the foot and then rotating it 45° toward the affected side. (C) Obturator oblique view: It is obtained by rotating the anterior–posterior view approximately 45° toward the affected side. (D) Pubic ramus inlet view: First place the model in the anterior–posterior view, then tilt the pelvis until the superior and inferior pubic ramus overlap, and the pubic body looks like a triangle. There are fewer steps to adjust the pelvis to obturator oblique and Pubic ramus inlet views than the previous two.

Simulated screw insertion

CT data (in digital imaging and communication in medicine [DICOM] format) was loaded into Mimics Research 20.0 (Materialize's Interactive Medical Image Control System; Materialize, Belgium). Virtual 3D models of the pelvis were created based on the CT scans. The proximal femur was removed to facilitate 3D rendering, and then we adjusted the transparency to 30% so that the medullary cavity was clear. Two identical copies of the 3D model data were produced, one of which used the obturator-outlet and iliac-inlet views to guide the screw placement; the other group used the obturator oblique and pubic ramus inlet views to guide the screw placement. The former was the control group and the latter was the experimental group. In the control group, the semi-transparent pelvis models were rotated to obturator-outlet view (Fig. 2A). We established a new cylinder with a diameter of 6.5 mm using the analysis objects feature of the CAD module to simulate the anterior column screw. The entry point was determined based on the Routt *et al.*[2]: it was located inferior to the pubic tubercle and lateral to the symphyseal meniscus. We dragged the other end of the cylinder to ensure that the cylinder was in the superior pubic ramus and did not penetrate the acetabulum at the obturator-outlet view. Then the pelvic models were adjusted to the iliac-inlet view (Fig. 2B), making sure that the screw did not exit the superior pubic ramus either anteriorly, toward the femoral neurovascular structures, or posteriorly, toward the bladder. To accurately insert the screw, we repeatedly monitored the screw position in these two views. For the experimental group, we first rotated pelvic models to the obturator oblique view (Fig. 2D) to ensure that the screw did not penetrate the acetabulum or exit the anterior column superiorly. Second, pelvic models were adjusted to the pubic ramus inlet view (Fig. 2E) to ensure that the screw did not exit the superior pubic ramus either anteriorly or posteriorly. In addition, two-dimensional images of transverse, coronal, and sagittal planes were used to ensure that the virtual cylindrical implant was intraosseous. Finally, all screws in these two groups were implanted according to the two approaches, respectively.

Measurement

Screw placement quality

Our experimental results revealed that as long as the screw placement was guided strictly according to the two fluoroscopy views, the screw could be prevented from penetrating the acetabulum. However, some screws still travel outside the superior pubic ramus. We divide the quality of the screw placement into three grades (Fig. 3). Grade I: the screw travels completely within the anterior column bone corridor (Fig. 3A,B); Grade II: the screw exits the superior pubic ramus, but the length of the screw outside the channel does not exceed 1/2 of the anterior column (Fig. 3C); Grade III: the screw exits the superior pubic ramus and the length of the screw outside the corridor exceeds 1/2 of the anterior column (Fig. 3D). We recorded the number of cases and the screw placement quality in the experimental group and the control group.

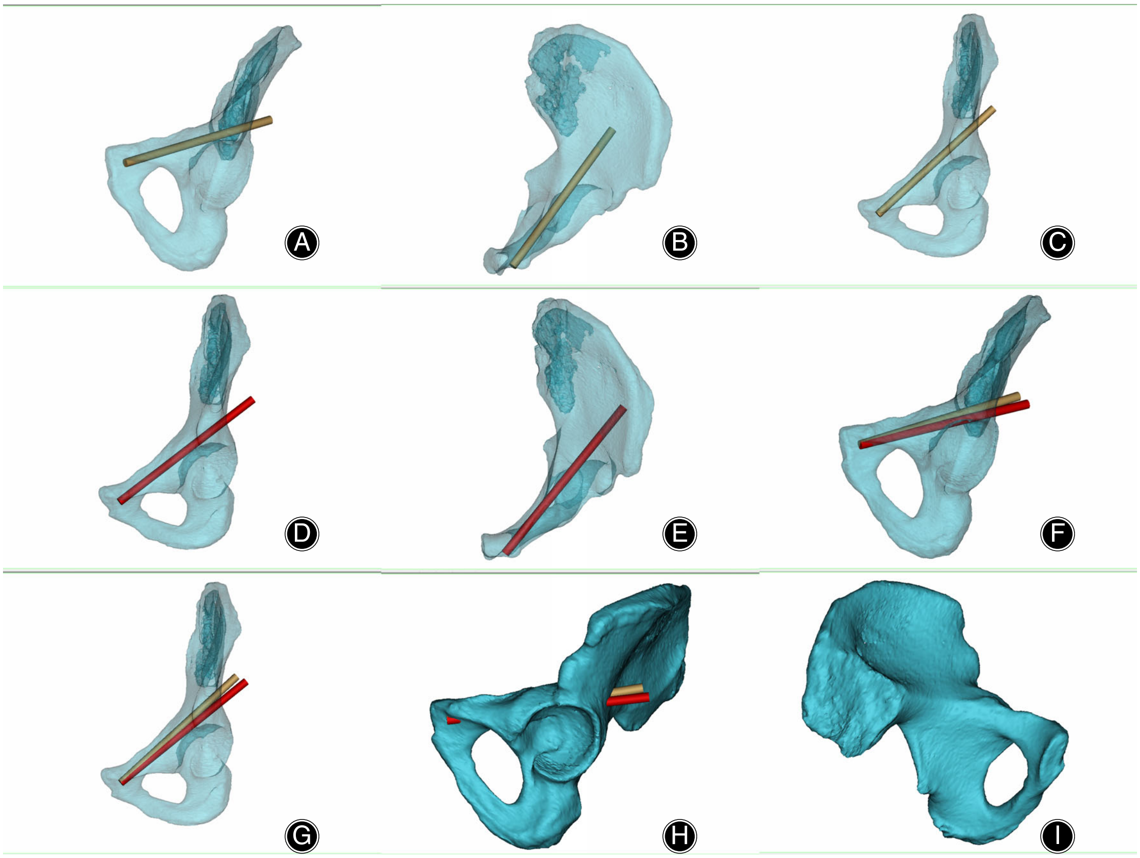

Fig. 2 Screw insertion guided by different fluoroscopy views and comparison of the two methods. (A) The obturator-outlet view was used to ensure that the anterior column screw did not penetrate the acetabulum or exit the anterior column superiorly. (B) The iliac-inlet view was used to ensure that the anterior column screw guide wire did not exit the superior pubic ramus either anteriorly or posteriorly. (C) After the control group screw insertion, there was still some space between the screw and the acetabulum. (D) The obturator oblique view was used to ensure that the anterior column screw did not penetrate the acetabulum or exit the anterior column superiorly. (E) The pubic ramus inlet view was used to ensure that the anterior column screw guide wire did not exit the superior pubic ramus either anteriorly or posteriorly. (F, G, H, I) Comparison of the placement of two screw of the control group (yellow cylinder) and the experimental group (red cylinder). The red cylinder seemed to penetrate the acetabulum on obturator-outlet view (F), but on obturator oblique view, the red cylinder did not enter the hip joint (G), and, in fact, these two cylinders were totally intraosseous (H, I). The experimental group's imaging method makes the screw closer to the acetabulum to reduce the risk of penetrating the pubic ramus. The experimental group's imaging method can more accurately determine whether or not the screw enters the acetabulum.

Distance

The distance between the screw and the acetabulum is defined as the closest distance between the screw and the subchondral bone of the acetabulum on different CT slices. According to the above definition, we recorded the screw placement quality of the two groups and measured the distance between the screws and the subchondral cortex of the acetabulum (Fig. 4).

Statistical analysis

The difference in screw placement quality between the two groups of models was calculated using the Wilcoxon signed rank test. The distance between the screw and the acetabular subchondral bone was also compared using the Wilcoxon signed rank test. All statistical analysis was performed using the SPSS statistical software package for Windows (version 21.0; SPSS, Chicago, IL, USA).

Results

This study included 110 3D hemipelvic models, comprising 80 men (72.7%) and 30 women (27.3%), with an average age of 46.76 ± 14.26 years old.

No screws penetrated the acetabulum. The quality of screw placement is shown in Table 1, and the difference between control and experimental groups is statistically significant ($Z = -5.355$, $P < 0.01$).

Screw placement quality

In the male control group, 77.5% were Grade I, 15.0% were Grade II, and 7.5% were Grade III quality. In the experimental

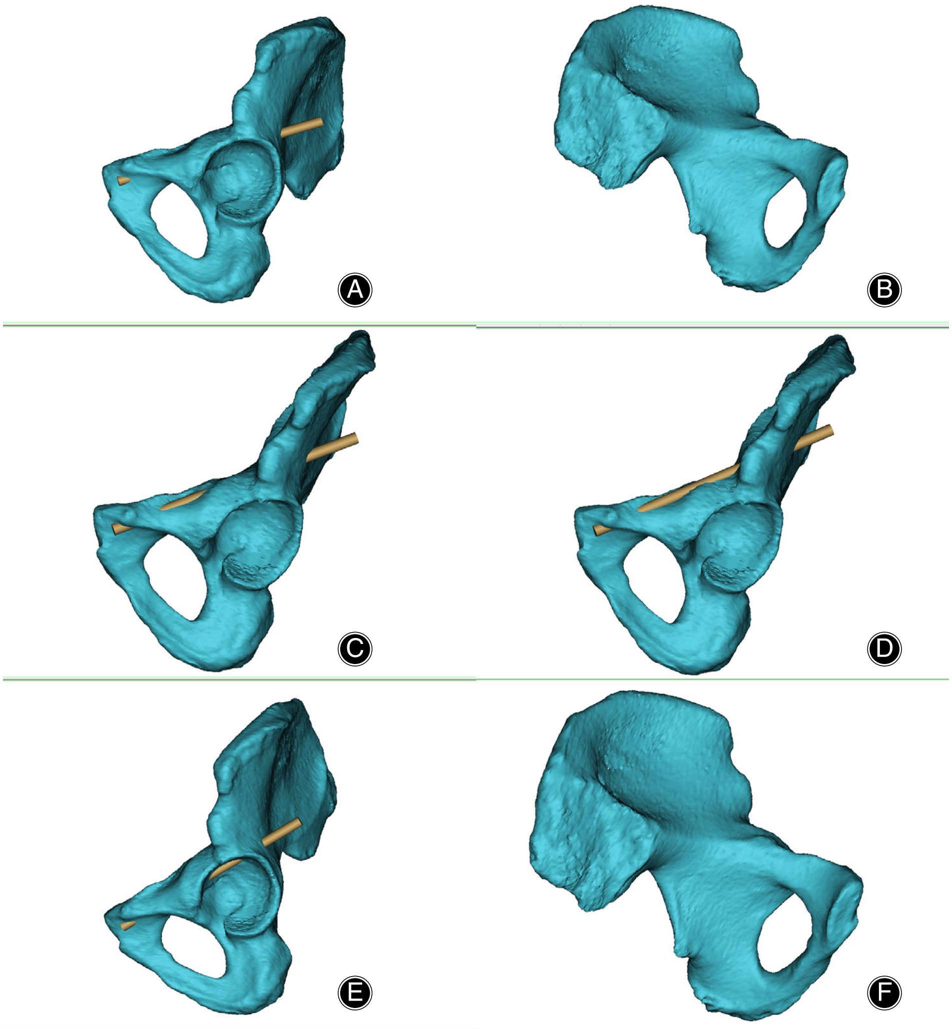

Fig. 3 Screw placement quality. Grade I: The screw travels completely within the anterior column bone corridor (A, B). Grade II: The screw exits superior pubic ramus, but the length of the screw outside the channel does not exceed 1/2 of the anterior column (C). Grade III: The screw exits the superior pubic ramus and the length of the screw outside the corridor exceeds 1/2 of the anterior column (D). (E, F) The screw penetrates the acetabulum while not exiting the anterior column. The quality of screw placement in the experimental group is much better than in the control group ($P < 0.05$).

TABLE 1 Comparison of the screw placement quality between the two groups and statistical analysis results

	Control group				Experimental group					
Quality	I	II	III	Total	I	II	III	Total	*Z*	*P*
Male	62 (77.5%)	12 (15.0%)	6 (7.5%)	80 (100%)	78 (97.5%)	2 (2.5%)	0 (0.0%)	80 (100%)	−3.640	<0.01
Female	2 (6.7%)	8 (26.7%)	20 (66.7%)	30 (100%)	16 (53.3%)	6 (20.0%)	8 (26.7%)	30 (100%)	−3.963	<0.01
Total	64 (58.2%)	20 (18.2%)	26 (23.6%)	110 (100%)	94 (85.5%)	8 (7.3%)	8 (7.3%)	110 (100%)	−5.355	<0.01

group, 97.5% were Grade I, 2.5% were Grade II, and no Grade III screws were recorded. For male pelvises, the screw placement in the experimental group was significantly better than that in the control group, and the difference between the two groups was statistically significant ($Z = -3.640$, $P < 0.01$).

The quality of screws for the female pelvises was recorded as follows. In the control group, most of the screws were placed in Grade III, accounting for 66.7%. Grade I and Grade II accounted for 6.7% and 26.7%, respectively. In the experimental group, 53.3% of the cases had a screw placement quality of Grade I, while those of Grade II and III accounted for 20.0% and 26.7%, respectively. For the female pelvis, screw placement in the experimental group was significantly better than that in the control group, and the difference between the two groups was statistically significant ($Z = -3.963$, $P < 0.01$).

Distance

The distance between the screw and the acetabulum in the control group was 0.92 ± 0.49 mm and in the experimental group was 2.78 ± 1.15 mm. The difference between the two groups was statistically significant ($Z = 9.047$, $P < 0.01$).

Discussion

Percutaneous screw configuration

Minimally invasive surgery is a focus of surgical development. It can achieve percutaneous fixation or appropriate soft tissue exposure to complete fracture fixation, which can greatly reduce the trauma and post-surgery complications compared with open surgery[14]. However, due to the complex structure and large variation of the pelvis, there are certain difficulties in performing minimally invasive treatment. With the existence of important structures such as the bladder, the femoral nerve, and the femoral artery, the fracture site is difficult to expose and the process of exposing the fracture site can cause secondary damage[14, 15]. Routt *et al.*[2] first reported the use of the percutaneous screw fixation technique and, since then, percutaneous fixation of the acetabular anterior column has become increasingly popular among orthopaedic doctors. For acetabular anterior column fractures, if the displacement is small or closed reduction is satisfactory, the fracture can be fixed with percutaneous screws. The traditional acetabular anterior column screw insertion is guided under fluoroscopy in obturator-outlet and iliac-inlet views. However, due to the variation of the anterior column of the acetabulum and the superior pubic ramus, the passage for the screw is relatively narrow, which brings certain difficulties to the screw configuration.

Ideal screw insertion

To determine the ideal view for guiding the screw placement, in this study, we used a 3D model of the pelvis to explore the optimal screw insertion and found that after the traditional screw insertion, there was still some space between the screw and the acetabulum. The anterior column screw corridor was not fully utilized, and when the obturator oblique and pubic ramus inlet views were used, the screw could be close to the acetabulum without entering the acetabulum, thereby increasing the space for the screw channel, improving the quality of screw placement, and reducing the difficulty of screw placement. In contrast, in the obturator oblique view, the screw was close to the acetabulum, and when adjusted to the obturator-outlet view, it looked like the screw had penetrated into the acetabulum, but, in fact, the screw was totally intraosseous (Fig. 2F,G,H,I).

Screw quality evaluation

Percutaneous fixation of pelvic and acetabular fractures is a very promising area of treatment, and six related percutaneous screw fixation methods have been developed[1]. Percutaneous minimally invasive screw placement minimizes soft tissue dissection and blood loss in the already traumatized patient[15]. However, percutaneous screw placement for pelvic and acetabular fractures is a challenging operation. Although intraoperative CT and O-arm navigation are performed in many hospitals and can guide screw placement very well[15], they are rarely performed in developing countries like China, not even in hospitals affiliated to medical universities. Therefore, this study simulated the anterior column screw placement under fluoroscopy views. Studies have demonstrated that women have narrower screw corridors than men[5]. Our hospital often uses 6.5-mm hollow screws to treat pelvic ring fractures. At the same time, Chang *et al.* (2001) reported that their biomechanical experiment demonstrated that a 6.5-mm screw can provide sufficient biomechanical strength[16]. Therefore, we used 6.5-mm cylinders to simulate the insertion of the front column screw. Chen *et al.* found that the anterior column of a man will accommodate a 6.5-mm lag screw very well, but it does not fit in all women[6]. Consistent with prior studies, our study indicated that in female patients the 6.5-mm diameter cylindrical simulation screw had a higher chance of exiting the superior pubic ramus. When the obturator oblique view guides screw placement, the screw is closer to the subchondral cortex of the acetabular surface, and this view can also be used to determine whether the screw has penetrated the acetabulum. From the obturator-outlet view, the screw was close to the acetabulum; when adjusted to the obturator oblique view, there was still a certain distance between the screw and the acetabulum (Fig. 2A,C). When viewing the screw close to the acetabulum in the obturator oblique position, we adjusted to the obturator-outlet view; the screw looked like it was entering the acetabulum (Fig. 2D,F,G) when, in fact, the cylinders were totally intraosseous. Both methods can effectively avoid the screw penetrating the acetabulum. Guimares *et al.* found that the obturator oblique view most accurately predicts the adequate position of an anterior column acetabular screw using five synthetic pelvic models[10]. We used 110 cases for a semi-pelvic 3D simulation study to prove that the obturator oblique view is more accurate than the obturator-outlet view in indicating whether the screw enters the acetabulum.

We used the obturator-outlet view, the iliac-inlet view, the obturator oblique position, and the public ramus inlet view to guide the placement of the anterior column screws in the same 3D pelvic model. It was found that neither method of screw insertion caused the screw to enter the acetabulum. Therefore, the effectiveness of the two methods to prevent the screw from entering the acetabulum was satisfactory. However, when the obturator-outlet and the iliac-inlet views guided the screw placement, the screw penetrating the superior pubic ramus cortex was more common. In men, the bone corridor was relatively wide and it was relatively easy to insert the screw. However, 22.5% of the anterior column acetabular screws still passed outside the anterior column bone channel, mainly through the superior pubic ramus. In most women, the screw ran out of the anterior acetabular column bone corridor (the incidence was 93.3%). When the obturator oblique and the pubic ramus inlet views were used to guide the screw placement, 97.5% of the screws in the male pelvis traveled in the anterior column of the acetabulum, 2.5% of the screws passed outside the pubic ramus, and the screw placement quality

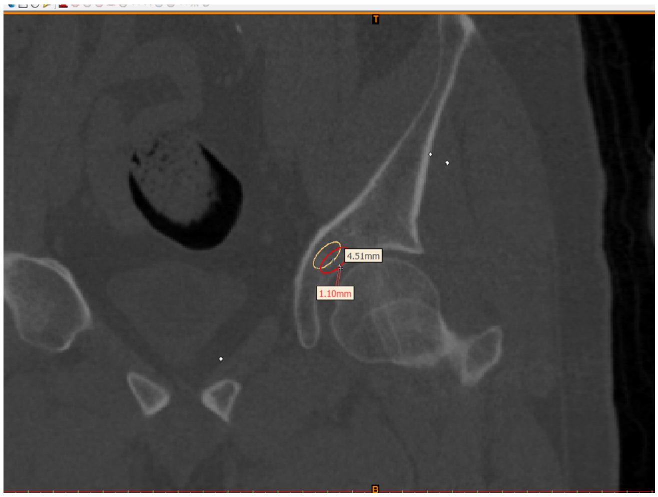

Fig. 4 Distance between screws and the acetabulum. The yellow ring refers to the control group and the red ring refers to the experimental group. The distance between the screw and the acetabulum in the experimental group was significantly shorter than that in the control group (0.92 ± 0.49 mm and 2.78 ± 1.15 mm, respectively).

was excellent. In the female pelvis, 53.3% of the screws ran completely in the anterior column bone channel (Grade I quality), 20% of the screws were of Grade II quality, and only 26.7% of the model screws exited the cortex of the pubic ramus by more than 1/2 the length of anterior column (Grade III quality). When the obturator oblique and the pubic ramus inlet views were used to guide the placement of the anterior column screw, the quality of the screw position was much better than that of the obturator-outlet and the iliac-inlet view-guided screw placement. We also found that screws in the obturator oblique and the pubic ramus inlet group were closer to the subchondral bone of the acetabulum than those in control group (Fig. 4). The closest distance between the screw and the acetabulum in the control group and the experimental group was 0.92 ± 0.49 mm and 2.78 ± 1.15 mm respectively. This is the reason why the experimental group has better screw placement quality and a lower penetrating rate. While increasing the space for screw placement, this approach of screw placement can also effectively fix the fracture fragments and increase the screw's holding force on the subchondral bone.

Screw corridors

The width of the channel was reported in Chen *et al.* (2009) as 8.16 ± 1.21 mm[6]. Some studies have suggested that the anterior column screw corridor of male patients can safely accommodate 7.3-mm screws [14, 17]. Because the screw passage corridor is mainly located in the front ring of the pelvis and is roughly 1/4 of the circumference of pelvic ring, the width of the channel that accommodates the screw is often less than 8 mm. In applying the combinations of fluoroscopy views discussed in this paper, the narrow screw passage corridor of the suprapubic ramus and the acetabular anterior column can be better utilized. With the two methods, the screws may travel outside the suprapubic ramus superiorly and posteriorly but not pass through anteriorly. This can effectively prevent the guide pin and screw from damaging the vessels and nerves in front of the pubic ramus. Most of the models in which the screw penetrated the pubic ramus were narrow and curved. When the obturator oblique and the pubic ramus inlet views are used to guide the screw placement, the screw is closer to the acetabular joint surface; therefore, the half-threaded screws can also provide more effective fracture reduction and compression throughout the fracture. In addition, screw placement space is significantly increased, especially for women's pelvises. The proportion of screws placed of Grade I quality in the experimental group increased by 46.6% compared with the control group. For screw placement of female patients, according to our research results and reports in the literature, the entry point of the retrograde screw needs to be 1–2-cm below the pubic tubercle[14]. In female patients, the entry point was located significantly more lateral to the symphysis and closer to the cranial margin of the superior ramus ossis pubis[18], so that moving the entry point lateral can achieve better results in women. Previous studies by Zhang *et al.*[19] and our team[20] found that the anterior column axial view can achieve better results in female patients than the traditional approach. However, in clinical applications, it has been found that the axial method requires more fluoroscopy time. In this study, we used obturator oblique and pubic ramus inlet views to simulate anterior column screw placement, and it was proved that the new fluoroscopy views were practical and effective. Their use can also reduce the chance of the screw penetrating the pubic ramus and the anterior column of the acetabulum.

Limitations of the study

There are certain limitations to our study. First, we used a computer-aided 3D model to simulate the study. Whether the modified technology can accurately represent the anatomical structure of the human pelvis remains controversial. Second, we only used 6.5-mm diameter screws, so it is impossible to evaluate the placement effect of screws with different diameters. In female patients, a smaller screw may achieve better results.

Conclusion

Despite the above limitations, we can still draw meaningful conclusions from our experimental results. First, using obturator oblique and pubic ramus inlet view-guided insertion makes the best use of the bony corridor of the anterior column and increases the success rate of screw placement, especially for female patients with narrow and curved corridors. Second, the obturator oblique view can more accurately predict whether the screw penetrates the hip joint. Third, obturator oblique view-guided insertion brings the screw closer to the subchondral bone of the acetabulum, this is the potential mechanism of better screw quality in the experimental group. In future research, suitable screw diameters for male and female patients should be further studied and related biomechanical analysis undertaken.

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