RESEARCH ARTICLE

Percutaneous Sacroiliac Screw Fixation: A Modified Screw Insertion Method Using Just 2 Fluoroscopy Views

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Abstract

Objectives: Percutaneous sacroiliac screw fixation (PSSF) is a well-defined method of surgery to fix unstable fractures of the pelvic ring with fewer post-surgical complications. However, the complex anatomy of the mentioned area makes PSSF a formidable challenge. The present study aimed to investigate a modified screw insertion method using two views of fluoroscopy X-ray instead of the prior three views to reduce the duration of operations and radiation exposures.

Methods: The present study was performed on 10 radiopaque plastic pelvic models (including 20 half pelvis) during simulated surgical procedures. Of the 20 screws, 10 were inserted using the conventional method with the navigation of three fluoroscopy views (Group A). The remaining 10 were inserted using the modified method with the navigation of two fluoroscopy views, including just the outlet and inlet views, without taking the lateral view, based on our theory and order of fluoroscopy (Group B). Following screw insertion, the accuracy of screw locations was evaluated using a computed tomography (CT) scan, and the duration of operations and radiation exposures were compared between the two surgery methods at the end of the study.

Results: In both groups, nine screws (90%) were located correctly, and one screw (10%) perforated the anterior wall of the first sacral vertebra. The mean±SD of the duration of radiation exposure in groups A and B was 6.1±1.0 min and 4.2±0.1 min, respectively (P=0.01). Moreover, the mean±SD of operation duration in group A was 45.7±5.8 min, but this value in group B was 35.5±4.5, which showed a significant decrease in operation duration (P=0.04).).

Conclusion: PSSF using a modified screw insertion method with just two fluoroscopy views not only had similar accuracy to conventional methods but also could decrease operation time and the following radiation exposure.

Level of evidence: IV

Keywords: Fluoroscopy, Pelvic imaging navigation, Percutaneous screw insertion, Sacroiliac Joint

Introduction

In recent decades, the application of Percutaneous Sacroiliac Screw Fixation (PSSF) is an established method for reducing the unstable fractures of the pelvic ring. The use of previous reduction techniques, including open reduction and internal fixation, has been associated with severe complications, including massive blood loss, postoperative infection, and nervous injuries,[1] while percutaneous fixation has lower rates of these surgical complications. However, due to the specific anatomic features of the area, screw insertion during PSSF is still challenging.[2] According to previous reports, screw malpositioning occurs in 2%-68% of the PSSF procedures,[3,4] and may lead to severe complications, including L5 root injury, cauda equina syndrome, and vascular injuries. Therefore, intraoperative imaging and navigation methods play an essential role in this procedure.

Intraoperative C-arm fluoroscopy for PSSF is a

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conventional navigation method in operating rooms.[5] However, this imaging modality, consisting of the inlet, outlet, and true lateral views, causes massive radiation exposure for both patient and surgeon.[6] Furthermore, the procedure is often repeated several times to properly adjust the screw locations, prolonging the operation duration. Therefore, new imaging and navigation technologies have been recently developed and are associated with reduced risk of screw malpositioning and decreased radiation exposure during PSSF.[7,8] However, studies on the advantages of these novel methods are still controversial and could not prove their superiority over conventional methods. Therefore, the present study aimed at investigating a modified screw insertion method using just two views of fluoroscopy X-ray (inlet and outlet views) instead of three conventional views (inlet, outlet, and lateral views) for PSSF.

Materials and Methods

Experiment Establishment

The present experimental study was performed using simulated surgical procedures on 10 radiopaque plastic pelvis models [Figure 1.A]. Before the surgery, the models were restrained on a radiolucent table in the supine position. Moreover, all the iliosacral joints were previously fixed in anatomical reduction using two screws outside the surgical field to simulate a fracture dislocation after reduction. To mitigate potential bias from using screws as landmarks, our focus, was on the position of the screw within the body of the first sacral vertebra. Based on this focus, we carefully selected the best order for screw insertion, aiming to minimize the possibility of posterior violation of the cortex, which could result in injury to the nerve roots or the cauda equina, as well as penetration into the S1 foramen. Additionally, we aimed to avoid trajectories that would intersect with the L5 root like in-out-in trajectory and prevent the screw from heading toward the endplate of S1. These considerations were integral to ensuring the accuracy and safety of our screw insertion method. In addition, The pelvis models were covered using a sheet for realistic surgery simulation and obscuring the anatomical and surgical landmarks [Figure 1.B]. Also, there was no fracture or displacement in the iliosacral joints, and the procedures were performed in the reduced anatomical position. In both groups of the study, simulation of soft tissue was not explicitly mentioned. However, it's important to note that in our experimental setup, the focus was primarily on evaluating the efficacy of different fluoroscopy views for screw insertion in a controlled environment. While soft tissue simulation can be crucial in clinical practice, its absence in our study may have less impact on the final results given the standardized conditions of the experiment. We acknowledge the importance of soft tissue anatomy and plan to incorporate this aspect into further cadaveric studies, which are currently in the planning stages. While the surgeon was not directly involved in the analysis of measurements and interpretation of results, rigorous measures were implemented to minimize systematic errors and biases. Randomized screw insertion order and blinded evaluators during analysis were implemented to enhance the objectivity and reliability of the study. Also The surgeon performing the procedures was blinded to the subsequent analysis, ensuring that the evaluations were conducted objectively and impartially.

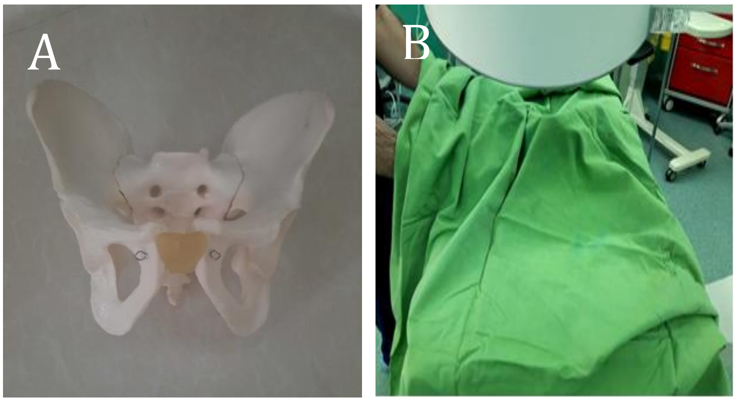

Figure 1. Radiopaque plastic pelvic model used in the present study (A). The use of a cover sheet to obscure the anatomical and surgical landmarks before the simulated surgery (B)

Screw Insertion and Fluoroscopy

The plastic pelvic models were used Twenty cannulated screws with 6.5 mm diameter were inserted into the bodies of the first sacral vertebrae (S1) of the pelvic models. Of these 20 screws, ten were inserted using the conventional method of 3D fluoroscopy in one side, which consisted of the inlet, outlet, and true lateral views (Group A). The remaining screws (n=10) were inserted using the modified navigation method of 2 fluoroscopy views in another side of the pelvic models, consisting of just outlet and inlet views (Group B). In the conventional method group (Group A), cortical density assessment of the ilium and identifying the appropriate point for screw insertion was performed using the true lateral view first, followed by inlet and outlet views [Figure 2]. However, in Group B, without taking lateral view, the screw insertion was first navigated using the outlet view, followed by the inlet view. In this group, outlet view was used to identify the S1 foramen, and the guidewire was inserted exactly above this foramen. Subsequently, adjusting the guidewire into the middle of the S1 body with a slightly posterior orientation using the inlet view [Figure 3]. when these two perfect directions obtain in both inlet and outlet views then the screw apply over the guidewire. All the simulated surgeries were performed by a single trained orthopedic surgeon. Moreover, the screws were alternately inserted in each half of the pelvic using conventional and modified methods on different days to reduce systematic errors and biases. Also, imaging was performed by an expert radiology technician using the C-arm fluoroscopy.

Measurement

Following screw insertion, correct screw insertion was first evaluated by direct visualizing the plastic pelvic model, where we carefully assessed for posterior violation of the cortex, which could result in injury to the nerve roots or the cauda equina, as well as penetration into the S1 foramen. Additionally, we aimed to avoid trajectories that would intersect with the L5 root, such as the in-out-in trajectory, and prevent the screw from heading toward the endplate of S1. These considerations were integral to ensuring the accuracy and safety of our screw insertion method. Subsequently, we further evaluated the screw trajectory using CT scan. Any cortical perforation of the S1 body and screw insertion into the spinal canal was considered as misplacement and recorded. Furthermore, the imaging repetitions and radiation exposure duration were recorded to evaluate the effect of the modified screw insertion method on the imaging variables. The fluoroscopy procedures were performed using the Siemens® AG C-arm fluoroscopy device, which recorded the radiation exposure in minutes. Moreover, the operation duration, defined as the interval between the beginning of the surgery and the screw insertion completion, was measured in each group and underwent intergroup comparisons.

Statistical Analysis

Statistical Analysis was performed using the SPSS software version 25, and the significance level was considered at 0.05. The qualitative variables were described in frequency and percentage, while quantitative variables were described using the mean and Standard Deviation (SD). The normal distribution of the variables was investigated using the Shapiro-Wilk and Kolmogorov-Smirnov tests, while the qualitative variables were investigated using the chi-squared test. Finally, the independent sample t-test and Mann-Whitney U test were used for intergroup comparisons of the normal and non-normal variables, respectively.

Figure 2. Percutaneous sacroiliac screw fixation using conventional imaging method with 3D fluoroscopy. The lateral view used for iliac cortical density assessment and identifying the entry point of the guidewire (A). Outlet view (B). Inlet view (C). The screws observed in the figures were inserted out of the surgical field before the simulated surgery to fix the sacroiliac joints in anatomical position

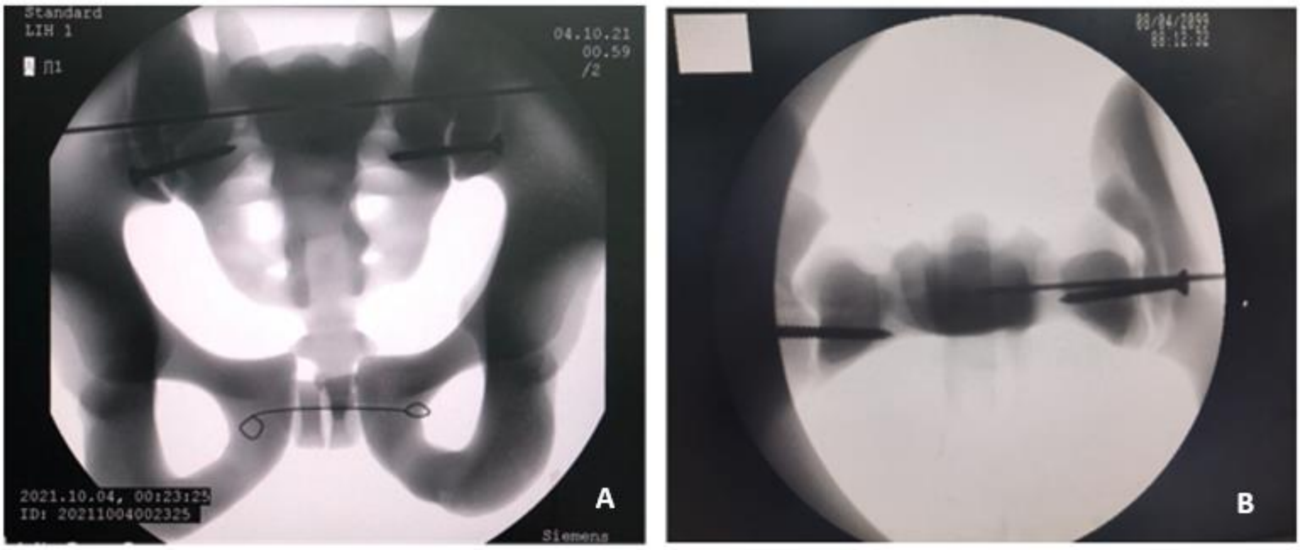

Figure 3. Percutaneous sacroiliac screw fixation using novel modified screw insertion methods with just two views of fluoroscopy following our new modified concept of screw insertion method. Outlet view used to identify the entry point of the guidewire, which was inserted exactly above the S1 foramen (A). The inlet view used after the outlet view to adjust the guidewire into the middle of the S1 body with a slightly posterior orientation (B). The screws observed in the figures were inserted out of the surgical field before the simulated surgery to fix the sacroiliac joints in anatomical position

Results

Screw Positioning

After the simulated surgery completion, the accuracy of screw insertion was evaluated using the CT scan in both groups [Figure 4]. In Group A, which used the conventional method, nine screws (90%) out of 10 were in the correct position, and only one (10%) attempt led to the perforation of the anterior cortex of the S1 body. In Group B, which used the new modified method, nine screws (90%) were correctly inserted, and only one (10%) screw perforated the anterior wall of the S1 body. Therefore, no significant difference in screw misplacement was observed between the conventional and modified imaging methods used for screw insertion in PSSF.

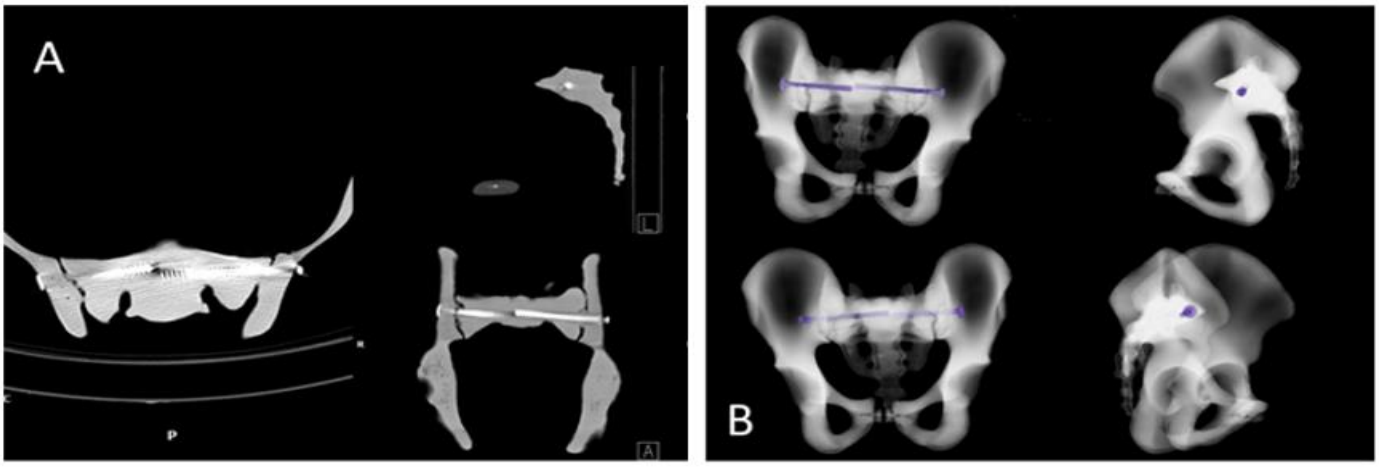

Figure 4. Evaluation of the screws inserted using the 2D (A) and 3D (B) fluoroscopy methods by Computed Tomography (CT) scan after the simulated surgery. The screws alongside the washer were inserted using the conventional method, while other screws were inserted using the modified screw insertion method

Number of Imaging Repetitions and Radiation Exposure Duration

The imaging repetitions and radiation exposure duration were recorded in both groups and underwent intergroup comparisons to evaluate the effect of the modified screw insertion method on these variables. In Group A, the mean ± SD of the imaging repetitions was 33±5.6, with a range of 25 to 42. Moreover, the mean± SD of the imaging repetitions was 21.6 ± 2.5 in Group B, with a range of 18 to 26. Therefore, the imaging repetitions were higher in Group A than Group B. However, the difference was not significant. On the other hand, the mean ± SD of radiation exposure duration was 6.1±1.0 min in Group A, with a range of 4.6-7.8 min, while it was 4.2±0.1 min in Group B, with a range of 3.9-5.0 min. Therefore, there was a significant intergroup difference (P=0.01). The imaging repetitions and radiation exposure duration by group are presented in Table 1 in detail.

Operation Duration

In Group A, the means of operation duration was 45.7±5.8 min, with a range of 34-52 min. Moreover, Group B had the mean operation duration of 35.5±4.5 min, with a range of 28-35.5 min [Table 1]. Therefore, the modified screw insertion method with just two fluoroscopy views could significantly decrease the operation duration of PSSF (P=0.04).

Table 1. The imaging repetitions and radiation exposure duration by group

Variable	Groups		
Mean ± SD	Group A (n=10)	Group B (n=10)	P-value
Imaging repetition	33.0 ± 5.6	21.6 ± 2.5	0.058
Radiation exposure duration (min)	6.1 ± 1.0	4.2 ± 0.1	0.01*
Operation duration (min)	45.7 ± 5.8	35.5 ± 4.5	0.04*

*P<0.05

Discussion

According to our results, the use of a modified imaging method of 2 fluoroscopy views (outlet and inlet views) for screw insertion based on our theory and our concept (the screw insertion was first navigated using the outlet view, followed by the inlet view. outlet view was used to identify the S1 foramen, and the guidewire was inserted exactly above this foramen. Subsequently, adjusting the guidewire into the middle of the S1 body with a slightly posterior orientation using the inlet view. When these two perfect directions obtain in both inlet and outlet views then the screw apply over the guidewire) could significantly reduce the duration of the PSSF procedure compared to the conventional 3D fluoroscopy method (lateral, outlet, and inlet views). Moreover, omitting the lateral view in 2 fluoroscopy views significantly reduced the radiation exposure duration for both patient and surgeon. However, it did not lead to a significant difference in the rate of malpositioned screws. Therefore, it can be concluded that the modified screw insertion with just 2 views of fluoroscopy without taking lateral image, following our new method of insertion concept can be considered as an alternative imaging method for PSSF.

Recently, some novel and computer-assisted navigation methods have been introduced for PSSF, including 2D fluoroscopy,[9] 3D fluoroscopy,[10] CT scan,[11] and robot-assisted navigation systems.[12] Although these novel methods can lead to shorter operation duration and improved accuracy of screw insertion, they only can be utilized by skilled operators. Moreover, they are not available in all settings. Also, according to some reports, these methods have some limitations. A study by Behrendt et al.[13] suggested avoiding 3D fluoroscopy navigation systems in young patients due to excessive radiation exposure compared to the 2D fluoroscopy methods. In addition, Wang et al.[14] reported that using robot-assisted navigation systems for PSSF increased the surgery-related costs remarkably. Hence, it seems that conventional methods can be considered as the most executable navigation methods.

However, some studies have recommended the use of novel methods. Javadimehr et al.[15] defined a new navigation method for screw insertion that only used the lateral view of the fluoroscopy X-ray to detect the anterosuperior quadrant of the S1 body. Afterward, the screw was inserted in the posteroinferior quadrant. This method could reduce the operation duration and improve the accuracy of screw insertion. However, the study did not investigate the radiation exposure or imaging repetitions in the novel method. Moreover, previous studies have reported that bowel gas and obesity may limit the use of lateral view in intraoperative fluoroscopy.[2,7,8] Therefore, it seems that the results by Javadimehr et al.[15] should be further evaluated in clinical settings. Another study by Ecker et al.[16] provided a new preoperative planning approach for the PSSF procedure. They reported that preoperative CT scan helped the surgeons to identify the entry points of the screws and reduced the operation duration and imaging repetitions. However, this preoperative planning approach exposed the patients to excessive radiation caused by the CT scan.

In the present study we found that application of the described modified screw insertion method using According to our results, the modified method of 2 fluoroscopy views, without taking lateral view, including the use of the outlet view and then the inlet view, could reduce the variables of operation duration and imaging repetitions in the PSSF procedure. It is worth noting that a shorter operation duration also decreases the risk of surgical site infection.[17] Additionally, a study outlined the application of an innovative Hula Hoop technique, which circumvents invasive open procedures, shortens anesthesia time, decreases the size and number of incisions, and minimizes bleeding for stabilizing an unstable posterior pelvic ring fracture.[18]

A rare case involving a pregnant patient with fractures in both the pelvic ring and sacrum is reported, successfully treated using an external fixator as the primary approach.[19]

Since the lateral view is not used in this modified method, there is no need to reposition the C-arm fluoroscope, which reduces the possibility of operating field contamination.

The present study had some limitations as well. First, our study included simulated surgeries on the same type of plastic pelvis models, while the pelvis may be of different shapes in different patients. Therefore, further investigations should be made using real operations in clinical settings like a cadaveric study. Moreover, in our study, all the screw insertions were performed by the same surgeon skilled in the PSSF procedure. This may lead to different results compared to real clinical settings.

Conclusion

The present study introduced a modified screw insertion method using just two views of fluoroscopy X-ray, which included the outlet view followed by the inlet view without taking lateral view. In conclusion, our study represents a significant contribution to the field of orthopedic surgery by introducing a modified screw insertion method for percutaneous sacroiliac screw fixation. The findings underscore the potential of this approach to streamline surgical procedures, reduce radiation exposure, and enhance patient outcomes. We introduce new criteria for C-arm positioning that facilitate the correct positioning of the screw within the body of S1, based on our investigations. Importantly, our method eliminates the need for the lateral view, simplifying the surgical process and reducing the time and radiation exposure associated with conventional methods. In fact, based on our theory it is important to insert the guidewire exactly above the S1 foramen in outlet view then, adjusting the guidewire into the middle of the S1 body with a slightly posterior orientation using the inlet view. When we use this order of screw insertion, there is no need to reposition the C-arm to achieve a lateral view. The accuracy of screw insertion was not different between the modified and conventional insertion methods. However, the modified method of insertion could reduce the operation duration and radiation exposure significantly. Moreover, it reduced the imaging repetitions during surgery, which was not significant.

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