

Original Article

Percutaneous iliosacral screw insertion with only outlet and inlet fluoroscopic view for unstable pelvic ring injuries: Clinical and radiological outcomes

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ABSTRACT

Background: Percutaneous iliosacral screw fixation in posterior pelvic ring fractures is challenging and commonly performed under fluoroscopy or navigation techniques. This study aimed to assess the safety and efficacy of percutaneous iliosacral screw implantation under fluoroscopy guidance with only inlet and outlet views.

Methods: This retrospective study included 58 consecutive unstable posterior pelvic injury patients (36 sacral fractures and 22 sacroiliac joint disruptions) treated with percutaneous iliosacral screws between January 2015 and November 2019. Acceptable inlet radiographs show the anterior cortex of the S1 body superimposed on the S2 body. Acceptable outlet radiographs show the superior pubic symphysis at the level of the S2 foramen and visualize the S1 and S2 sacral foramina. In our technique, the screw was inserted at the inferior half of the outlet view and the posterior half of the inlet view. The time needed for screw insertion and the radiation exposure time was recorded. Intra and postoperative complications were documented. Postoperative computed tomography (CT) scans assessed screw position.

Results: In total, 69 iliosacral screws were inserted in 58 patients. In postoperative CT scans, the screw position was assessed, 89.8% were in a secure position, and 10.2% had malposition. The mean operation time per screw was 21.18 min and the mean fluoroscopy time per screw was 112 s. There was no evidence of wound infection or iatrogenic neurovascular injury. No reoperation was performed.

Conclusion: Percutaneous iliosacral screws can be placed using the only outlet and inlet fluoroscopic views with comparable radiological and clinical outcomes to the conventional method.

Keywords: Inlet view, Outlet view, Pelvic ring fracture, Percutaneous iliosacral screw, Sacral fracture

INTRODUCTION

Unstable pelvic fractures account for 40% of all pelvic fractures^[11] and roughly 8% of in-hospital mortalities.^[14] The posterior pelvic ring disruption includes the sacral fractures, pure sacroiliac (SI) joint dislocation, fracture-dislocation of the SI joint, and the ilium fractures.^[15] Surgical management of patients with posterior pelvic ring injury is categorized as non-operative,

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open reduction, internal fixation, and percutaneous screw fixation.^[15] Percutaneous iliosacral screw fixation has become the gold standard for surgical stabilization of acute pelvic ring disruptions with unstable posterior pelvic injuries.^[15,21,28] Compared to open surgery, the advantages of this method include a shorter duration of the surgery, less soft-tissue damage, and lower blood loss.^[11,23,30] Percutaneous iliosacral screw fixation provides stability and minimizes deformity, facilitates the patient's mobilization, and improves posterior pelvic ring injuries.^[17,24]

Appropriate fluoroscopic visualization of the posterior pelvic ring is essential for the safe percutaneous iliosacral screw placement.^[33] Low quality of fluoroscopic images and thereby misinterpretation of the osseous anatomy might lead to difficulties like screw malposition or neighboring neurovascular structure injuries.^[3,25,33] A high level of expertise in the surgical procedure is necessary to minimize iatrogenic complications and radiation exposure.^[7,29]

The fluoroscopy technique's significant disadvantages are radiation exposure to the surgical team and patient^[7,21,30] and the restricted sight of the pelvic bone, which may be hampered by intestinal gas and obesity.^[30] Another disadvantage of this technique is that every guidewire movement should be verified from several views.^[7,30] Lateral fluoroscopic imaging is recommended to detect the iliac cortical density, identify the procedure's starting point, and ensure that the screw has not breached the anterior cortical bone.^[27] However, obtaining lateral pelvic imaging can be technically complex, and interpretation of anatomic details might be challenging, especially in obese patients.^[6] To address these problems, the inlet and outlet views have been suggested as alternative fluoroscopic views for the insertion of iliosacral screws.^[4,20] This retrospective study aims to assess the accuracy and safety of iliosacral screw placement using fluoroscopy with only inlet and outlet views in posteriorly unstable pelvic ring injuries and report the radiological and clinical outcome, including complication and screw malposition rate, operative time, and radiation exposure rate of this technique.

MATERIALS AND METHODS

Reviewing our database, patients were included in the study if they were older than 18 years and had undergone percutaneous iliosacral screws fixation due to unstable pelvic ring traumatic fracture between January 2015 and November 2019. Pelvic ring instability was defined as at least one of the following conditions: (1) A break in the anterior and posterior pelvic ring; (2) an extremely misshapen pelvis; (3) a displaced posterior ring injury; and (4) a displaced triradiate fracture. Data of the subjects with any of the following conditions were excluded from the study: (1) Lumbosacral dysplasia and sacral dysmorphism, (2) history of the pelvic girdle neoplasm,

(3) history of seronegative arthropathies, and (4) the previous sacral fracture or lumbosacral dislocation.

The patients' demographic information, such as gender and age, was gathered from the medical records, and postoperative images were reviewed. After explaining the study goals and receiving written informed consent, a postoperative computed tomography (CT) scan was performed for each subject to evaluate the intraosseous screw implantation and reduction of the SI joint and sacral fracture. Pre and postoperative neurological examinations of muscles and dermatomes served by the L4, L5, and S1 roots were obtained retrospectively. The amount of time spent exposed to radiation (fluoroscopy time) per screw and operative time per screw was recorded. All screw misplacements that were outside of the favorable anatomical safe zone were accurately measured and recorded. Early outcome factors were operative and fluoroscopy times, intraoperative loss of blood, and length of hospital stay. Late outcome factors were determined as SI joint pain and radiological outcome. A visual analog scale (VAS) was utilized to measure the pain intensity.

Surgical technique

Patients were positioned on a transparent table in a supine position,^[5,28] and to give better posterior pelvic access, the patient's pelvis was elevated^[5,15,28] using a bolster from the operating room table. The patients could be to the edge of the table to facilitate drill motion when possible. The X-ray captor was positioned above the patient^[29] to minimize magnification. A 2.8-mm guide wire and a 5-mm cannulated drill were used^[5] to prepare the trajectory, and finally, cannulated, partially threaded 7.3 mm screws^[5,18,28] of the appropriate length were inserted. In cases of symphyseal disruption or ramus fracture, after anterior plate fixation or reduction with traction, posterior fixation with an iliosacral screw was performed.^[5] Iliosacral screws were inserted in S2 in cases where it was impossible to insert the screws at S1 due to the comminution of the ilium at the level of S1.

The entire process of insertion of the screw was performed under fluoroscopic control using one C-Arm.^[18] Inlet view was acceptable when the anterior cortex of the S1 body was superimposed on the S2 body, and the double-cortical density of the overlaid vertebral bodies was visualized.^[11,32] Outlet view was acceptable when the superior pubic symphysis was at the level of the S2 foramen, and S1 and S2 sacral foramina were visualized, and also the symphysis was aligned with the spinous processes.^[11,32] The approximate location of the entry point was identified by drawing a line from the anterior superior iliac spine directed perpendicularly to the floor and the second line with the femoral shaft.^[5,11] The intersection of the lines was formed in four quadrants.^[5,11] The posterosuperior quadrant represented the approximate

entry point.^[11,29] The entry point's precise location was initially obtained by acquiring the outlet view for the correct caudocephalad direction [Figure 1], followed by the inlet view for the anteroposterior direction [Figure 2]. After the guidewire is contacted with the ilium's outer table, the surgeon stabilizes its position using a mallet, and inlet and outlet views are obtained again.^[5] The direction of the screw pathway in the iliosacral joint lesion is perpendicular to the joint surface; the trajectory is posterior to anterior and inferior to superior.^[5,11,29] In the sacral fractures, the direction of the screw pathway should be perpendicular to the fracture's axis, and screws are inserted transversely.^[5,11,29] The guidewire is then advanced under C-arm guidance [Figure 3] until about 1 cm or more beyond the midline in the S1 body.^[29] The wire is placed at the inferior half portion on the outlet view between the foramina caudally and the sacral ala's cranial border and the posterior half portion on the inlet

view between ventral and dorsal borders of the sacral ala and S1 body [Figure 4].^[32]

In contrast to SI joint dislocation, screw fixation of a comminuted Zone II sacral fracture does not require compression of the fragments, leading to the nerve roots injury.^[29] For SI joint dislocation, Zone I or III sacral fractures, and non-comminuted Zone II sacral fractures, a washer is inserted, and a partial thread (32-mm thread) screw is utilized.^[5,18,29] However, a full-thread screw is used for comminuted Zone II sacral fractures.^[18] Screws' lengths are usually between 65 and 95 mm, depending on the width of the pelvis^[29] [Figure 5].

Assessments

The primary outcome of interest in this retrospective study was the accurate positioning of iliosacral screws, which were

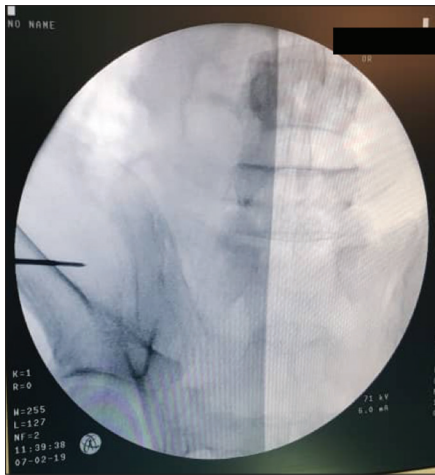


Figure 1: The precise location of the entry point obtained by acquisition of the outlet view.

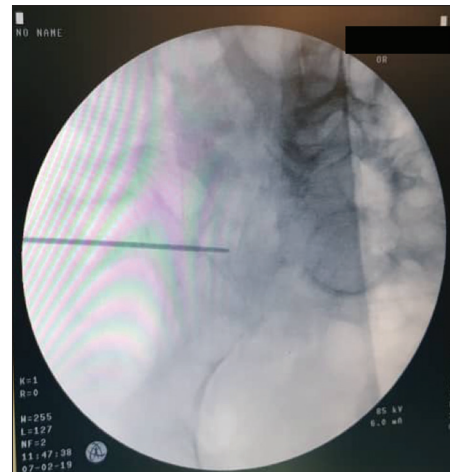


Figure 3: Guidewire advancement under the guidance of the C-Arm.

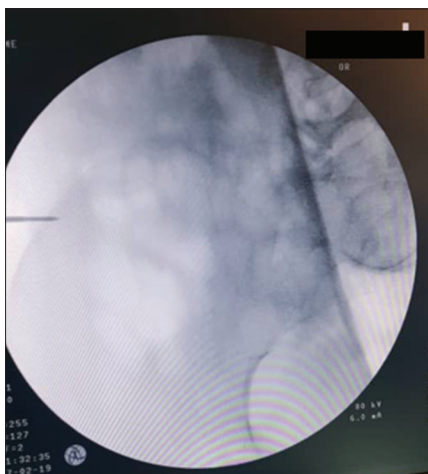


Figure 2: An appropriate inlet view for anteroposterior direction.

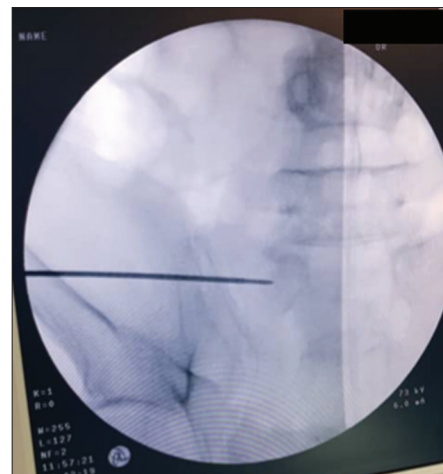


Figure 4: Further guidewire advancement to reach the final position.

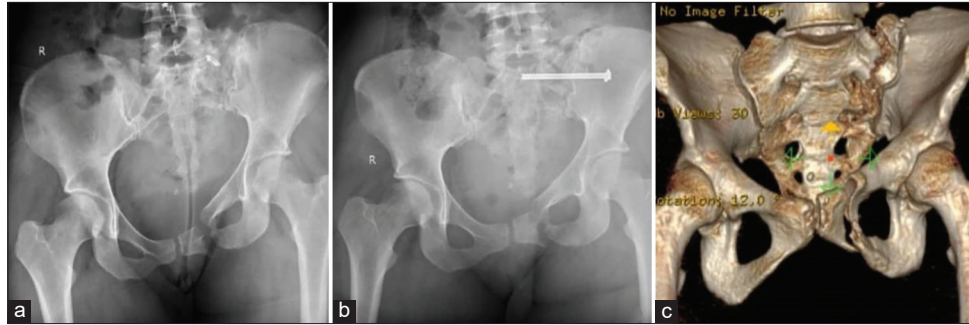


Figure 5: Preoperative (a) and postoperative (b) radiographs and preoperative CT scan with 3D reconstruction (c) of a 29-year-old patient with a left sacral fracture who underwent fixation through percutaneous iliosacral screw insertion.

defined as screws being within the sacrum's cortical margins with no bony perforation or neural foramen hit. The final screw position was measured on a postoperative CT.^[5] Any portion of the screw crossing the cortical margin on any CT reconstruction views^[18] was defined as cortical breach and screw malposition. Furthermore, operative time per screw and fluoroscopy time per screw were recorded. Data of at least 1-year follow-up were reviewed for all the subjects. Clinical consequences were analyzed and reported, including postoperative pain intensity, pain in daily living activities, hardware failure, loss of reduction, non-union, revision surgery, and malposition screw.

Statistical analysis

All analyses were carried out using SPSS, version 25. $P < 0.05$ was considered significant.

RESULTS

Fifty-eight patients underwent fixation with percutaneous iliosacral screw for unstable pelvic injuries between January 2015 and November 2019. This study was conducted on 39 male and 19 female patients with ages ranging from 17 to 64 years (mean = 34). Of the subjects, 22 had iliosacral fracture-dislocations and 36 patients had sacral fractures [Table 1].

Of 69 screws, 62 (89.8%) were in the secure position [Table 2]. Screws with neural foramen hits and extraosseous trajectories in postoperative CT scans were identified. Neural foramen hits occurred in 3 screws (4.3%) and extraosseous dislocation was observed in 4 screws (5.7%). After analyzing each sacral level screw, we found 58 (84%) and 11 (16%) screws in S1 and S2, respectively. We detected cortical breach in 6 (10.3%) of S1 screws and 1 (9%) of S2 screws [Table 3] which was not statistically significant ($P = 0.13$). Reduction of dislocation was achieved in all patients (reduction was defined as <5 mm displacement).

Table 1: Patients' demographics, baseline, and follow-up VAS score.

Patients' demographic	
Number of subjects	58
Age (mean [rang]) (year)	34 (17–64)
Sex (Male/Female)	39/19
No of patients with sacral fracture	36 (62%)
No of patients with iliosacral fracture dislocation	22 (38%)
Follow-up (mean (range)) (months)	23 (14–62)
VAS score (mean, SD)	
At baseline	8.5 (3.1)
1-month postoperatively	3.6 (1.9)
12-month postoperatively	2.4 (1.8)

VAS: Visual Analog Scale, SD: Standard deviation

Table 2: Screws' characteristics according to postoperative computed tomography scans.

Screws' Characteristics (n=69)	Screw in bone (n=62) (%)	Screw with cortical breach (n=7) (%)
Types of screw		
Sacroiliac screw	40 (64.6)	3 (42.8)
Trans-sacral screw	22 (35.4)	4 (57.2)
Screw level		
S1	52 (83.8)	6 (85.7)
S2	10 (16.2)	1 (14.3)

Table 3: The number of perforations in various anatomic areas.

Location	S1	S2
Sacral ala	1	-
S1 foramina	3	-
S1 superior endplate	-	-
Sacrum anterior cortex	1	1
Canal	1	-
Total	6	1

In total, 43 (62.3%) S1 screws and 26 (37.7%) trans-sacral screws were placed [Table 2]. We found cortical breach in

3 (7%) SI screws and 4 (15.3%) trans-sacral screws. This statistically significant difference ($P = 0.03$) indicates that trans-sacral screws might have a higher chance of cortical breach.

Neurological loss, pain intensity, and revision rate were considered secondary outcome measures, including implant failure or breakage and non-union. Neurologic pain occurred in two patients. Severe pain in one of the patients was due to an S1 neural foramen hit, and another patient had neurologic pain while the iliosacral screw was in the proper place. Both of the patients were treated conservatively and no reoperation was performed. We failed to find any intraoperative difficulties or postoperative neurological deficits among the individuals.

The average operational time per screw was 21.18 min (15–72 min) and the mean fluoroscopic time included management of the patient's position on the operating table before the surgery, reduction maneuvers, capturing images for screw placement, and documenting final screw position during the operation was 112 s per screw (range 98–324). The average blood loss during the operation was 54.6 ml and the patients' mean length of stay in the hospital was 3.5 days [Table 4]. We found a mean VAS score of 8.5 for preoperative SI joint and sacral pain, which decreased to 3.6 and 2.4 at 1-month and 12-month postoperatively.

DISCUSSION

Percutaneous iliosacral screw placement is a challenging and technically demanding surgery, mostly due to highly varied pelvic anatomy and screw trajectories.^[16] Due to complex osseous anatomy, obesity, and bowel gas, the iliosacral screw position assessment can be challenging.^[34] Screw malpositioning has been reported to have an incidence between 3 and 17%, with damage to neurons seen in 0–8% of patients.^[5,25,26,34] Sacral dysmorphism, fracture or dislocation mal-reduction, and S2 screw may increase the risk of malposition screw.^[30] The surgeon's experience may influence the iliosacral screw malposition rate.^[8] Verbeek *et al.*^[30] reported that higher operating practice is probably associated with a reduction in malposition rate. In this study, a single surgeon performed all procedures and it was impossible to evaluate the effect of surgical experience on screw malposition rate.

The previous studies compared the screw malposition rate concerning the application of fluoroscopy or computer

navigation. Zwingmann *et al.*^[36] compared three-dimensional fluoroscopically guided computer-navigated surgeries and conventional fluoroscopy and reported correct positioning and revision rate: 81% adequately positioned screws and 1.6% revision rate for the 3D-computer navigation, 42% adequately positioned screws, and 19% revision rate for the conventional fluoroscopy. In another study, Zwingmann *et al.*^[37] revealed a similar rate of intraoperative and postoperative complications with the application of the navigation techniques and the conventional technique. The incidence of screw malpositioning while using conventional fluoroscopy for iliosacral screw placement has been reported to be 32% by Herman *et al.*^[10]. They suggested that for secure screw placement, the proportional screw position cephalad to the superior aspect of the neural foramen should resemble the proportional position posterior to the anterior sacral ala-cortex as closely as possible (within 20%), and this inlet-outlet safe zone definition is superior to the lateral safe zone.^[10] The safe zone for screw insertion, even in the dysmorphic sacrum, was found to be larger than 10 mm.^[13] In a morphological study,^[32] the rate of the partial cut-out of SI screws from the sacral ala slope through inlet and outlet view was 12.5%, 0%, 70%, and 20% in posterosuperior, posteroinferior, anterosuperior, and anteroinferior, respectively. According to this finding, the SI screws should be positioned in the inferior half of the outlet view and the posterior half of the inlet view. In our study, the rate of iliosacral screw malposition using the conventional method was 10.2%, with a comparable success rate reported previously in the literature.^[12]

Correct inlet and outlet views using the intraoperative C-arm necessitate various angles because of variations in the sacral bone anatomy.^[19] Identifying the necessary inlet and outlet view angle can reduce operative time and intraoperative irradiation.^[22,33] Ozmeric *et al.*^[19] studied the optimum inlet angles for iliosacral fixation. They suggested that two different inlet views, inlet anterior and inlet posterior, should be used separately because of the sacrum's conical shape and to evaluate the sacrum's body's borders^[19]. Gusic *et al.*^[9] analyzed 30 pelvic CT scans from individuals of all ages and genders at random and reported that the average angles required to obtain appropriate intraoperative inlet and outlet views were 22.3° (range 10.4–39.8°) and 42.3° (range 31.5–53.1°), respectively. Ricci *et al.*^[22] recommended that the accurate angle for inlet view was 25° when it was 60° for outlet views. In our study, the inlet view was acceptable when radiographs showed the anterior cortex of the S1 body superimposed on the S2 body, and the double-cortical density of the overlaid vertebral bodies was visualized. Outlet view was acceptable when radiographs showed the superior pubic symphysis at the level of S2 foramen and visualization of S1 and S2 sacral foramina. If on the outlet view, the trajectory of the screw is superior to the S1 foramen, and within the alar confines on the inlet view, violation of the anterior or

Table 4: Characteristics of operations and postoperative conditions.

Measure	Mean (Range)
Operative time (Min)	21.8 (15–72)
Fluoroscopy time (Sec)	112 (98–324)
Blood loss (Milliliter)	54.6 (20–85)
Hospital stay (Days)	3.5 (2–7)

posterior neurovascular structures is implausible. To avoid partial cut-out risk, we placed the screw at the inferior half on the outlet view and the posterior half on the inlet view.^[32]

The amount of radiation exposure and operative time in iliosacral screw placement under fluoroscopy guidance is associated with the surgical and fluoroscopic techniques. Appropriate protection use, sparse use of fluoroscopy, systemic approach to screw insertion, preoperative planning, and good communication with the X-ray technician will decrease fluoroscopy shots and operating time.^[12] Average fluoroscopy time per screw for standard iliosacral screw placement varies between 1.8 and 7.3 min,^[1,2] and average operating time per screw has been reported between 16 and 75 min.^[18,21,31,35] Two fluoroscopes' simultaneous use was reported to provide a faster approach with less exposure to radiation for percutaneous iliosacral screw placement.^[21] Yin *et al.*^[31] studied the percutaneous placement of iliosacral screws under the axial view projection of the S1 pedicle. They found that the median duration from the start of preparation to the first screw insertion was 14 ± 5 min and the respective radiation exposure times were 50 ± 9 s.^[31] Our study measured a fluoroscopic time of 108 ± 12 s per screw and an operating time of 21.18 min. The possibility of lesser radiation exposure to the patient and surgical team and a quicker operating time is two advantages of our fluoroscopic technology. However, comparing fluoroscopic and operating times for percutaneous screw insertion in various studies are challenging due to the variety of pelvic ring injuries, operation settings, and surgeon's experience.

The average preoperative VAS score was 8.5, which decreased to 3.6 and 2.4 at 1- and 12-month postoperative, respectively. Furthermore, no case of wound infection was found in our series. These results are consistent with the previous studies.^[1,2]

Retrospective design and short follow-up might be considered the major limitations of our study. Furthermore, the small sample size of the study and performing the procedures in two different operating rooms and with two different C-Arms might decrease the accuracy of the results. We suggest feasibility studies and measurement of outcomes for future studies while the procedures are done by residents and junior surgeons. Comparison of the outcomes while doing the operation using only one C-Arm or 2 C-Arms should also be addressed in the future studies.

CONCLUSION

In summary, percutaneous iliosacral screw placement with only outlet and inlet fluoroscopic view is a safe, easily obtained, reproducible, and anatomically based technique with comparable clinical and radiological results to other techniques with shorter operating time and lower radiation

exposure than the conventional method. Clear C-arm images and precise evaluation of the images are crucial to avoid possible complications such as malposition screw and neurovascular injuries.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Conflicts of interest

There are no conflicts of interest.

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