

FUNCTIONAL AND RADIOLOGICAL OUTCOMES FOLLOWING ANTERIOR PLATE FIXATION OF UNSTABLE PELVIC RING INJURIES THROUGH THE STOPPA APPROACH

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Abstract

Background: Unstable pelvic ring injuries are complex orthopedic injuries that require accurate reduction and stable fixation to restore pelvic stability and minimize long-term functional disability. The modified Stoppa approach provides direct access to the anterior pelvic ring and may facilitate accurate reduction with reduced soft-tissue dissection. This study evaluated the radiological and functional outcomes of anterior plate fixation through the Stoppa approach in patients with unstable pelvic ring injuries.

Methods: A prospective observational study was conducted in the Department of Orthopaedics, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, from June 2025 to January 2026. Twenty-two adult patients aged 23–61 years with unstable pelvic ring injuries classified according to the Young–Burgess system were included. All patients underwent anterior plate fixation through the Stoppa approach. Radiological outcomes were assessed using Matta’s criteria, while functional outcomes were evaluated using the Merle d’Aubigné–Postel score. Patients were followed clinically and radiologically at predefined postoperative intervals. Postoperative complications were also documented. Statistical significance was considered at a p-value <0.05.

Results: The mean age of the patients was 41 years, with a slight female predominance (55%). Lateral compression injuries were the most common fracture pattern (55%), followed by vertical shear (27%) and anteroposterior compression injuries (18%). Anatomical reduction (<2 mm residual displacement) was achieved in 16 patients (73%), while 6 patients (27%) achieved nearly anatomical reduction (2–4 mm); no patient had poor reduction. At final follow-up, 7 patients (32%) achieved excellent functional outcomes, 12 (55%) achieved good outcomes, and 3 (13%) had fair outcomes. No patient had a poor functional outcome. A statistically significant association was observed between radiological reduction and functional outcome (p=0.04), indicating better functional recovery among patients achieving more accurate fracture reduction.

Conclusion: Anterior plate fixation through the Stoppa approach provides reliable radiological reduction and favorable functional outcomes in appropriately selected patients with unstable pelvic ring injuries. The high rate of anatomical reduction and good-to-excellent functional recovery supports the Stoppa approach as an effective technique for anterior pelvic ring stabilization. Larger studies with longer follow-up are warranted to further establish its long-term efficacy and safety.

Keywords: Unstable pelvic ring injury; Stoppa approach; anterior pelvic ring; plate fixation; Matta criteria; Merle d’Aubigné–Postel score; radiological outcome; functional outcome.

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Introduction

Pelvic ring injuries are serious orthopedic injuries that are commonly associated with high-energy trauma, including motor vehicle collisions, falls from height,

and crush injuries. Disruption of the pelvic ring may involve the anterior and/or posterior osseoligamentous structures and can result in substantial rotational or vertical instability. Because of the proximity of major neurovascular structures and pelvic viscera, these

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injuries may be associated with significant hemorrhage, visceral injury, and considerable morbidity.

The pelvis is a biomechanically complex ring formed by the sacrum and two innominate bones, with stability provided by the pubic symphysis, sacroiliac joints, and strong surrounding ligamentous structures. The direction and magnitude of the traumatic force determine the resulting fracture pattern. The Young–Burgess classification categorizes pelvic ring injuries into lateral compression, anteroposterior compression, vertical shear, and combined mechanisms, whereas the Tile classification emphasizes the degree of rotational and vertical instability. Accurate assessment of the fracture pattern and mechanical stability is essential for determining the appropriate treatment strategy.

Stable pelvic ring injuries may be managed conservatively; however, unstable injuries frequently require operative stabilization to restore pelvic alignment, maintain mechanical stability, facilitate mobilization, and minimize long-term complications such as chronic pain, deformity, gait disturbance, and functional disability. Surgical management may include external fixation, percutaneous fixation, or open reduction and internal fixation depending on the injury pattern and the patient's physiological condition.

Anterior pelvic ring fixation has traditionally been performed through the ilioinguinal approach. Although this approach provides adequate exposure, it requires extensive soft-tissue dissection and may be associated with complications such as vascular or nerve injury, lymphatic complications, wound problems, and prolonged operative time. The modified Stoppa approach, also known as the anterior intrapelvic approach, was introduced as an alternative that provides direct access to the pelvic brim, pubic symphysis, superior pubic rami, and medial pelvic structures through a relatively limited incision.

The Stoppa approach provides excellent visualization of the anterior pelvic ring and allows placement of plates along the pelvic brim, with screws directed into the superior pubic ramus and anterior pelvic structures. This facilitates accurate fracture reduction and stable fixation while potentially reducing soft-tissue dissection compared with the conventional ilioinguinal approach. Evidence from comparative studies and meta-analysis suggests that the modified Stoppa approach may reduce operative time and intraoperative blood loss while providing favorable reduction quality compared with the ilioinguinal approach.

Clinical outcomes reported with the Stoppa approach have also been encouraging. Oh et al. evaluated anterior plate fixation through the Stoppa approach in unstable pelvic ring injuries and reported fracture

union in all patients at a mean of 3.5 months. Anatomical reduction according to the Matta criteria was achieved in 73% of patients, while 27% achieved nearly anatomical reduction. Functional assessment using the Merle d'Aubigné-Postel score demonstrated excellent or good outcomes in 87% of patients. No wound complications or approach-related neurovascular complications were reported in that series.

Despite these advantages, the Stoppa approach is technically demanding and requires careful identification and protection of important neurovascular structures. Complications such as obturator nerve injury, external iliac vessel injury, injury to the corona mortis, peritoneal tears, and other vascular complications have been described. A recent single-institution series reported obturator nerve and vascular injuries as important perioperative complications, particularly in patients with previous abdominal surgery. Therefore, meticulous preoperative planning, knowledge of pelvic anatomy, careful soft-tissue dissection, and appropriate fluoroscopic assessment are essential to achieve satisfactory outcomes.

In view of the increasing use of the Stoppa approach for unstable anterior pelvic ring injuries, evaluation of its radiological and functional outcomes is clinically relevant. The present study therefore aims to assess the functional, radiological, and postoperative outcomes of anterior plate fixation through the Stoppa approach in patients with unstable pelvic ring injuries, with particular emphasis on fracture reduction, union, functional recovery, fixation-related complications, and approach-related morbidity.

Aim

To evaluate the functional, radiological, and clinical outcomes of anterior plate fixation using the Stoppa approach in patients with unstable pelvic ring injuries.

Objectives

1. To assess the quality of fracture reduction following anterior plate fixation through the Stoppa approach using established radiological criteria.
2. To evaluate the time to fracture union following surgical fixation.
3. To assess functional outcomes after surgery using an appropriate validated functional scoring system.

Materials and Methods

This study was conducted in the Department of Orthopaedics, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, from June 2025 to January 2026. The study was designed to evaluate the radiological and functional outcomes following anterior plate fixation through the Stoppa approach in patients with unstable pelvic ring injuries.

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Approval was obtained from the Institutional Ethics Review Board before commencement of the study, and written informed consent was obtained from all participants prior to enrollment. Adult patients aged 23–61 years diagnosed with unstable pelvic ring injuries according to the Young and Burgess classification were included. Patients with fracture patterns involving the region of the iliopectineal eminence and pubic symphysis requiring anterior pelvic ring fixation were considered eligible. Patients with nondisplaced pubic rami fractures, isolated simple pubic symphysis diastasis, or parasymphyseal fractures amenable to alternative fixation techniques were excluded. Patients with significant posterior pelvic ring injuries requiring isolated posterior fixation and those with medical comorbidities contraindicating major surgical intervention were also excluded.

Preoperatively, all patients underwent detailed clinical and radiological assessment. Pelvic ring injuries were classified according to the Young and Burgess classification into lateral compression (LC), anteroposterior compression (APC), vertical shear (VS), and combined injury patterns. Anteroposterior, inlet, and outlet pelvic radiographs were obtained in all patients, supplemented by computed tomography (CT) scanning to accurately determine fracture morphology, displacement, pelvic ring instability, and associated injuries. Baseline demographic and clinical parameters, including age, sex, mechanism of injury, fracture classification, associated injuries, and relevant comorbidities, were documented. All patients underwent surgical fixation under general anesthesia in the supine position on a radiolucent operating table. A Foley catheter was inserted before surgery to decompress the urinary bladder, and prophylactic intravenous first-generation cephalosporin was administered before skin incision. The modified Stoppa approach was used to expose the anterior pelvic ring, allowing visualization of the pubic symphysis, superior pubic ramus, pelvic brim, and iliopectineal region. Following adequate fracture reduction, appropriate anterior pelvic plates were positioned and fixed using screws to achieve stable fixation. Intraoperative fluoroscopy was used to assess reduction, implant position, and screw placement. The wound was irrigated and closed in layers after achieving satisfactory fixation.

Postoperatively, patients received appropriate analgesia and antibiotics, with antibiotic prophylaxis continued for 24 hours. Thromboembolic prophylaxis was provided with low-molecular-weight heparin for four weeks unless contraindicated. Initially, patients were maintained on non-weight-bearing status for approximately six weeks. Partial weight-bearing was subsequently initiated between 6 and 8 weeks

depending on clinical and radiological evidence of fracture healing, with progression to full weight-bearing by approximately 12 weeks after confirmation of adequate union and pelvic stability. Early hip and lower-limb range-of-motion exercises were initiated within 48 hours after surgery, followed by progressive muscle-strengthening exercises after six weeks. Patients were followed clinically and radiologically at 3 weeks, 6 weeks, 3 months, and 6 months postoperatively.

Radiological outcomes were assessed using Matta's criteria based on residual displacement of the pelvic ring. Reduction was classified as anatomical when residual displacement was less than 2 mm, nearly anatomical when displacement was 2–4 mm, and poor when displacement exceeded 4 mm. Serial AP, inlet, and outlet pelvic radiographs were evaluated to assess maintenance of reduction, implant position, fracture healing, and any loss of fixation or postoperative displacement. Functional outcomes were assessed using the Merle d'Aubigné-Postel score, which evaluates pain, mobility, and walking ability, with a maximum score of 18 points. Scores of 18 were considered excellent, while progressively lower scores indicated good, fair, or poor functional outcomes. Postoperative complications, including surgical-site infection, wound complications, neurovascular injury, thromboembolic events, implant failure, loss of reduction, delayed union, nonunion, and reoperation, were documented throughout the follow-up period.

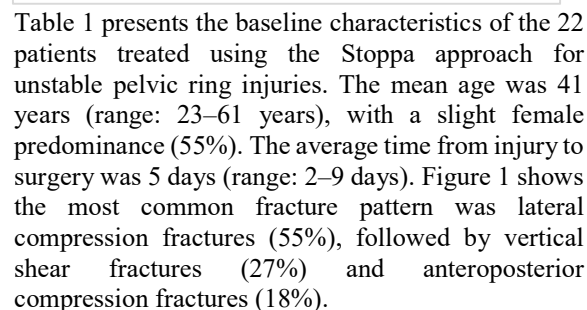
Statistical Analysis

Data were entered into Microsoft Excel and analyzed using appropriate statistical software. Continuous variables such as age, operative time, intraoperative blood loss, hospital stay, time to radiological union, and functional scores were expressed as mean $\pm$ standard deviation (SD) for normally distributed data and as median with interquartile range when appropriate. Categorical variables such as sex, fracture classification, quality of reduction, union status, functional outcome categories, and postoperative complications were expressed as frequencies and percentages. The distribution of continuous variables was assessed using the Shapiro–Wilk test. Comparisons of functional scores and radiological parameters at different follow-up intervals were performed using repeated-measures analysis of variance (ANOVA) for normally distributed data or the Friedman test for non-parametric data. Associations between categorical variables were evaluated using the chi-square test or Fisher's exact test, as appropriate. A two-sided p-value <0.05 was considered statistically significant.

Result:

Baseline Characteristics of Study Participants

Variable	Value
Mean age (years)	41 (range: 23–61)
Gender	Male: 10 (45%)
	Female: 12 (55%)
Time from injury to surgery (days)	5 (range: 2–9)



Radiological Outcome	Frequency	Percentage	p-value
Complete	10	100	0.0001
Partial	5	100	0.0001
No response	0	0	0.0001

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acem ent)			
Poor redu ction (>4 mm displ acem ent)	0	0%	

Table 2 shows the radiological outcomes assessed using Matta's method. Out of 22 patients, 16 (73%) achieved anatomical reduction (<2 mm displacement), while 6 (27%) had nearly anatomical reduction (2–4 mm displacement). There were no cases of poor reduction (>4 mm displacement). A chi-square test showed a statistically significant relationship between radiological outcomes and functional recovery ($p = 0.03$), suggesting that anatomical reductions are more likely to result in better functional outcomes compared to nearly anatomical reductions.

Functional Outcomes by Merle d'Aubigne-Postel Score

Function al Outco me	Sco re Ra nge	Frequ ency (n=22)	Perce ntage (%)	p- val ue
Excell ent	18 poi nts	7	32%	0.04 *
Good	15– 17 poi nts	12	55%	
Fair	12– 14 poi nts	3	13%	
Poor	<12 poi nts	0	0%	

Table 3 presents functional outcomes according to the Merle d'Aubigne-Postel score. At the 16-month follow-up (range: 10–51 months), 32% of patients (7

out of 22) achieved excellent scores (18 points), while 55% (12 patients) scored in the good range (15–17 points). 13% (3 patients) had fair outcomes (12–14 points), and no patients recorded poor outcomes (<12 points). A statistically significant relationship was observed between functional outcomes and the type of radiological reduction ($p = 0.04$), emphasizing that better fracture reduction correlated with higher functional scores.

Correlation Between Radiological and Functional Outcomes

Radi ologi cal Outc ome	Goo d to Exc elle nt Fun ctio nal Out com es (n= 19)	F a i r F u n c t i o n a l O u t c o m e s (n = 3)	p - v a l u e
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Anat omic al redu ction	15	1	
Near ly anat omic al	4	2	0.03*

Table 4 illustrates the relationship between radiological and functional outcomes. Out of 16 patients with anatomical reductions, 15 (94%) had good to excellent functional outcomes compared to 4 out of 6 patients (67%) with nearly anatomical reductions. A chi-square test revealed a significant correlation between anatomical reductions and superior functional outcomes ($p = 0.03$), highlighting that achieving anatomical reduction is critical for optimal recovery.

Discussion

The present study evaluated the radiological and functional outcomes of anterior plate fixation through the Stoppa approach in 22 patients with unstable pelvic ring injuries. The mean age of the study population was 41 years, with patients ranging from 23 to 61 years, and there was a slight female predominance (55%). The mean interval between injury and surgery was 5 days. The relatively short interval to definitive fixation reflects the importance of restoring pelvic stability once the patient's general condition permits surgery. Early and stable fixation can facilitate mobilization, reduce complications associated with prolonged immobilization, and improve functional recovery in appropriately selected patients.

In the present series, lateral compression injuries constituted the most common fracture pattern (55%), followed by vertical shear injuries (27%) and anteroposterior compression injuries (18%). The distribution highlights the heterogeneous nature of unstable pelvic ring injuries and the importance of preoperative imaging for determining the fracture morphology and selecting an appropriate fixation strategy. The Young–Burgess classification remains useful because it relates the observed fracture pattern to the mechanism of injury and provides a framework for understanding the degree and direction of pelvic instability.

A major finding of this study was the high rate of satisfactory radiological reduction. Anatomical

reduction, defined as less than 2 mm residual displacement according to Matta's criteria, was achieved in 16 patients (73%), while the remaining six patients (27%) achieved nearly anatomical reduction. Importantly, no patient had poor reduction. These findings suggest that the Stoppa approach provides adequate visualization of the anterior pelvic ring and facilitates accurate reduction and stable plate fixation. The approach allows direct access to the pubic symphysis, superior pubic ramus, pelvic brim, and quadrilateral surface while avoiding some of the extensive dissection associated with the ilioinguinal approach.

The radiological results of the present study are comparable with previously published clinical experience. Oh et al. reported anatomical reduction in approximately 73% of patients undergoing anterior pelvic fixation through the Stoppa approach, with the remaining patients achieving nearly anatomical reduction. They also reported satisfactory fracture union and favorable functional outcomes, supporting the effectiveness of this approach for unstable pelvic ring injuries. The absence of poor reduction in the current series is particularly encouraging because residual pelvic displacement has been associated with persistent pain, altered gait mechanics, and inferior functional recovery.

Functional assessment using the Merle d'Aubigné–Postel score demonstrated favorable outcomes. Seven patients (32%) achieved an excellent score of 18 points, while 12 patients (55%) achieved good scores of 15–17 points. Only three patients (13%) had fair functional outcomes, and none had a poor score. Thus, 87% of patients achieved good-to-excellent functional results. The statistically significant association between radiological reduction and functional outcome ($p=0.04$) indicates that restoration of pelvic anatomy may contribute substantially to functional recovery. Similar relationships between quality of reduction and postoperative function have been described in pelvic and acetabular fracture literature.

The Stoppa approach also has potential advantages over the traditional ilioinguinal approach, including reduced soft-tissue dissection and direct visualization of important anterior pelvic structures. Comparative evidence suggests that the modified Stoppa approach may be associated with shorter operative time and reduced blood loss while achieving comparable or superior reduction quality in selected injuries. Nevertheless, the technique is not without complications. The obturator nerve, external iliac vessels, corona mortis, and urinary bladder are vulnerable during exposure, emphasizing the need for detailed anatomical knowledge and meticulous surgical technique.

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Overall, the present findings indicate that anterior plate fixation through the Stoppa approach provides reliable anatomical reduction and favorable functional recovery in appropriately selected patients with unstable pelvic ring injuries. The high proportion of anatomical or nearly anatomical reductions and the predominance of good-to-excellent functional outcomes support the use of this approach as an effective method for anterior pelvic ring stabilization.

Conclusion

The present study demonstrates that anterior plate fixation through the Stoppa approach provides favorable radiological and functional outcomes in patients with unstable pelvic ring injuries. Anatomical reduction was achieved in 73% of patients, while the remaining 27% achieved nearly anatomical reduction, with no cases of poor reduction. Functionally, 87% of patients achieved good-to-excellent outcomes according to the Merle d'Aubigné-Postel score, and no patient had a poor functional outcome. The significant association between quality of radiological reduction and functional recovery emphasizes the importance of achieving accurate anatomical restoration of the pelvic ring. Overall, the Stoppa approach provides adequate exposure for precise reduction and stable anterior plate fixation while allowing satisfactory functional recovery. It can therefore be considered an effective surgical approach for appropriately selected patients with unstable pelvic ring injuries. Further studies with larger sample sizes and longer follow-up are recommended to validate these findings.

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