

## Full length article

# Midterm radiologic and functional outcomes of minimally-invasive fixation of unstable pelvic fractures using anterior internal fixator (INFIX) and percutaneous iliosacral screws



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## ABSTRACT

**Background:** Anterior pelvic external fixation is associated with pin site infections, aseptic loosening with loss of reduction, frame bulkiness hindering patient mobilization and consequent difficulties in inpatient nursing. We performed a single-center prospective series to evaluate the feasibility, safety, limitations and midterm radiologic and functional outcomes of an alternative minimally invasive pelvic internal fixation technique using an anterior subcutaneous pelvic internal fixator (INFIX) and percutaneous iliosacral screws in unstable pelvic ring fractures.

**Methods:** Fifteen consecutive patients with vertically and/or rotationally unstable pelvic fractures, presenting to a Level-1 trauma center were treated with closed reduction, appropriate posterior stabilization with percutaneous iliosacral screws and anterior INFIX application. Outcomes were analyzed with respect to the quality of fracture reduction (Matta's radiologic criteria), ease of inpatient nursing, patient mobility and comfort, functional outcomes at final follow-up (Majeed score, SF-12 score), social reintegration and complications.

**Results:** Most common injury pattern was AO/OTA type 61-C pelvic fracture in thirteen patients. Mean procedure time and intra-operative blood loss were, 57.1+/-4.9 min (range, 51–68 min) and 115.3 +/–26.7 ml (range, 80–170 ml) respectively. Mean follow-up was 34.9+/-4.1 months (range, 31–42 months). Fracture reduction was excellent in twelve and good in three patients (Matta's criteria). Functional outcomes were excellent in eight and good in seven patients (Majeed score). Mean SF-12 scores for physical and mental health were 48.58+/-5.61 and 50.89+/-3.97 respectively. Thirteen patients returned to their pre-injury jobs. All fifteen patients reintegrated into society without any restrictions. INFIX was removed at a mean post-operative period of 7.3+/-1.5 months (range, 5.5–11 months). Complications included, lateral femoral cutaneous nerve irritation (n=1), superficial wound infection (n=1) and loss of reduction (n=2).

**Conclusion:** Minimally invasive pelvic stabilization using INFIX and percutaneous iliosacral screws is easy to learn and apply, achieves good fracture reduction and definitive stabilization with minimum complications and offers excellent functional outcomes at a minimum follow-up of 31 months.

**Level of evidence:** Level IV.

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## 1. Introduction

High energy pelvic fractures often disrupt the integrity of the anterior and/or posterior osteoligamentous structures, thereby resulting in vertical or rotational instability of the pelvic ring. Early

restoration of the structural integrity and stability of the pelvic ring is imperative to normalize the patient's acute physiology and to allow for early restoration of mobility and function. While posterior pelvic ring stability is typically restored by open or percutaneous methods, percutaneous fixation with cannulated iliosacral screws is now popular as it offers less blood loss, shorter operative times and fewer surgical wound complications compared to open techniques.<sup>1–9</sup> Concurrent anterior stabilization significantly improves biomechanical stability and can be performed as a temporary or definitive procedure. Definitive anterior

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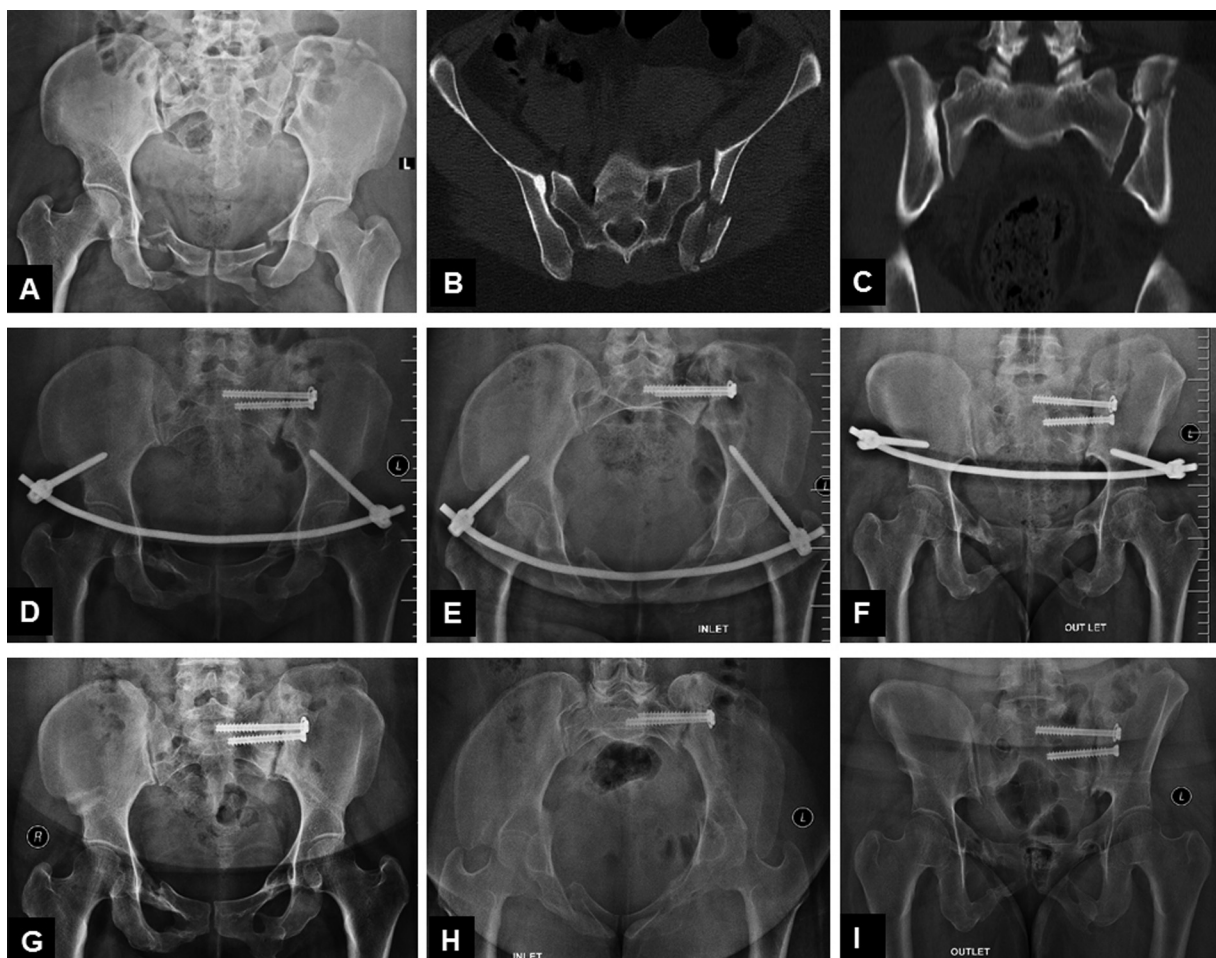
pelvic ring osteosynthesis has traditionally been performed with open plating, transamus intraosseous screws, or external fixation. **1** Open reduction and internal fixation (ORIF) of comminuted unstable anterior ring fractures is associated with excessive soft tissue damage resulting in increased incidence of surgical site infection and wound complications, risk of neurovascular injury, injury to bladder and spermatic cord, surgical site hernia and implant failure.<sup>1</sup> Anterior external fixation has been used temporarily in damage control scenarios, to rapidly stabilize an unstable pelvic ring with restoration of hemodynamic stability, although their application can be made definitive in combination with posterior fixation.<sup>10–13</sup> It is associated with several complications including pin site infections, osteomyelitis, aseptic loosening with loss of reduction, frame bulkiness hindering hip flexion with limitation in patient mobilization, difficulties in nursing care, and hindrance to wound access or surgical access to abdomen.<sup>14–16</sup> As an alternative to traditional external fixation, Vaidya et al. in 2012, described a novel anterior subcutaneous internal fixation device, “INFIX” for stabilizing unstable pelvic fractures using the established principles of anterior external fixation. The INFIX involves insertion of supra-acetabular spinal pedicle screws connected by a contoured subcutaneous rod.<sup>17</sup> Biomechanical studies have shown that the INFIX has superior

stability to external fixation in the management of vertically and rotationally unstable pelvic ring injuries.<sup>18–20</sup> We evaluated the merits, limitations, outcomes and complications of this minimally invasive technique in unstable pelvic fractures.

## 2. Methods

An Institutional Review Board approved, single-center prospective clinical series was performed on patients who presented to a Level-1 trauma center between January 2013 and February 2014. All patients were treated as per ATLS (Advanced Trauma Life Support) protocol. GCS (Glasgow Coma Scale) score, ISS (Injury Severity Score) and serum lactate levels were recorded. All patients underwent a detailed neurological examination and a complete radiological evaluation including anteroposterior, pelvic inlet and outlet views and computed tomography (CT) scan of pelvis.

None of our patients received INFIX as an emergency procedure for pelvic tamponade and restoration of hemodynamic instability. In patients with hemodynamic instability resulting from pelvic ring injury, emergent pelvic tamponade and stabilization was accomplished with an anterior external fixator as a “damage control” procedure. Conversion of external fixator construct was carried out once the patient’s physiology became stable and serum



**Fig. 1.** Anteroposterior plain radiograph (A), axial (B) and coronal (C) CT scan images of pelvis demonstrating a left sacroiliac joint fracture-dislocation with complete instability and displacement of left hemipelvis, with concomitant bilateral superior and inferior pubic rami fractures. Post-operative plain radiographs – anteroposterior (D), inlet (E) and outlet (F) views of pelvis at 5 months showing healing of anterior and posterior pelvic ring fractures. Plain radiographs – anteroposterior (G), inlet (H) and outlet (I) views of pelvis taken after implant (INFIX) removal at 6 months showing healed anterior and posterior pelvic ring fractures with good maintenance of reduction.

lactate levels normalized. Hemodynamically stable patients with normal serum lactate levels at presentation, underwent elective primary pelvic stabilization with percutaneous iliosacral screws and anterior INFIX.

The indication for use of INFIX was to restore the integrity and stability of anterior pelvic ring, in an unstable posterior pelvic ring fracture associated with *additional anterior ring disruption (pubic rami fractures and symphyseal disruption)*, which required stabilization: 1) vertically unstable injuries (AO/OTA type 61-C), 2) lateral compression injuries (AO/OTA type 61-B2), 3) open book injuries (AO/OTA type 61-B3.1).

Our exclusion criteria were open fractures, poor skin condition or infection in the surgical area of INFIX application, surgical site hernias, insufficiency fractures in elderly, history of conservatively or surgically treated pelvic fractures and fractures presenting late when closed reduction was not possible.

## 2.1. Surgical technique

Sacroiliac disruption/sacral fracture was addressed first using the standard iliosacral

reduction techniques and percutaneous iliosacral screw osteosynthesis using 6.5mm-diameter cancellous screws ranging from 60 mm to 100 mm in length.<sup>1–3</sup> Anterior pelvic ring stability was then restored by application of INFIX using the technique described by Vaidya et al.<sup>17</sup> Through a 3 cm vertical incision centered on anterior inferior iliac spine (AIIS), the entry point on the AIIS was approached by meticulous dissection through the interval between sartorius and tensor fascia lata (TFL), taking utmost care to protect the lateral femoral cutaneous nerve (LFCN). We used 7-mm-diameter polyaxial pedicle screws of 70–100 mm length, with at least 50–60 mm of screw being intraosseous and 20–40 mm outside the bone, depending on the habitus of the patient. We ensured the pedicle screw head remained above the

**Table 1**  
Demographic profile, mechanism of injury, fracture classification and associated injuries.

Case No.	Age	Gender	Mode of injury	Mechanism of injury (Young-Burgess Classification) <sup>#</sup>	Type of Pelvic fracture (AO/OTA Classification) <sup>£</sup>	Associated injuries	Neurology
1	51	Male	RTA (motorcycle crash)	VS <sup>\$</sup>	61-C1.2	No	Normal
2	33	Female	Fall of heavy object	VS	61-C1.1	No	Normal
3	29	Male	RTA (4-wheeler crash)	VS	61-C1.1	Splenic rupture, laceration of right kidney, right ulna fracture, Grade III B compound fracture of both bones of left leg, medial wall and anterior column fracture of right acetabulum	Normal
4	47	Female	Fall from height	VS	61-C1.3	Burst fracture of D12 vertebral body with neurodeficit, hemoperitoneum	ASIA C neurology
5	53	Female	RTA (motorcycle crash)	VS	61-C1.1	No	Normal
6	66	Male	RTA (pedestrian vs 4-wheeler)	VS	61-C1.2	Head injury (hemorrhagic contusion in right parietal and occipital lobe), right maxilla and zygoma fracture, fracture of right orbit	Normal
7	22	Female	RTA (motorcycle crash)	VS	61-C1.2	Lung contusion, retroperitoneal hemorrhage	Normal
8	48	Female	Fall from height	VS	61-C1.3	Left tibial pilon fracture and trimalleolar ankle fracture	Normal
9	27	Female	RTA (motorcycle crash)	VS	61-C1.2	Bilateral clavicle fracture, right glenoid fracture	Normal
10	39	Female	RTA (4-wheeler vs motorcycle collision)	VS	61-C1.2	Head injury (hemorrhagic contusion of right temporal lobe and right capsuloganglionic region with midline shift), multiple rib fractures with hemopneumothorax, fracture of both bones of right forearm, right scapula fracture, posterior dislocation of right hip with right femoral head fracture, posterior wall fracture of right acetabulum	Normal
11	33	Male	Fall of heavy object	VS	61-C1.2	No	Normal
12	31	Male	RTA (motorcycle crash)	VS	61-C1.2	Retroperitoneal hemorrhage, epidural hematoma from L2 to L4 level with neurodeficit	Right L2, L3, L4, L5, S1, MRC grade 2 power
13	34	Male	RTA (motorcycle crash)	VS	61-C1.2	Retroperitoneal hemorrhage	Normal
14	26	Male	RTA (4-wheeler vs 4-wheeler collision)	APC 2 <sup>\$</sup>	61-B3.1	Blowout fracture of left orbit, maxilla fracture, C7, T1 spinous process fracture, left femoral shaft fracture, trimalleolar fracture of left ankle	Normal
15	27	Male	Fall from height	LC 1 <sup>\$</sup>	61-B2.1	Anterior column fracture of right acetabulum	Normal

<sup>#</sup>Burgess AR, et al. Pelvic ring disruptions: effective classification system and treatment protocols. J Trauma 1990;30(7):848–56.

<sup>£</sup>Marsh JL, Slong TF, Agel J, et al. Fracture and Dislocation Classification Compendium 2007: Orthopaedic Trauma Association Classification, Database and Outcomes Committee. J Orthop Trauma. 2007;21 Supplement 10 pp: S1-S163.

<sup>\$</sup>-LC = lateral compression, APC = anteroposterior compression, VS = vertical shear.

\*MRC – Medical Research Council grading of muscle power.

deep fascia, to avoid compression on the femoral nerve and inguinal ligament. A 5.7-mm pre-contoured titanium rod was tunneled subcutaneously, connected to pedicle screw heads and locked at one end. Reduction of the anterior pelvic ring injury was achieved by compression or distraction over rods as appropriate, prior to locking of the remaining screw head. Quality of reduction and implant position were confirmed on fluoroscopic anteroposterior, inlet and outlet views.

## 2.2. Postoperative protocol

The operative time, intraoperative blood loss and complications were recorded. All patients received antithrombotic prophylaxis for 6 weeks. Ease of nursing, patient mobility and comfort were observed during hospital stay. Patients could sit up from second day onwards depending on their general condition, associated injuries, functional status and pain tolerance.

## 2.3. Follow-up

Patients were followed up at monthly intervals for the first three months, bimonthly up to one year, quarterly till two years and biannually thereafter. At each follow-up, patients' general condition, VAS scores, a detailed neurological examination, including the femoral nerve and LFCN, ease of mobility during daily activities, quality of reduction and implant position on radiographs (anteroposterior, inlet and outlet views of pelvis) [Fig. 1] and complications (if any) were assessed. The quality of fracture reduction was evaluated according to Matta's radiologic criteria.<sup>21</sup>

Patients were allowed toe-touch walking at 2–4 weeks, partial weight bearing at 6–8 weeks and full weight bearing at 8–10 weeks, post-surgery. Removal of INFIX device was planned once the fracture showed radiological signs of healing. Functional outcomes and return to work status were assessed using Majeed score (excellent: score of 95 or more, good: 85–94, fair: 70–84,

**Table 2**  
Operative details of minimally invasive internal fixation of unstable pelvic ring injuries using INFIX and percutaneous iliosacral screws.

Case No.	Type of Pelvic fracture (AO/OTA Classification)	Anterior external fixator application as damage control procedure	Duration from injury to surgery (days)	Surgical procedure	Duration for INFIX application (min)	Duration for percutaneous iliosacral screw fixation (min)	Duration for combined procedure (min)	Blood loss (ml)	Intra-operative fracture reduction
1	61-C1.2	Yes	6	INFIX + percutaneous iliosacral screw fixation	26	26	52	130	Good
2	61-C1.1	No	10	INFIX + percutaneous iliosacral screw fixation	28	23	51	120	Good
3	61-C1.1	Yes	12	INFIX + percutaneous iliosacral screw fixation	33	25	58	100	Good
4	61-C1.3	No	2	INFIX + percutaneous iliosacral screw fixation	37	31	68	140	Good
5	61-C1.1	Yes	8	INFIX + percutaneous iliosacral screw fixation	30	32	62	170	Good
6	61-C1.2	No	8	INFIX + percutaneous iliosacral screw fixation	29	28	57	150	Good
7	61-C1.2	No	6	INFIX + percutaneous iliosacral screw fixation	27	25	52	100	Fair
8	61-C1.3	No	9	INFIX + percutaneous iliosacral screw fixation	26	27	53	80	Good
9	61-C1.2	Yes	4	INFIX + percutaneous iliosacral screw fixation	29	31	60	120	Good
10	61-C1.2	No	5	INFIX + percutaneous iliosacral screw fixation	32	26	58	90	Good
11	61-C1.2	No	3	INFIX + percutaneous iliosacral screw fixation	30	35	65	110	Good
12	61-C1.2	Yes	5	INFIX + percutaneous iliosacral screw fixation	29	24	53	140	Good
13	61-C1.2	No	0	INFIX + percutaneous iliosacral screw fixation	33	23	56	80	Fair
14	61-B3.1	Yes	6	INFIX + percutaneous iliosacral screw fixation	31	25	56	110	Good
15	61-B2.1	No	7	INFIX + percutaneous iliosacral screw fixation	29	27	56	90	Good

poor: <70).<sup>22</sup> General health-related quality of life was assessed using SF-12 questionnaire.<sup>23</sup>

### 3. Results

#### 3.1. Demographic profile and injury patterns

Fifteen patients (8 males, 7 females) with a mean age of 37.7  $\pm$  12.5 years (range, 22–66 years) were included in the study. The most common mode of injury was road traffic accident (RTA) followed by fall from height (Table 1). The mean ISS and GCS at presentation were 26.2  $\pm$  1.8 points and 13.8  $\pm$  3.3 points respectively. The most common injury pattern according to AO/OTA classification was vertically unstable (AO/OTA type 61-C) pelvic fracture seen in 13 cases, while there was one case of anteroposterior compression injury (AO/OTA type 61-B3) and one case of lateral compression injury (AO/OTA type 61-B2) (Table 1).

Five patients had medical comorbidities [(diabetes mellitus (n = 3) and hypertension (n = 2)], at presentation.

#### 3.2. Associated injuries

The most common associated injuries were extremity fractures followed by abdominal injuries [retroperitoneal hemorrhage (n = 3), hemoperitoneum (n = 1), splenic rupture (n = 1), kidney laceration (n = 1)], spine injuries (n = 3), head injury (n = 3) and chest injuries (1 case of hemopneumothorax, 1 case of lung contusion) in that order. Two patients had neurological deficit at presentation due to associated spinal injuries (Table 1).

#### 3.3. Operative considerations (Table 2)

Overall, 6/15 patients required temporary anterior external fixation as damage control procedure, which was converted to

**Table 3**

Outcomes and complications of minimally invasive stabilization of unstable pelvic ring injuries using INFIX and percutaneous iliosacral screws.

Case No.	Surgical procedure	Implant removal done at(months)	Duration of follow-up (months)	Complications		Functional outcome (Majeed score)	Quality of life measure (SF-12)		Return to work
							PCS	MCS	
1	INFIX + percutaneous iliosacral screw fixation	7	31	Nil		92 (good)	48.53	49.91	Same job with reduced performance Returned to pre-injury job
2	INFIX + percutaneous iliosacral screw fixation	7	38	Nil		96 (excellent)	50.15	49.91	
3	INFIX + percutaneous iliosacral screw fixation	7.5	31	Screw loosening which needed revision. Loss of reduction (residual pubic diastasis of 7 mm)		92 (good)	40.91	46.34	Returned to pre-injury job
4	INFIX + percutaneous iliosacral screw fixation	11	40	Nil		90 (good)	42.45	48.63	Returned to pre-injury job
5	INFIX + percutaneous iliosacral screw fixation	8	42	UTI (Pseudomonas aeruginosa) leading to superficial surgical (INFIX)site infection-Resolved with 2 weeks of intravenous antibiotics. Loss of reduction with residual vertical displacement Unilateral anterolateral thigh paresthesia due to LFCN compression- recovered after removal of implant		85 (good)	40.91	46.34	Change of job
6	INFIX + percutaneous iliosacral screw fixation	5.5	34			94 (good)	53.11	52.6	Returned to pre-injury job
7	INFIX + percutaneous iliosacral screw fixation	8.5	32	Nil		96 (excellent)	54.94	57.12	Returned to pre-injury job
8	INFIX + percutaneous iliosacral screw fixation	Not opted for removal	41	Nil		96 (excellent)	51.49	52.71	Returned to pre-injury job
9	INFIX + percutaneous iliosacral screw fixation	6	39	Nil		95 (excellent)	53.11	52.6	Returned to pre-injury job
10	INFIX + percutaneous iliosacral screw fixation	6	37	Nil		97 (excellent)	52.84	49.74	Returned to pre-injury job
11	INFIX + percutaneous iliosacral screw fixation	Not opted for removal	32	Nil		95 (excellent)	53.85	59.57	Returned to pre-injury job
12	INFIX + percutaneous iliosacral screw fixation	7	33	Nil		86 (good)	40.91	46.34	Change of job
13	INFIX + percutaneous iliosacral screw fixation	7.5	32	Nil		95 (excellent)	53.11	52.6	Returned to pre-injury job
14	INFIX + percutaneous iliosacral screw fixation	6.5	31	Nil		92 (good)	40.91	46.34	Returned to pre-injury job
15	INFIX + percutaneous iliosacral screw fixation	Not opted for removal	31	Nil		97 (excellent)	51.49	52.71	Returned to pre-injury job



INFIX after restoring hemodynamic stability. Nine patients received primary definitive INFIX and iliosacral screw fixation. The mean injury-to-surgery interval was  $6.1 \pm 3.1$  days (range, 0–12 days). All fifteen patients had minimally invasive fixation of both anterior and posterior pelvic ring injuries with INFIX and percutaneous iliosacral screws. The mean procedure time for INFIX and percutaneous iliosacral screw fixation were  $29.9 \pm 2.9$  min (range, 26–37 min) and  $27.2 \pm 3.5$  min (range, 23–35 min) respectively. The mean intraoperative blood loss for INFIX procedure was  $115.3 \pm 26.7$  ml (range, 80–170 ml).

### 3.4. Nursing care and patient mobility

Patients could sit, turn in bed, lie on their sides or prone even in the early post-operative period. Hence nursing care was easy, especially in the intensive care unit.

### 3.5. Radiological outcome- status of fracture healing and adequacy of reduction

Fracture healing was seen at a mean post-operative period of 3.5 months (range, 3–6 months). Reduction was excellent in twelve cases and good in three at final follow-up, according to Matta's criteria.<sup>21</sup>

### 3.6. Functional outcomes, social integration and return to work status (Table 3)

The mean follow-up duration was  $34.9 \pm 4.1$  months (range, 31–42 months). No patient was lost to follow-up. Functional outcomes were excellent in eight and good in seven patients, as assessed by Majeed score.<sup>22</sup> Thirteen patients had returned to their pre-injury jobs, while two had to change their jobs involving lighter duties. The mean SF-12 scores for physical health and mental health were  $48.58 \pm 5.61$  and  $50.89 \pm 3.97$  respectively, which was comparable with reference values of normal population. All patients reintegrated into society without any restrictions.

### 3.7. Complications (Table 3)

No intraabdominal/neurovascular injuries were observed in relation to screw insertion or subcutaneous insertion of rod. INFIX was successfully applied in all 15 cases. Minor complications were encountered. One patient had unilateral anterolateral thigh

paresthesia, due to LFCN compression which recovered following implant removal. One patient had early superficial surgical site infection within a week after surgery (probably due to the associated urinary tract infection) which settled with administration of culture specific antibiotics. In 14/15 cases, there were no signs of implant failure such as screw loosening or rod breakage. There was loss of reduction in two patients at follow-up. Heterotopic ossification was not observed in our series.

### 3.8. Implant removal

The INFIX was removed at a mean postoperative period of  $7.3 \pm 1.5$  months (range, 5.5–11 months). No complications were observed during this procedure. Three of our patients who did not opt for implant removal, had no problems till date.

## 4. Discussion

Unstable pelvic fractures often require concurrent stabilization of anterior and posterior pelvic ring. While posterior pelvic ring stability can be satisfactorily restored by closed reduction and percutaneous fixation, concurrent anterior stabilization restores the integrity of the anterior ring and prevents displacement around a posteriorly fixed pelvis. In unstable pelvic fractures with hemodynamic instability resulting from intrapelvic hemorrhage, emergent pelvic tamponade and stabilization can be accomplished with a temporary anterior external fixator as a “damage control” procedure which may later be converted to a definitive form of internal fixation.<sup>24,25</sup> ORIF of comminuted anterior pelvic ring fractures is associated with extensive soft tissue damage and increased incidence of surgical site infection and wound complications, risk of neurovascular and visceral injury, surgical site hernia and implant failure.<sup>1</sup> Definitive anterior external fixation is preferred in certain clinical scenarios such as in the presence of urological injuries, presence of a suprapubic catheter, displaced but vertically stable lateral compression fractures, multiple comminuted pubic rami fractures, refractory coagulopathy, and open pelvic fractures, among others.<sup>10–13</sup>

But, anterior external fixation is associated with several complications including pin site infections (2–50%), osteomyelitis (0–7%), aseptic loosening (0–19%), loss of reduction (0–33%), frame bulkiness hindering patient mobilization, difficulties in nursing care, and hindrance to wound access or surgical access to abdomen.<sup>14–16</sup> To overcome the complications of anterior external fixation, to

**Table 4**

A comparison of results of INFIX procedure with published studies.

Author (Year)	Study design (number of cases)	Predominant pelvic fracture type	Mean duration of follow-up	Mean Procedure time (min)	Intraoperative blood loss (mL)	LFCN palsy	Infection rate	Loss of reduction	Heterotopic ossification	Mean Implant removal time (in months, postoperatively)
Vaidya et al. <sup>17</sup>	Prospective series (24)	VS injury	19 months	–	–	2/24	Nil	Nil	Nil	5.4 months
Vaidya et al. <sup>35</sup>	Retrospective review (91)	VS injury	15 months	–	–	27/91	3/91	3/91	32/91	3–6 months
Gardner et al. <sup>33</sup>	Prospective series (24)	VS injury	12 months	–	–	2/24	Nil	Nil	6/24	4 months (2–8 months)
Muller et al. <sup>30</sup>	Retrospective analysis (31)	VS injury	4.5 years	–	–	6/31	2/31	1/31	9/31	9.4 months (27 days–40.2 months)
Scheyerer et al. <sup>28</sup>	Case report (4)	LC injury	Short term	50	–	Nil	Nil	Nil	1/4	3–4 months
Hoskins et al. <sup>31</sup>	Prospective series (21)	LC injury	342 days	51	–	12/21	3 out of 42 screws	–	9/21	3.6 months
Present study (2017)	Prospective series (15)	VS injury	34.9 months (all patients had a minimum follow-up of 31 months)	$57.1 \pm 4.9$	$115.3 \pm 26.7$	1/15	1/15	2/15	Nil	7.4 months (5.5–11 months)

improve patient comfort and facilitate early mobilization, several innovative techniques of minimally invasive anterior pelvic ring stabilization have been described in recent years.<sup>17,26–34</sup>

The “INFIX” is one such technique which utilizes the already established principles of external fixation. Biomechanical studies have shown that the INFIX has superior stability with respect to axial stiffness and stiffness at pubic symphysis, in the management of vertically and rotationally unstable pelvic ring injuries.<sup>18–20</sup>

The indications for use of INFIX has expanded since its initial description. Majority of fractures in our series were AO/OTA type 61-C injuries, similar to three other studies.<sup>17,30,33</sup> In the largest series published by Vaidya et al., INFIX was used to treat lateral compression fractures, anteroposterior compression fractures, vertical shear or combined fracture patterns.<sup>35</sup> Hoskins et al. used INFIX for lateral compression and anteroposterior compression fractures.<sup>31</sup> Scheyerer et al. used minimally invasive INFIX as an alternative to external fixation/anterior plating, in pelvic fractures with concomitant abdominal injuries necessitating multiple abdominal surgeries.<sup>28</sup> Recently, INFIX has also been used in cases of open pelvic injuries.<sup>36</sup>

We addressed posterior ring instability first similar to the case series reported by Vaidya et al. and Hoskins et al.<sup>17,31</sup> On the other hand, Gardner et al. performed anterior fixation prior to posterior fixation.<sup>33</sup> Our mean procedure time of 57.1+/-4.9 min (range, 51–68 min) for combined procedure was slightly longer than those of Hoskins et al. and Scheyerer et al. who averaged an operative time of 50 min and 51 min respectively.<sup>28,31</sup> The mean intraoperative blood loss of 115.3 ml+/-26.7 ml (range, 80–170 ml) was much less than other open methods of anterior pelvic ring osteosynthesis.

One main advantage of this procedure was the ease of nursing patients especially in the ICU setting due to the subcutaneous nature of the frame which facilitated easy patient mobilization and wound care. Six of our patients were polytrauma victims who had a mean ICU stay of 10.5 (range, 4–12) days. The mean VAS scores were low in the early post-operative period (3.9+/-1.3). The INFIX functions as an internal fixator being placed entirely under the skin, thus avoiding external pin related complications.

Fracture healing was seen at a mean post-operative period of 3.5+/-0.5 months (range, 3–6 months). Fracture reduction was excellent in twelve cases and good in three at final follow-up.

The functional outcomes assessed by Majeed scores at final follow-up were excellent in 8/15 and good in 7/15 patients. 13/15 patients had returned to their pre-injury jobs, while 2/15 had to change their jobs. The mean SF-12 scores for physical health (PCS) and mental health (MCS) were comparable with reference values for normal population. More importantly, the score for mental health was higher than average. All 15 patients reintegrated into society early, without any restrictions. We attribute these to the better psychological satisfaction of the patient due to the absence of social stigma of a bulky, cumbersome external fixator and its drawbacks of pin site pain, difficulty in lying sides/prone and wearing clothes.

Two patients had loss of reduction at final follow-up. Both had AO/OTA type 61-C fracture. One patient required revision of INFIX screws due to loosening. This patient had residual pubic diastasis at follow-up. The other patient had residual vertical displacement at follow-up.

The incidence of LFCN injury was less (1/15) in comparison with studies published thus far (Table 4), possibly due to our meticulous approach during dissection, taking care to protect the LFCN from injury due to our awareness of this complication from previous studies. We ensured that the screw head remained above deep fascia to prevent compression of femoral nerve and inguinal ligament. We used 7mm-diameter polyaxial pedicle screws in comparison to that used by Vaidya et al. (7- to 8.5-mm), Muller

et al. (6- to 7-mm), Gardner et al. (7- or 7.5-mm) and Hoskins et al. (10 mm).<sup>17,30,31,33</sup>

In contrast to previous studies, there were no cases of heterotopic ossification in our series at a mean follow-up of 34.9+/-4.1 months (Table 4). The incidence of this complication varies from 0 to 42% in previous studies.<sup>17,28,31,33</sup> It is unclear why there were no cases of heterotopic ossification in our series.

One patient with coexistent urinary tract infection developed superficial surgical site infection (*Pseudomonas aeruginosa*), which settled with appropriate culture specific antibiotics.

We recommended hardware removal to our patients after radiological evidence of healing of anterior and posterior ring fractures. In comparison with previous studies where INFIX was removed at mean postoperative periods ranging from 3 to 9.4 months (Table 4), in our series, the INFIX was removed after a mean postoperative period of 7.3+/-1.5 months (5.5–11 months). However, in due course of the study we found that in three of our patients whose refused implant removal, the INFIX was still in situ without showing any radiological signs of loosening or breakage and without causing any complaints till the latest follow-up. Implant removal was done as a day care procedure and was uneventful in all 12 patients. There was substantially less soft tissue damage during implant removal. Implant removal is to be determined on an individual basis, after radiological healing of the fractures.

Ours is the first study to examine the feasibility, safety, limitations and midterm radiologic and functional outcomes of minimally invasive stabilization of vertically and rotationally unstable pelvic ring injuries, in Indian population using INFIX and percutaneous iliosacral screws, at a minimum follow-up of 31 months. Though our minimum follow-up period is longer than most published studies, we acknowledge that small sample size is a limitation of this study, and a study involving a larger patient group with a longer follow-up would give a better understanding of the outcomes, limitations and complications of this novel technique and specific indications for its application.

The combination of INFIX and percutaneous iliosacral screws is a minimally invasive, biomechanically stable and effective surgical technique for definitive management of vertically and/or rotationally unstable pelvic ring injuries. The technique is easy to learn and apply, achieves good fracture reduction with minimum complications and offers good functional and radiological outcomes with high patient satisfaction and return to pre-injury level function.

### Institutional review board (IRB) approval

The study was approved by the IRB and Ethics committee of Ganga Hospital, Coimbatore, India.

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### Conflict of interest

The authors have none to declare.

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