Fwd: Fw: reviewer ASJ 0337 RI

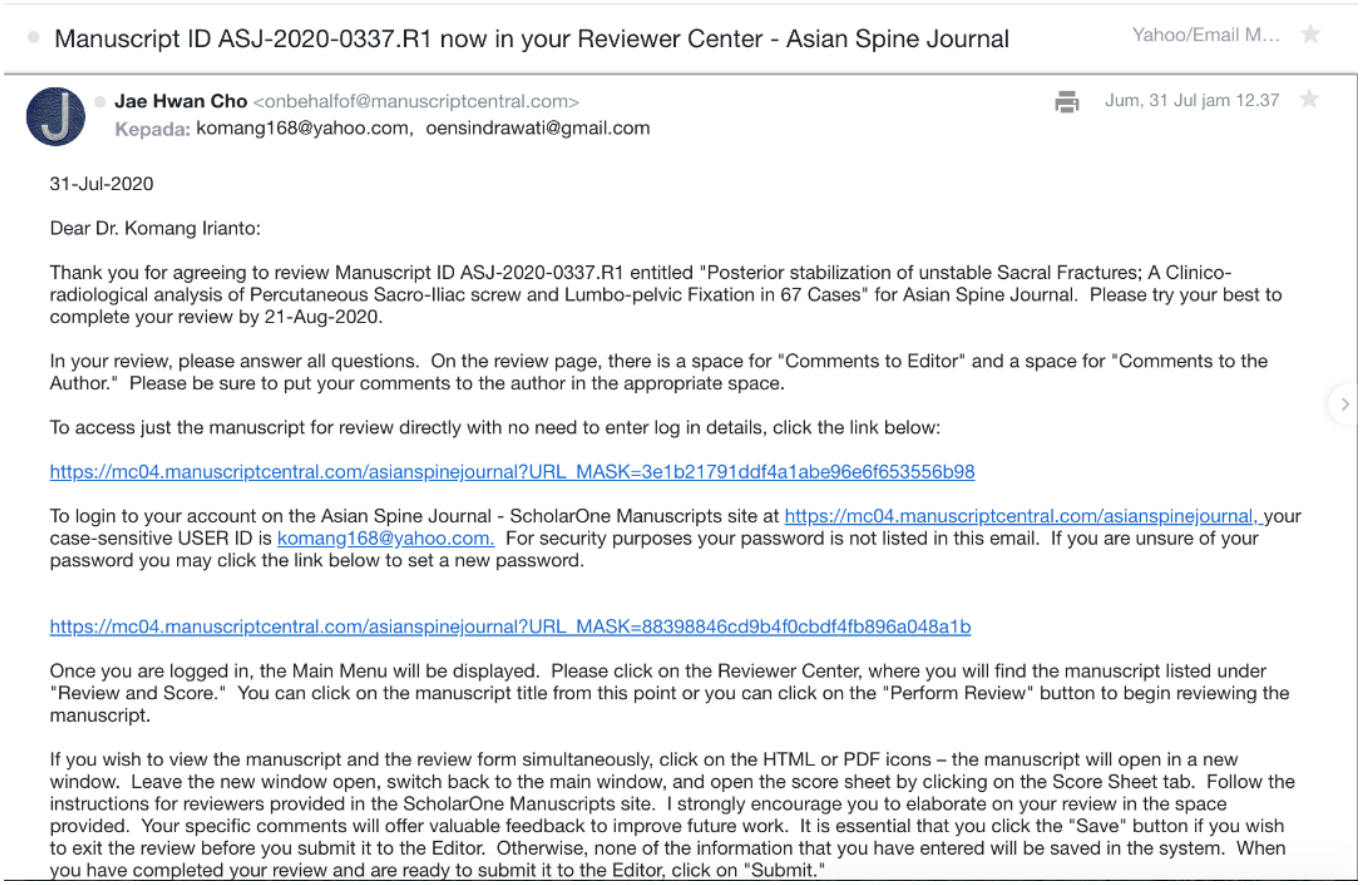
Dari: Linta Meyla Putri (lintameyla@gmail.com)

Kepada: yuyunhand@yahoo.com

Tanggal: Jumat, 5 November 2021 11.13 WIB

---------- Forwarded message ---------
From: **yuyun herastutik** <yuyunhand@yahoo.com>
Date: Wed, 19 Aug 2020 at 13.33
Subject: Fw: reviewer ASJ 0337 RI
To: Linta Meyla Putri <lintameyla@gmail.com>

----- Pesan yang Diteruskan -----
Dari: komang kopling <komang168@yahoo.com>
Kepada: Yuyun Herastutik <yuyunhand@yahoo.com>
Terkirim: Senin, 3 Agustus 2020 05.31.21 WIB
Judul: reviewer ASJ 0337 RI



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Kepada: komang168@yahoo.com, oensindrawati@gmail.com

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31-Jul-2020

Dear Dr. Komang Irianto:

Thank you for agreeing to review Manuscript ID ASJ-2020-0337.R1 entitled "Posterior stabilization of unstable Sacral Fractures; A Clinico-radiological analysis of Percutaneous Sacro-Iliac screw and Lumbo-pelvic Fixation in 67 Cases" for Asian Spine Journal. Please try your best to complete your review by 21-Aug-2020.

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Kepada: komang168@yahoo.com, oensindrawati@gmail.com

Sen, 3 Agu jam 05.23

02-Aug-2020

Dear Dr. Komang Irianto:

Thank you for reviewing manuscript # ASJ-2020-0337.R1 entitled "Posterior stabilization of unstable Sacral Fractures; A Clinico-radiological analysis of Percutaneous Sacro-Iliac screw and Lumbo-pelvic Fixation in 67 Cases" for the Asian Spine Journal.

On behalf of the Editors of the Asian Spine Journal, we appreciate the voluntary contribution that each reviewer gives to the Journal. We thank you for your participation in the online review process and hope that we may call upon you again to review future manuscripts.

Sincerely,

Hak-Sun Kim, MD, PhD, Editor-in-Chief
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Asian Spine Journal
spinecjh@gmail.com

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Warm regards,
Linta Meyla Putri S. KM

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Posterior stabilization of unstable Sacral Fractures; A Clinico-radiological analysis of Percutaneous Sacro-Iliac screw and Lumbo-pelvic Fixation in 67 Cases

Journal:	*Asian Spine Journal*
Manuscript ID	ASJ-2020-0337.R1
Manuscript Type:	Original article
Keywords:	Unstable sacral fractures; Spinopelvic dissociation; Surgical management; Lumbopelvic fixation; Sacroiliac screw

Posterior Stabilization of Unstable Sacral Fractures; A Clinico-Radiological Analysis of Percutaneous Sacro-Iliac Screw and Lumbo-Pelvic Fixation in 67 Cases

Abstract

Study design: Retrospective

Purpose: Recent advances in intraoperative imaging and closed reduction techniques have led to a shifting trend towards surgical management in every unstable sacral fracture. Our aim was to evaluate clinico-radiological outcome of Sacro-iliac screw (SI screw) and Lumbopelvic fixation (LPF) techniques and thereby, delineate the indications for each.

Overview of literature: Optimal management guidelines for unstable sacral fractures are still lacking probably due to the rarity of these injuries and varying fixation trends.

Methods: Out of 67 patients, 40 were in **SI** group and 27 in **LPF** group. Electronic medical record for each patient was reviewed, including patient demographic data, mode of trauma, co-existing injuries, neurological status (Gibbon's four-grade system), Injury Severity Score, time from admission to operative stabilization, type of surgical stabilization, complications, return to operating room and treatment outcome measures using Majeed's functional grading system and Matta's radiological criteria. The minimum follow-up period was 2 years.

Results: Non-comminuted longitudinal injuries with normal neurology and acceptable closed reduction have undergone SI screw fixation (N=40). Irreducible, comminuted or high transverse fractures, associated dysmorphic anatomy or neurodeficit were managed by Lumbo-pelvic fixation (N=27). Surgical duration, blood loss and complications were significantly reduced in **SI** group($P<0.001$). Post-operatively, we had excellent and good Majeed score and Matta score in 86.57% and 92.54% of the patients respectively. There was no significant difference in outcome between the two groups. A subgroup analysis between vertically unstable injuries in both groups showed no significant difference in outcomes.

Conclusion: Unstable sacral fractures can be effectively managed with percutaneous SI screw including vertically unstable injuries by paying strict attention to pre-operative patient selection where as LPF can be reserved for comminuted fractures, unacceptable closed reduction, associated neurodeficit, lumbo-sacral dysmorphism, and high transverse fractures.

***Keywords*:** Unstable sacral fractures; Spinopelvic dissociation; Surgical management; Lumbopelvic fixation; Sacroiliac screw

Main Text

Introduction

Management of unstable sacral fractures, especially those with associated multi-system injuries and overlapping fracture patterns, is a challenge even to the most experienced surgeon. Any sacral fracture with associated posterior pelvic ring disruption is deemed unstable, vertical instability being the worst, and warrants surgical stabilization. Spino-pelvic dissociation is a relatively newer terminology which represents a spectrum of highly complex atypical sacral fractures resulting in multi-planar instability of lumbo-pelvis . Optimal management guidelines are still lacking probably due to rarity of these injuries and varying fixation trends.

Among the surgical techniques described for sacral fractures like sacro-iliac screws (SI screws), posterior tension band plating, transiliac rods etc., lumbo-pelvic fixation (LPF) with or without percutaneous SI screws has surpassed all other techniques, and their combination, otherwise known as 'triangular osteo-synthesis' is reported to have the greatest mechanical stability.[1] The description of closed reduction and minimally invasive strategies has popularized LPF, and is the preferred option for Spino-pelvic dissociation .

Although the advantages of LPF have been proven clinically and biomechanically in rotationally and vertically unstable injuries not amenable to SI screw fixation, there has been a rising trend towards its routine use in every unstable sacral fracture.[2] Unless indicated, LPF is considered an overtreatment adding to surgical morbidity especially in patients with multi-system afflictions.[3] More-over, a steep learning curve, loss of motion segments and implant-related complications further deters its routine use. In this study, we sought to evaluate clinico-radiological outcome of SI screw and LPF strategies in unstable sacral fractures and thereby, delineate the indications for LPF.

Material and methods

After obtaining Institutional Review Board approval and informed consent, a total of 75 consecutive adult patients (18-50 years) who underwent surgical management for traumatic sacral fractures at our hospital between January 2013 and December 2017 with minimum follow-up of 2 years were retrospectively analyzed. All patients having unstable sacral fracture and associated pelvic ring injury, open or closed, unilateral or bilateral, with or without neuro-deficit were included. Isolated sacro-iliac joint injuries and pelvic injuries without sacral fractures were excluded. 5 patients were lost to follow up and 3 patients were excluded due to incomplete radiographic imaging. Thus a total of 67 patients constituted the final study group (48 males and 19

females). Based on surgical technique employed, study group was divided into two groups; Sacro-iliac screw **(SI group)** and Lumbo-pelvic fixation **(LPF group).** Electronic medical records were reviewed and recorded, including patient demographic data, mode of trauma, co-existing injuries, neurological status (Gibbon's four-grade system), Injury Severity Score (ISS), time from admission to operative stabilization, type of surgical stabilization, complications, return to operating room and treatment outcome measures. [4]

All patients were initially evaluated according to the Advanced Trauma Life Support protocol. After stabilization of general condition, plain X-rays of pelvis (Antero-Posterior/Inlet-Outlet views) and computed tomography scan with 3-D reconstruction were taken pre-operatively to determine fracture morphology. Denis and Roy-Camille classification systems were used for sacral fractures along with morphological types like H-type, T-type, U-type and lambda-type whereas pelvic stability was assessed as per Young and Burgess classification system.[5-8] Denis zone II and III injuries and Young-Burgess antero-posterior (types II and III), lateral compression (types II and III) and vertical shear injuries were considered indications for surgery. Pre-operative distal femoral skeletal traction was applied in all cases with vertical shear injuries. Anterior stabilization when indicated (displaced pubic-rami fractures >10 mm or pubic diastasis > 20mm) was done first using symphyseal reconstruction plating, pubic rami screws or in-fix (anterior subcutaneous internal fixation using bilateral supracetabular pedicle screws through anterior inferior iliac spine connected via a subcutaneous contoured rod) followed by posterior fixation.

SI Screw: Standardized percutaneous technique in prone position was used for SI screw fixation. Decision to use single or dual screws and its length were taken per-operatively by senior author depending on screw purchase and fracture morphology.

Indications: Non-comminuted longitudinal fractures, acceptable closed reduction with a residual displacement less than 1 cm, absence of neuro-deficit/ lumbo-sacral dysmorphism, absence of high transverse fracture **(Fig. 1).**[9]

Lumbo-pelvic fixation: LPF was performed by paraspinal approach in unilateral injuries with normal neurology (midline approach for bilateral injuries/neurodeficit) using L4/L5 pedicle screw (extension to L4 in L5 pedicle fracture/L4-5 pre-existing instability), Iliac screw and connecting rod.

Indications: Neurological deficit, Comminuted sacral fracture, lumbo-sacral dysmorphism, extension of fracture into L5-S1 facet, high transverse fractures, failure of closed reduction.**(Fig. 2)**

Reduction technique: Vertical displacement was reduced by distal femoral traction whereas rotational correction was obtained by associated hip external rotation. In case of transverse fractures, postural reduction

was achieved by keeping pillows under thighs to assist pelvis extension while intraoperative maneuvers included bifemoral traction and lumbopelvic distraction.

Post-operative care: Immediate postoperatively, all patients were allowed to move in bed with strict emphasis on pelvic lifting and Quadriceps/ankle exercises. DVT prophylaxis was given in the form of intermittent pneumatic compression device and low-molecular weight Heparin followed by low dose Aspirin at the time of discharge for 6 weeks. Case-sensitive, gradual weight-bearing on crutches was allowed 3 weeks after the operation except in spino-pelvic dissociation and/or vertical instability. Full weight-bearing was allowed after 6th postoperative week depending on follow-up x-ray. Patients were examined at 3 weeks, 6 weeks, 3 months, 6 months, 9 months and 12 months following their discharge from hospital and every 6 months thereafter. Minimum follow-up period was 2 years.

Complications such as infection, neurodeterioration, loss of fixation, hardware prominence, non-union and unplanned return to operating room were recorded.

At final follow up , all patients had a detailed neurological evaluation along with functional outcome assessment using Majeed's grading system and radiological evaluation using Matta criteria and pelvic incidence (in case of transverse fractures).[9,10]

SPSS (version 17) software was used for statistical analysis. Results are presented as Mean ± Standard Deviation (SD) values and frequency as numbers(%).Unpaired t test was used to compare means of two groups and Z test for proportions to compare proportions between two groups. Categorical data was analyzed by chi-square test. A P value of 0.05 or less was considered for statistical significance.

Results

There were a total of 67 patients; 40 patients (28 males; 12 females) in SI group (39 unilateral; 1bilateral) and 27 patients (20 males; 7 females) in LPF group (24 unilateral; 3 bilateral). The mean age was 35.61± 14.01 years (range;18-45 years) with an average follow-up period of 28.4 months (range; 26-49 months). Road-traffic-accident was the commonest mode of injury (67.16 %) while remaining cases were due to fall from height (32.84 %). Comparison of age, timing of surgery, ISS, duration of surgery and blood loss has been summarized in **Table 1.** Two groups are matched age-wise as well as with timing of surgery following injury. ISS, surgical duration and blood loss was found to be significantly higher in LPF group.

SI screw and Lumbo-pelvic fixation

The commonest sacral fracture morphology was vertical (79.1 %). Among associated pelvic-ring injuries, APC-2 (47.7%) was the commonest followed by vertical shear (20.9%). Different morphological patterns were detailed in **Table 2.** 13 patients (19.4%) required supplemental anterior stabilization (symphyseal

plating ;7, pubic ramus screw;1 and Infix;5) (**Fig 3.)** Infix removal was performed routinely as out-patient procedure at 6 months follow-up after confirming radiological healing. Initial ex-fix application was required in 9 patients and distal femoral traction was applied in 14 patients which were removed at the time of definitive surgery. Mean time from admission to definitive operative stabilization was 7.2 ± 1.8 days.

9 patients had associated spine trauma at other locations requiring surgical stabilization (4 Lumbar, 4 thoracic and 1cervical) and 15 had other orthopedic injuries. None of the associated spine trauma patients had neurodeficit. 9 patients had other system injuries (Head; 3, Chest; 4, Abdomen ;2) and the mean ISS score was 23.5 ± 11.6. Only 3 patients had neurodeficit at presentation, all associated with Denis zone III injury and had undergone decompression (S1-4 laminectomy using high speed burr). There were no open injuries, though 4 had associated Morel-Lavelle lesion which necessitated open debridement.

Complications

Overall, we had 6 complications (8.9%) which were summarized in **Table 3**. There were 3 infections (4.4%), all from LPF group of which 2 required implant removal after fracture healing and 1got subsided with debridement. None of them required revision fixation. Screw malposition occurred in 1 patient (1.5%) from SI group and screw revision was done. 2 patients (3%) from LPF group had undergone implant removal for hardware prominence causing skin irritation. There were no patients with neuro-deterioration, loss of fixation or non-union. Complication rate was significantly high in LPF group (P = 0.04).

Outcome

At 2-year follow-up, out of 3 patients with Gibbon's grade 3 neurological status pre-operatively, 1 had complete recovery while other 2 remained the same.

According to Majeed Score, functional outcome showed 39 patients (58.2%) with excellent, 19 patients (28.3%) with good and 9 patients with (13.4%) fair results. 45 patients (67.16%) had maximum radiologic scoring with excellent reduction, 17 patients (25.37%) had good score, and 5 patients (0.07 %) had fair reduction.**(Fig.4)** Mean post-operative pelvic incidence was 63.58º.There was no statistically significant difference between the two groups in functional (P = 0.22) and radiological (P = 0.88) scorings. Outcome scores are summarized in **Tables 4 and 5.** A subgroup analysis between vertically unstable injuries in the two groups showed no significant difference in outcomes **(Table 6).**

Discussion

Fractures of sacrum, although rare, with a reported incidence of approximately 45% of all pelvic fractures, can have significant impact on patient's quality of life as a consequence of chronic pelvic instability, deformity, prolonged recumbency and neurological impairment.[5] Role of surgical management in promoting early mobilization and improved outcomes have been clearly demonstrated.[11,12] However, no single management algorithm is applicable for all traumatic sacral fractures and proper treatment has yet to be standardized. Despite the numerous salvage techniques described over last three decades, recent advances in intra-operative imaging has led to the emergence of SI screw and LPF as two major pillars for the surgeons to lean on.[1]

In this study, we deliberately excluded isolated sacral fractures with-out pelvic ring disruption as they seldom create any management dilemma in the minds of treating surgeon. Even then, our sample size (N = 67) was large enough as compared to majority of the literature on unstable sacral fractures.[13-16] Associated vertebral fracture was seen in 13.4% of patients as opposed to 44.26 % by Park et al. in his retrospective study on 71 patients.[17] Although, this appears low, there is less likelihood for missed injuries in our institute due to the poly-trauma protocol we follow in which all those patients had whole body CT scan and whole spine screening. Operative stabilization was performed for the vertebral fractures on the same day of definitive pelvic surgery; since none of them had any neurological deficit, it didn't have any significant impact over treatment outcomes. Jazini et al reported an average ISS score of 27 ± 13.6 in his retrospective study of lumbo-pelvic fixation on 32 patients which is comparable to our score (23.5 ± 11.6).[2]

The incidence of spino-pelvic dissociation in our study was 49.25 % which is significantly higher than previously reported rates of 3-10%.[17,18] This probably is due to the fact that we included only those patients having a combination of unstable sacral fractures and pelvic ring disruption, which invariably signifies a high velocity trauma. Initial reports on LPF and Triangular osteosynthesis have considered presence of vertical instability with fracture comminution and/or spino-pelvic dissociation as the only indication for these procedures.[19,20] However, a review of recent literature on management of unstable fractures showed a major drift towards routine use of LPF irrespective of the presence of fracture comminution or spino-pelvic dissociation. The introduction of minimally invasive techniques expanded this further.[2,16] In our study, we didn't consider LPF imperative for all vertically unstable injuries unlike the above mentioned publications provided the fracture was non- comminuted, neurologically normal and acceptable closed reduction could be obtained pre-operatively **(Fig.3).** We had 11 patients in the SI group with vertical instability and all of them had satisfactory outcome in the long term both clinically and radiologically, comparable to that achieved using

LPF.**(Table 6)** In addition, they had significant reduction in surgical duration, intraoperative blood loss and complications.**(Table 1 & 3)** A high mean ISS score (23.5 ± 11.6) also denotes the magnitude of injury which would justify an intervention with the least possible surgical trauma. In a retrospective analysis of 38 vertically unstable pelvic injuries treated by SI screw, Keating at al observed favorable outcome with fewer complication rates.[21] Similarly in 2015, Iorio et al in his review article has clearly pointed out the advantages and effectiveness of SI screw even in patients with vertical instability or spino-pelvic dissociation.[22] Complex fracture patterns like U- and H- shaped sacral fractures have also been managed successfully by SI screw fixation with satisfactory restoration of pelvic parameters using a novel closed reduction technique described by Ruatti et al in 2013.[23]

Outcome scores in our series corresponded closely with previously reported similar studies. In a retrospective analysis of 22 patients with AO/type C posterior pelvic ring injuries treated by contemporary spinal instrumentation, Korovessis et al reported good and excellent Majeed score and Matta score in 81.81% and 95.45 % patients respectively.[16] With a sample size almost 3 times higher than Korovessis's study, our functional and radiological scores were comparable (86.57% and 92.54% respectively).

Our complication rates were very low (8.9 %) as opposed to the existing publications on SI screw as well as LPF.[13, 24] All the surgeries being performed by senior author as well as appropriate patient selection and precautionary measures taken in screw head recession might have helped the cause. Moreover, our study group comprised of patients in younger age group (mean; 35.61± 14.01 years) which might have reduced the complications related to implant purchase and wound healing. The complication rate was noted significantly higher in LPF group (P = 0.04) though the number is too small for statistical analysis. This could partly be attributed to injury factors as well since all patients had sustained a high velocity trauma. Patients with neurodeficit were all belonged to zone III injury which was consistent with the findings of Denis et al in his retrospective analysis of 236 patients.[5] Regardless of the role of decompression surgery in neurodeficit, we performed direct decompression in all our patients (N=3) in which one had complete recovery.[25-27]

Though our study was limited by its retrospective design, we would be rather justified by rarity of these injuries as evidenced by smaller sample sizes in existing literature.[2,11,14,16] We also agreed to the fact that our sample size is inadequate for power analysis and has high risk for type II error to occur. Since our study group included varying patterns of complex sacral fractures forming an unmatched cohort of patients managed by two separate techniques, our series is difficult if not impossible to compare and to draw a conclusion. A relatively younger age group of patient population might restrict the applicability of our inference in older,

osteoporotic patients with similar injuries. A prospective study design with matched study groups and randomization is needed ideally for better interpretation of conclusions. Through this study, we believe that LPF is not always the rule in unstable sacral fracture management. Although it offers early weight bearing as compared to SI screw fixation, this is often precluded by associated injuries in the form of intra-articular fractures of lower limb or other systemic injuries.

Conclusion

Unstable sacral fractures can be effectively managed with percutaneous SI screw including vertically unstable injuries by paying strict attention to pre-operative patient selection in terms of fracture pattern and comminution, neurodeficit and closed reduction techniques, thereby reducing the complications associated with LPF. LPF can be reserved for comminuted fractures with vertical instability, unacceptable closed reduction, associated neurodeficit, lumbo-sacral dysmorphism and high transverse fractures.

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Figure legends

Fig 1. Pre-operative CT-scan and post-operative AP radiographs of a 25-year-old male showing Denis zone-2 injury managed by Sacro-iliac screw

Fig 2. Pre-operative CT-scan and post-operative radiographs of a 16-year-old male showing Roy-Camille type-2 injury managed by lumbo-pelvic fixation

Fig 3. Pre-operative CT-scan and post-operative AP radiographs and clinical photographs of a 32-year-old male showing vertical shear injury with spino-pelvic dissociation (L5 Transverse process fracture) managed by SI-screw alone with good radiographic and functional outcome at 2 year follow-up. Anterior stabilization was done by dual-plating of symphysis pubis.

Fig.4 – Illustrative diagram showing outcome scores at 2-year follow-up

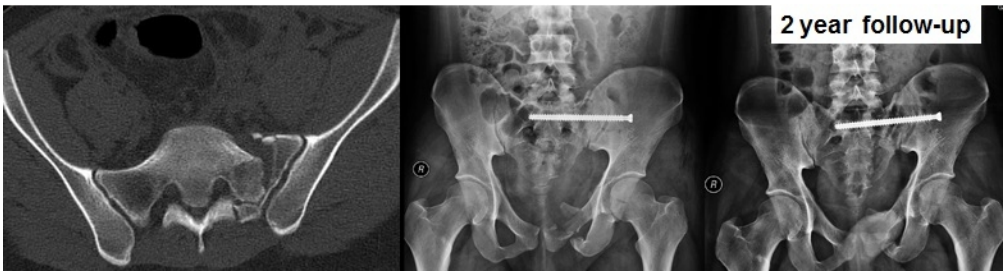

Fig 1. Pre-operative CT-scan and post-operative AP radiographs of a 25-year-old male showing Denis zone-2 injury managed by Sacro-iliac screw

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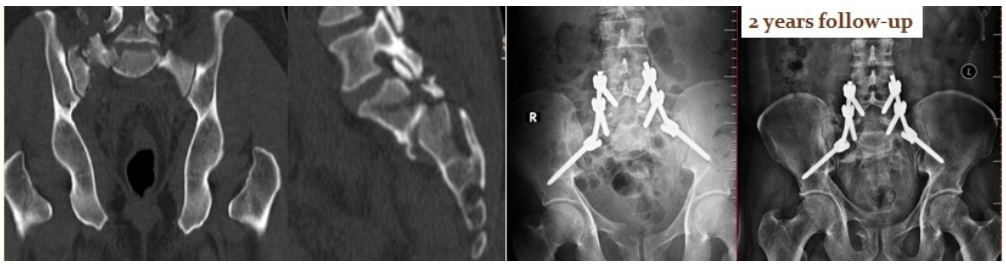

Fig 2. Pre-operative CT-scan and post-operative radiographs of a 16-year-old male showing Roy-Camille type-2 injury managed by lumbo-pelvic fixation

217x55mm (96 x 96 DPI)

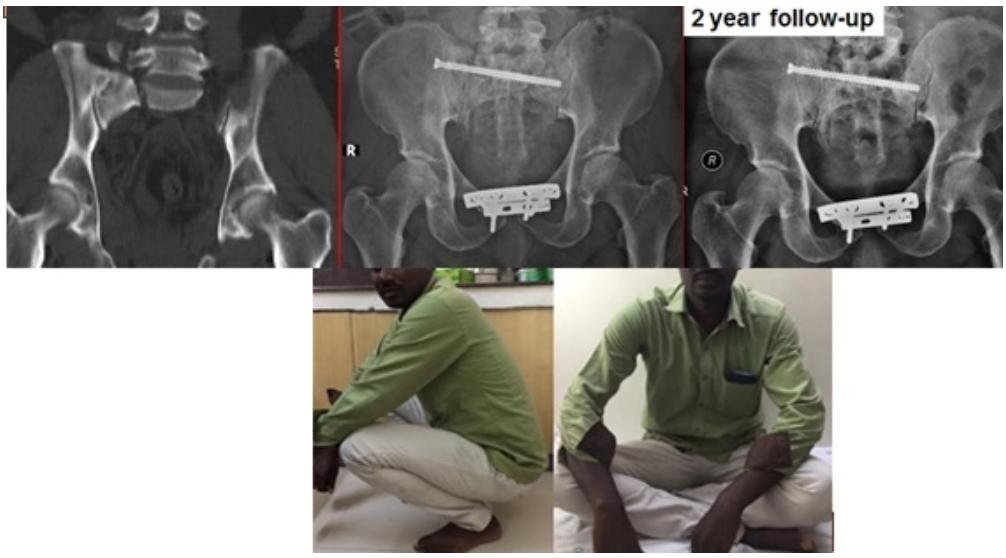

Fig 3. Pre-operative CT-scan and post-operative AP radiographs and clinical photographs of a 32-year-old male showing vertical shear injury with spino-pelvic dissociation (L5 Transverse process fracture) managed by SI-screw alone with good radiographic and functional outcome at 2 year follow-up. Anterior stabilization was done by dual-plating of symphysis pubis.

150x82mm (96 x 96 DPI)

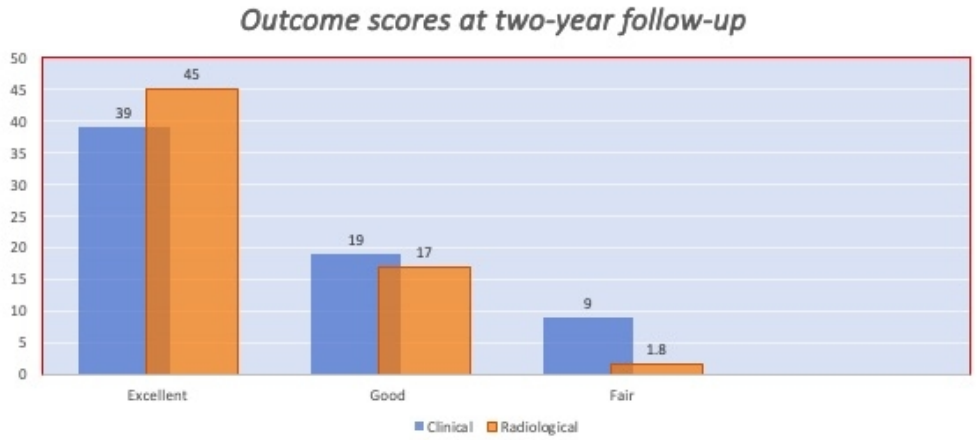

Fig.4 – Illustrative diagram showing the outcome scores at 2-year follow-up

200x91mm (72 x 72 DPI)

Tables

Table 1. The comparison of different parameters between the two groups

Parameter	SI screw	LPF	P – value
Age (Years)	36.62 ± 11.42	39.31 ± 15.42	0.21
Timing of surgery (Days)	8.12 ± 2.34	7.82 ± 1.86	0.29
ISS	22.24 ± 2.65	24.20 ± 1.82	0.001
Duration of surgery (Hours)	32.45 ± 9.46	102.12 ± 12.45	< 0.001
Blood loss(ml)	96.16 ± 15.34	320.82 ± 44.18	< 0.001

Table 2. The distribution of different injury patterns between the two groups

Classification	SI Group (40)		LPF Group (27)	
Denis	Zone 1 – 0 Zone 2 – 28 Zone 3 – 12		Zone 1 – 0 Zone 2– 10 Zone 3 – 3	
Roy- Camille	Type 1 – 0 Type 2 – 0 Type 3 – 0		Type 1 – 0 Type 2 – 12 Type 3 – 2	
Morphology	H – 0 T – 0 U – 0	Comminuted – 0 L-S dysmorphism – 0	H – 1 T – 1 U – 1	Comminuted – 4 L-S dysmorphism – 1

	Lambda – 0			Lambda – 0		
Young & Burgess	APC II – 19 APC III – 7	LC II – 0 LC III – 3	VS – 11	APC II – 11 APC III – 6	LC II – 3 LC III –4	VS – 3
Spino-pelvic dissociation	L5 transverse process fracture – 11 Bilateral vertical fracture – 0 High transverse fracture – 0			L5 transverse process fracture – 3 Bilateral vertical fracture – 3 High transverse fracture – 16		

Table 3. The complications between two groups

Complication	SI group	LPF group
Infection	0	3
Screw malposition	1	0
Implant prominence	0	2
Loss of fixation	0	0
Non-union	0	0
Neuro-deterioration	0	0
TOTAL	***1(2.5%)***	***5(18.5%***
P-value - 0.04,Sig		

Table 4. The functional outcome score (Majeed score) between the two groups

Majeed	SI group	LPF group	P-value
Excellent	23 (57.5%)	16 (59.3%)	**0.22**
Good	11 (27.5%)	8 (29.6%)	

Fair	6 (15.0%)	3 (11.1%)	

Table 5. The radiological outcome score (Matta score) between the two groups

Matta	SI group	LPF group	P-value
Excellent	26 (65.0%)	19 (70.4%)	**0.88**
Good	11 (27.5%)	6 (22.2%)	
Fair	3 (7.5%)	2 (7.4%)	

Table 6. Comparison between Matta and Majeed grading between SI group and LPF group in vertical instability fractures.

	SI group (N=11)	LPF group (N=3)	P-value
Matta Excellent Rate	45.0%	63.6%	0.06
Majeed Excellent Rate	57.5%	54.5%	0.41