Percutaneous pedicle screw fixation for thoracolumbar burst fracture: a Singapore experience

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INTRODUCTION This study aimed to evaluate the clinical and radiological outcomes, and safety and efficacy of percutaneous pedicle screw fixation (PPSF) in the treatment of thoracolumbar burst fractures.

METHODS This was a retrospective review of patients with thoracolumbar burst fractures treated with PPSF in a single hospital from 2010 to 2011. Baseline data included patient demographics, mechanism of injuries, fracture level, neurologic status and the number of percutaneous screws inserted. Kyphotic angle correction, vertebral body height restoration and mid-sagittal canal diameter improvement were used to assess radiological outcome. Screw misplacement, operative complications, functional improvement (ASIA score) and pain score on visual analogue scale were used to assess safety and clinical outcomes.

RESULTS 21 patients with 25 thoracolumbar burst fractures were treated with 134 percutaneous screws. There was significant improvement in kyphotic angle correction (mean difference 6.1 degrees, p = 0.006), restoration of anterior and posterior vertebral height (mean difference 19.7%, p < 0.01 and mean difference 6.6%, p = 0.007, respectively) and mid-sagittal canal diameter (mean difference 15.6%, p = 0.007) on discharge. These improvements remained statistically significant at six months post operation for restoration of anterior vertebral body height (mean difference 9.8%, p = 0.05) and mid-sagittal diameter (mean difference 30.0%, p < 0.01).

CONCLUSION In this first local review, we have shown that PPSF is a relatively safe and effective technique for treating selected thoracolumbar burst fractures, and that it yields satisfactory results. However, its long-term outcome and efficacy need to be further evaluated.

Keywords: minimally invasive, thoracolumbar fractures
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INTRODUCTION

Thoracolumbar burst fractures are common spinal fractures. Many papers have been published regarding its management.[1-6] Part of the controversy is centred on the option of either surgery or conservative management for certain fracture types. Both options have their advantages and disadvantages. Conservative management carries its own set of morbidities of prolonged recumbence and its associated complications. Traditional open surgical fixation has been viewed by some to be an overtly aggressive approach for single-level involvement.[7] This is especially so with its approach-related morbidities such as long wound, muscle stripping, muscular atrophy, denervation and pain.[8]

Increasingly, studies have been able to provide promising results of minimally invasive techniques or percutaneous pedicle screw fixation (PPSF). PPSF addresses the approach-related morbidities of open surgery by having the advantage of minimal muscular trauma, small wounds with minimal blood loss and reduced postoperative pain.[7] Critics of this technique cited the lack of fusion, long learning curve and suboptimal correction of mechanical deformities as the undesirable disadvantages. To date, few papers have been published to address the mechanical efficacy and safety of this technique, especially in the area of spinal trauma. This paper is the first local review on the clinical and radiological outcome of patients who underwent PPSF for appropriate spinal fractures.

METHODS

We retrospectively reviewed the data of all patients with thoracolumbar burst fractures (AO type A.3) admitted to our institution between 2010 and 2011. Indications for operation included patients with one or more of the following: neurological deficits, kyphotic angle > 20 degrees, loss of vertebral body height (VBH) ≥ 50%, retropulsion of bony fragments involving ≥ 50% of the mid-sagittal diameter (MSD) of the fractured level. All patients had pre-operative computed tomography (CT) imaging of the spine for decision-making and calculation of deformities. Neurological deficits were assessed independently of the surgical team. The abovementioned parameters, such as kyphotic angle, VBH and MSD, were used for deformity calculation based on the formula adopted from Willén et al.[9] Correction of kyphotic angle, reduction of VBH loss and MSD loss were indicative of improvement after treatment. Calculations were done

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Fig. 1 Intra-operative photo shows rods being tunnelled through the topmost cannulated screws.

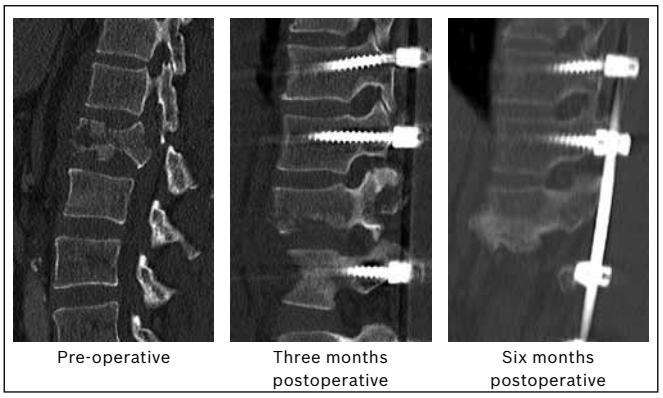

Fig. 2 Serial CT images of an L1 burst fracture treated with PPSF technique. There is sclerosis noted within the fracture site, indicating bone healing and further stabilisation of the fracture.

with CT imaging in the picture archiving and communication system (PACS) 2 programme (General Electric, Barrington, IL, USA).

Outcomes of procedural safety were based on the number of misplaced screws, operative time, intra-operative blood loss and postoperative complications. Misplacement of screws was defined as penetration of the medial wall of the pedicle or vertebral body wall ≥ 2 mm based on methods devised by Castro et al.[10] Outcome measures were postoperative length of stay, visual analogue scale (VAS) for pain assessment and improvement of neurological grading. The American Spinal Injury Association (ASIA) scoring scale was used to assess improvement in neurological status. All patients were started on ambulatory physiotherapy on the first postoperative day with a similar pain relief protocol. They were then assessed for VAS pain score upon discharge. Patients who underwent PPSF had postoperative CT imaging for assessment. Repeat CT was conducted at three- and six-month intervals to assess the deformity correction.

Statistical analyses of our data were performed using the Statistical Package for the Social Sciences version 12 for windows (SPSS Inc, Chicago, IL, USA). Paired student's *t*-test was used for comparison of pre- and postoperative pain scores, kyphotic angles, percentage loss of vertebral height and MSD of vertebrae on radiographic evaluation. Three- and six-month post-discharge data on the abovementioned radiographic parameters were analysed using repeated measures analysis of variance (ANOVA) for test of contrasts. The chi-square test was used for comparison of neurologic improvement post surgical intervention.

The anaesthetised patients were placed prone under strict log roll protection. Under imaging, entry points for the pedicles were identified on the skin using radiopaque markers, e.g. artery forceps. The point of entries for the right-sided and left-sided pedicles were the '3 o'clock' and '9 o'clock' positions, respectively. 1-cm skin incisions centred on the point of entry were made and deepened to the fascia plane. Cook's trephine needles were placed simultaneously on both sides of the patient at different levels to minimise the operating and imaging time. The positions of the needle tips were checked to correspond to the correct pedicle entry points. The needles were then advanced into the pedicles in a '3–9 o'clock' and '9–3 o'clock' trajectory under radiographic guidance.

Lateral projection of the radiographic beam was done to check the entry of the needles in the vertebral bodies and the cephalad-caudal angulations. Once the needle was in the vertebral body, it was checked for breach with electric stimulation via the intra-operative nerve monitoring system. If the stimulation resulted in a myogenic response at a stimulation intensity of 10mA or less, the needle would be adjusted. The trocars of the needles were then replaced with K-wires, which were further advanced into the bodies till the desired depth. The K-wires acted as a guidewire for the cannulated screws when the Cook's needles were removed. The remaining steps of tapping the tracts and screw insertion were then performed through the guidewires in the pre-determined entry and trajectory.

Each cannulated pedicle screw came with its own attached column to facilitate rod insertion and cap tightening, depending on the design and brand of the implants. The final step of treading the rod through the screw heads was done either with a separate stab skin incision or through the topmost or bottommost screws. The rod was tunnelled intramuscularly through the columns to sit in the polyaxial screw head (Fig. 1). Screw caps were then persuaded down to secure the rod onto the screws. Distraction of the collapsed vertebral bodies to restore the height and correction of the kyphotic deformity were done with the columns attached to the screws (Figs. 2 & 3). The final fixation was checked before the columns were removed. The wound was closed in two layers, namely the fascia and skin. In patients with acute cord compression, decompressive laminectomy was performed on the affected level. This was done through a short midline incision, followed by a standard laminectomy. The fixation was then done with multiple small incisions at the side, as described above.

RESULTS

Between 2010 and 2011, 21 patients with 25 thoracolumbar burst fractures were treated in our unit with 134 percutaneous screws. Of these, 86%, 9.0% and 4.5% of patients had level 1,

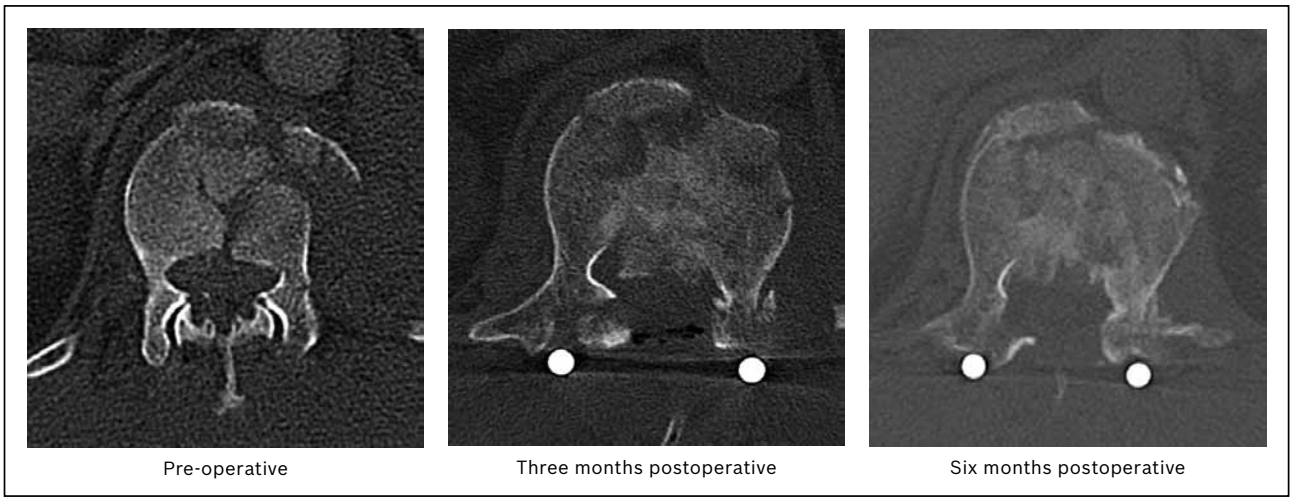

Fig. 3 Serial CT images show resorption of the retropulsed fragments of the same fracture.

Table I. Demographics and technical data of patients admitted with burst fractures.

Demographic/data	No. (%)
Male gender	14 (68.4)
Age* (yr)	39.6 ± 15.2; 21–68
Mechanism of injury	
Fall from height	13 (61.9)
Road traffic accident	5 (23.8)
Hit by falling objects	3 (14.3)
No. of vertebral fracture per patient	
1	18 (85.7)
2	2 (9.0)
3	1 (4.5)
No. of vertebral bodies instrumented per patient	
2	7 (33.3)
3	4 (19.0)
4	9 (42.9)
5	1 (4.5)
No. of screws placed	134
No. of pedicles breached	
Anterior	2 (1.7)
Medial	5 (4.2)
Duration of operation* (min)	179.0 ± 78.0; 70–300
Length of stay*(days)	22.3 ± 13.9; 10–67
Length of pre-op stay* (days)	5.1 ± 4.3; 0–15
Length of post-op stay* (days)	17.2 ± 15.0; 4–63

*Data is presented as mean ± standard deviation; range

2 and 3 vertebral fractures, respectively. Five patients required single-level decompressive laminectomies for cord compression. The number of vertebral bodies instrumented for spinal fixation and the demographic data of the patients are shown in Table I. The causes of admission for burst fractures were fall from height (62%), road traffic accidents (24%) and being hit by falling objects (14%). The mean length of hospital stay was 22.3 days and the mean length of stay post surgery was 17.2 days. Out of the 134 pedicle screws placed for spinal fixation, a total of seven (5.9%) screws breached the cortex, out of which five were medial breach of the pedicle cortex and two were anterior breach of the vertebral bodies. None of the misplaced screws resulted in any neurovascular injury. The mean operative time for each patient was 179 minutes (Table II). Intra-operative blood loss averaged 175 ml (range 50–250 ml).

Comparison of pre- and postoperative radiographs showed significant correction in the kyphotic angle (mean difference 6.1 degrees, 95% confidence interval [CI] 2.0–10.1, p = 0.006), restoration of anterior and posterior VBH (mean difference 19.7%, 95% CI 11.2–28.1, p < 0.01 and mean difference 6.6%, 95% CI 2.1–11.1, p = 0.007, respectively), and reduction of canal compromise in MSD (mean difference 15.6%, 95% CI 5.4–25.9, p = 0.007). At the three months follow-up, there remained significant restoration of the anterior and posterior vertebral height (mean difference 14.6%, 95% CI 6.8–22.4, p = 0.05 and mean difference 8.4%, 95% CI 3.6–13.3, p = 0.002) and reduction of canal compromise (mean difference 24.5%, 95% CI 11.0–37.9, p = 0.002). At six months post operation, only restoration in anterior VHB (mean difference 9.8%, 95% CI −0.1–19.7, p = 0.05) and reduction of canal compromise (mean difference 30.0%, 95% CI 18.2–41.8, p < 0.01) remained significant. Although correction of the kyphotic angle showed improvement at three and six months post operation, the results were not statistically significant (mean difference 2.6 degrees, 95% CI –1.0–6.1, p = 0.15 and mean difference 3.3 degrees, 95% CI 1.3–7.9, p = 0.15). The measure of within-subject contrasts for kyphotic angle correction, percentage loss of anterior and posterior VBH and loss of mid-saggital distance were all statistically significant, with p-values of 0.01, < 0.01, 0.02 and < 0.01, respectively. Kyphotic angle correction, and percentage loss of anterior and posterior vertebral height showed a quadratic relationship on repeated measures ANOVA, whereas percentage loss in MSD showed a linear relationship (Figs. 4 & 5).

Postoperatively, the patients reported an improvement in pain scores, with a mean difference of 3.6 in VAS (p < 0.01). Four (19%) patients reported a one-grade improvement and another four (19%) reported a two-grade improvement in neurologic function based on ASIA scoring. The distribution in ASIA grades is shown in Table III. Four (19%) patients suffered from postoperative superficial wound dehiscence, which required

Table II. Postoperative results of spinal fixation.

Parameter	Mean ± SD	Mean difference (95% CI)	p-value*	p-value**
Pain				
Pre-op	4.0 ± 1.8	3.6 (3.0–4.2)	< 0.01	
Post-op	0.4 ± 0.7			
Cobb angle				
Pre-op	17.1 ± 8.3	-		
Post-op	11.0 ± 7.4	6.1 (2.0–10.1)	0.006	0.01 (quadratic)
3-mth follow-up	14.5 ± 8.3	2.6 (–1.0–6.1)	0.15	
6-mth follow-up	13.8 ± 8.6	3.3 (–1.3–7.9)	0.15	
%loss of anterior VBH				
Pre-op	42.6 ± 15.9	-		
Post-op	22.9 ± 16.5	19.7 (11.2–28.1)	< 0.01	< 0.01 (quadratic)
3-mth follow-up	22.9 ± 16.5	14.6 (6.8–22.4)	0.001	
6-mth follow-up	32.8 ± 18.2	9.8 (–0.1–19.7)	0.05	
%loss of posterior VBH				
Pre-op	17.3 ± 8.1	-		
Post-op	10.7 ± 6.1	6.6 (2.1–11.1)	0.007	0.02 (quadratic)
3-mth follow-up	8.9 ± 5.1	8.4 (3.6–13.3)	0.002	
6-mth follow-up	13.4 ± 8.3	3.9 (–2.1–10.0)	0.19	
%loss of anterior MSD				
Pre-op	51.0 ± 17.2	-		
Post-op	35.4 ± 12.2	15.6 (5.4–25.9)	0.007	< 0.01 (linear)
3-mth follow-up	26.5 ± 11.4	24.5 (11.0–37.9)	0.002	
6-mth follow-up	21.0 ± 11.6	30.0 (18.2–41.8)	< 0.01	

*Paired student's *t*-test used with 95% confidence interval. **Measure of within-subject contrasts with repeated measures analysis of variance.
VBH: vertebral body height; MSD: mid-sagittal diameter

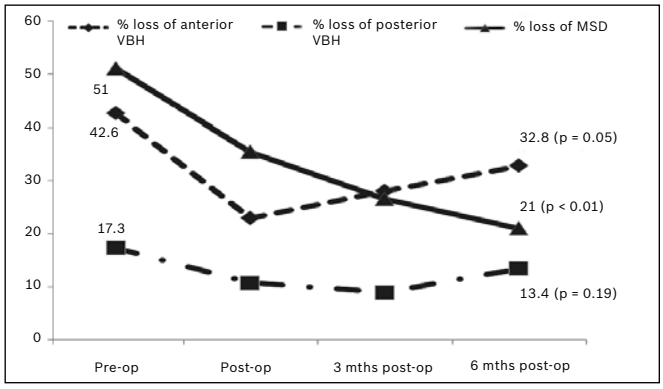

Fig. 4 Percentage loss in vertebral body height (VBH) and mid-sagittal diameter (MSD) on follow-up.

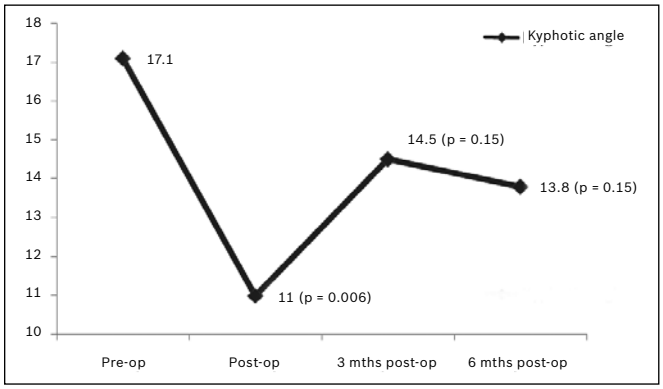

Fig. 5 Mean kyphotic angle of patients on follow-up.

treatment with dressings and antibiotics. Two patients suffered from three pedicle screw pullouts due to osteoporosis. One patient required revision of the pedicle screw one month after the initial operation due to worsening pain and tentage of skin by the screw. The other had the spinal implants removed one year post operation after the fractures had healed.

DISCUSSION

Traditionally, the application of minimally invasive technique in spinal surgery has been limited to degenerative correction. With improvement of implant technology and operator experience, surgeons have been applying the minimally invasive technique to a wide range of spinal conditions, most notably in the field of trauma. Standard open pedicle screw fixation and open posterior spine surgery have been associated with approach-related morbidities, mainly attributed to extensive paraspinal muscle stripping. PPSF has been shown to cause less paraspinal muscle damage and to have a positive effect on truncal muscle performance.[11] This would explain the significant improvement in the pain score of patients.

We describe the successful use of the PPSF technique in thoracolumbar burst fractures using long and short constructs. The correction of sagittal curvature, restoration of VBH and reduction of canal compromised by retropulsed bony fragments were all significant in the short term. In standard open fixations, screws were placed using anatomic landmarks, probing of the screws tracts to feel for breaches and fluoroscopy. Still, the reported rate of screw misplacement in open surgery is estimated to be 10%–20%.[10,12] PPSF substitutes this lack of tactile feedback with a heavy reliance on imaging to guide the screws. This turns out to be a safe option, as evidenced by the low screw misplacement rate of just below 5% in our case series. Moreover, none of our patients with misplaced screws reported any ill effects. A heavy reliance on imaging, however, translates into more

Table III. Neurologic outcomes of patients post spinal fixation.

ASIA grade	No. (%)		χ^2 {df}	p-value*
	Pre-op	Post-op		
A	2 (10.0)	1 (4.8)		
B	2 (10.0)	0		
C	3 (14.3)	1 (4.8)	33.5 {12}	0.001
D	4 (19.0)	6 (28.6)		
E	10 (47.6)	13 (61.9)		

*Statistical significance calculated with chi-square test with 95% confidence interval. ASIA: American Spinal Injury Association

radiation exposure to the patient and surgeons, and its significance will need to be addressed in future studies.

The obvious disadvantage of PPSF is the lack of bony fusion, which will add to the mechanical stability offered by standard fixation, although the necessity and reliability of fusion have constantly been challenged and debated by numerous authors. Recently, Wang et al showed that short segmental fixation without fusion for surgically treated burst fractures was satisfactory.[13] Sanderson et al has also shown that short-segment pedicle screw fixation without fusion could achieve satisfactory results for unstable thoracolumbar fractures.[14] These studies further substantiated PPSF as a good alternative to the open technique. Moreover, implants can be removed when the fractures are healed after 12 months.

While the improvement was reduced on follow-up at three and six months, our data still shows statistically significant trends. The loss of correction of kyphotic angle and posterior VBH observed during follow-up could partly be explained by the possibility of polyaxial screws having slight movement between the head and the screw arm after implantation. Another likely explanation would be due to bone resorption during the healing process. However, our result still showed a general trend of improvement. The significant improvement of anterior VBH and MSD shows that PPSF is effective as an internal splint for burst vertebral body fractures to heal naturally. Ultimately, fracture healing and bone remodelling are still the most important factors in maintaining stability of the injured segment. Bony resorption of the retropulsed fragment would explain the reduction of canal compromise in MSD as time passes. Notably, none of the patients suffered from worsening neurology or pain on follow-up.

The mean length of stay was 17 days post operation. The long postoperative stay can be attributed to the fact that most of the patients admitted to our hospital required step-down care facilities, such as community hospitals for rehabilitation, which were not readily available in our hospital. Furthermore, unique to our local context, the majority of patients admitted were foreign blue collar workers whose dormitories did not offer ideal conditions for rest and recovery.

The limitations of this study are the small sample size and the lack of comparison between PPSF and open surgery. As such, the authors can only draw comparisons from historical controls. The short follow-up period of six months may also mean that long-term data may result in non-significance of the correction of deformity and the patient's clinical outcome. In spite of these limitations, the result of this study is still encouraging. The authors plan to continue data collection and assessment of longer-term outcomes in this group of patients.

Although PPSF is commonly employed in a variety of spine conditions, it is still a relatively new venture in the area of spine fractures. From this retrospective review of 21 patients over a two-year period, we have shown that PPSF is a safe and effective technique for treating thoracolumbar burst fractures. For burst fractures where primary stability comes from the healing of the fracture site and bone remodelling, it is a suitable technique that yields a satisfactory outcome.

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