■ SPINE

Short segment pedicle screw instrumentation with an index level screw and cantilevered hyperlordotic reduction in the treatment of type-A fractures of the thoracolumbar spine

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The purpose of this study was to evaluate and compare the effect of short segment pedicle screw instrumentation and an intermediate screw (SSPI+IS) on the radiological outcome of type A thoracolumbar fractures, as judged by the load-sharing classification, percentage canal area reduction and remodelling.

We retrospectively evaluated 39 patients who had undergone hyperlordotic SSPI+IS for an AO-Magerl Type-A thoracolumbar fracture. Their mean age was 35.1 (16 to 60) and the mean follow-up was 22.9 months (12 to 36). There were 26 men and 13 women in the study group. In total, 18 patients had a load-sharing classification score of seven and 21 a score of six. All radiographs and CT scans were evaluated for sagittal index, anterior body height compression (%ABC), spinal canal area and encroachment. There were no significant differences between the low and high score groups with respect to age, duration of follow-up, pre-operative sagittal index or pre-operative anterior body height compression (p = 0.217, 0.104, 0.104, and 0.109 respectively). The mean pre-operative sagittal index was 19.6° (12° to 28°) which was corrected to -1.8° (-5° to 3°) post-operatively and 2.4° (0° to 8°) at final follow-up (p = 0.835 for sagittal deformity). No patient needed revision for loss of correction or failure of instrumentation.

Hyperlordotic reduction and short segment pedicle screw instrumentation and an intermediate screw is a safe and effective method of treating burst fractures of the thoracolumbar spine. It gives excellent radiological results with a very low rate of failure regardless of whether the fractures have a high or low load-sharing classification score.

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The diagnosis, classification and treatment of injuries to the thoracolumbar spine continue to attract controversy. The advent of transpedicular screw fixation systems have made short-segment pedicle screw instrumentation (SSPI) more reliable[1,2] but traditional SSPI involves placement of the pedicle screws only at the levels immediately adjacent to the fractured vertebral body. While this procedure is popular, several groups have reported an unacceptably high failure rate using this technique.[3-6]

The causes of failure appear to be the structural and mechanical deficiency of the anterior column, poor fixation in osteoporotic bone and insufficient points of fixation.[7,8] To prevent this, various surgical techniques such as transpedicular bone grafting, cementing, anterior approach-instrumentation and strut grafting or long-segment fixation,[9-12] have been used to augment the anterior column. These techniques have the disadvantage of lengthening the operating time and exposing the patient to the risk of additional morbidity over that of short segment transpedicular fixation.

In an attempt to achieve stiffer short-segment constructs, some surgeons add pedicle screws (termed intermediate or index-level screws at the level of the fractured vertebra.[7,12-14] Mahar et al[7] studied the clinical and biomechanical effects of adding an intermediate screw (IS) to the fractured vertebra (segmental fixation) and concluded that this technique increases construct stiffness and shields the fractured vertebral body from anterior loads and could be useful for treatment of thoracolumbar burst fractures that would otherwise require anterior column reconstruction.

Their study lacked sufficient patients (12) and length of follow-up (six months) to reach a definitive conclusion.

The purpose of this study was to evaluate and compare the effect of SSPI with IS on the radiological outcome in type A thoracolumbar fractures, as judged by the load sharing classification (LSC),[15] canal area reduction and remodelling.

Fig. 1a

Fig. 1b

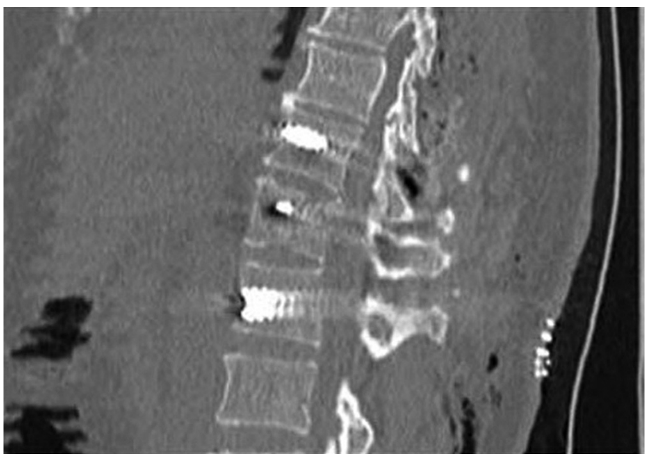

Fig. 1c

Fig. 1d

Fig. 1e

Fig. 1f

Pre-operative a) sagittal and b) axial CT view of a 43-year-old female with a T12 burst fracture with significant canal encroachment and ASIA-B neurological deficit. Immediate post-operative c) sagittal and d) axial CT view of same patient showing lordotic reduction of the fragments with good spinal alignment. e) Follow-up CT scan of same patient showing healed fracture with canal remodelling and f) standing radiograph of same patient at 24 months with no loss of correction.

Patients and Methods

After obtaining ethics committee approval for this study, we reviewed a consecutive series of 112 patients who had undergone surgery for a thoracolumbar fracture between 2009 and 2012. Our inclusion criteria were: fracture type A (according to the AO-Magerl classification)[16]; SSPI+IS and follow-up exceeding one year. Our exclusion criteria were: fracture type other than A; long segment instrumentation; short segment instrumentation without an intermediate screw; combined anterior-posterior surgeries; follow-up of less than one year; and pathological fractures, including those attributed to tumour or infection.

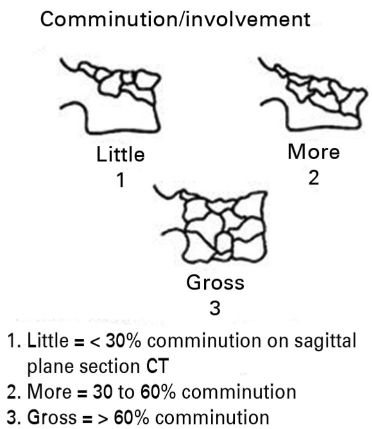

Fig. 2a

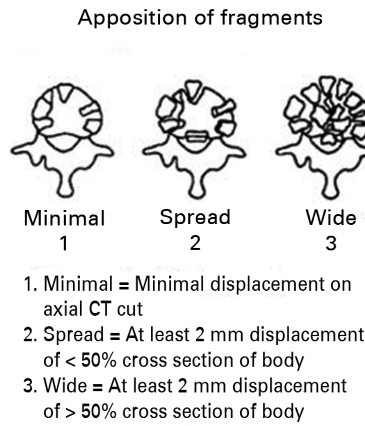

Fig. 2b

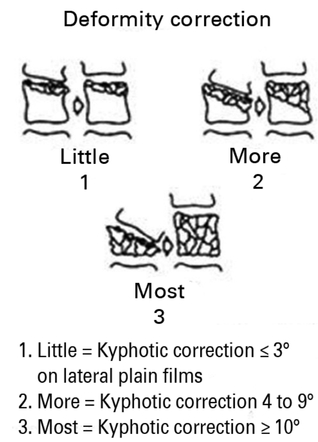

Fig. 2c

Line drawings showing the load sharing classification, as described by Mc Cormack et al[15]: a) comminution; b) apposition of fragments; c) deformity correction.

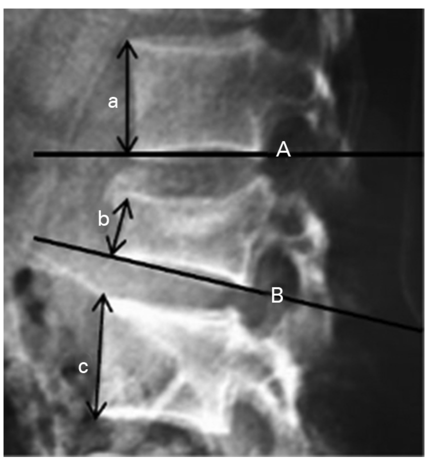

Fig. 3

Radiological measurements on a lateral radiograph. Sagittal index (SI) is the angle between lines A and B. Anterior body compression (ABC%) was calculated by dividing the anterior body height of the fractured vertebral body by the mean anterior body height of the intact vertebral bodies above and below the fractured vertebra: (b/[(a+c)/2]x100)

After application of the inclusion and exclusion criteria, 39 patients were left for study. Of the excluded 71 patients, only two were as a result of inadequate follow-up.

There were 26 men and 13 women with a mean age of 35 years (16 to 60). The mean follow-up was 22.9 months (12 to 36). The fracture types were A1.2 (n = 3); A1.3 (n = 4); A2.3 (n = 2); A3.1 (n = 8); A3.2 (n = 13), and A3.3 (n = 9). The details of their injury and treatment, including the type of trauma, level of fracture, neurological status (pre- and post-operative American Spinal Injury Association [ASIA] classification)[17] and complications were recorded. The patients and/or their families were informed that data from the case would be submitted for publication, and gave their informed consent.

All patients had pre-operative anteroposterior (AP) and lateral radiographs of their spine and a multiplanar CT scan. (Fig. 1). Each fracture was also retrospectively evaluated using the LSC described by McCormack et al[15] (Fig. 2). Each fracture was independently classified by two blinded senior attending spinal surgeons. Data were analysed according to two different subgroups. High-score fractures (n = 18) had a load sharing score (LSS) of ≥ 7. Low-score fractures (n = 21) had a LSS of ≤ 6.

The pre-operative, post-operative and follow-up radiographs were evaluated. Analysis of the plain radiographs included: Sagittal index (SI)[18] and percentage anterior body height compression (%ABC)[19] (Fig. 3). Data for initial, immediate post-operative and final follow-up radiological analyses were compared. At final follow-up, an increase in the local kyphosis of more than 10° over the early post-operative radiographs and/or implant failure were considered a failure.[9]

Pre-operative, post-operative and follow-up CT images through the levels of the pedicles of the involved vertebrae, as well as the adjacent levels, were obtained. The cross-sectional area of the injured spinal canal was estimated from a mean of the levels immediately above and below at the affected level and expressed as a percentage of the estimated value. This was done using the software tools in our Picture Archiving and Communication System (PACS) (Figs. 1 c-d).The measurements were done by a blinded researcher (EB) and all were checked again by a blinded senior spine surgeon (KCK).

Statistical analysis. This was performed using the unpaired *t*-test. Initial, immediate post-operative and final follow-up radiographs of the patients with LSS of ≤ 6 and ≥ 7 were compared in terms of the mean loss of sagittal correction. A p-value < 0.05 was considered statistically significant.

Table I. Distribution of fractures according to level

	T10	T11	T12	L1	L2	L3
High score (n = 18)	1	1	7	6	2	1
Low score (n = 21)	1	1	9	5	3	2

A classical posterior approach was used in all patients. The posterior ligamentous complex (PLC) and the facet joint capsules were preserved during the exposure. Monoaxial, bicortical and the thickest screws possible (usually 7 mm) were used in the upper and lower vertebrae and short polyaxial (5 x 30 mm to 35mm) screws in the middle (fractured) vertebra. The polyaxial screws were only intended to grip the pedicles: their angulation was not, therefore, critical.

Identical 6 mm titanium rods (with a stiffness of 35 on the Rockwell scale)[20] were bent to give a lordosis of 40º to 50°. They were first inserted into the upper screw and the bilateral set screws were tightened. The rods were then simultaneously cantilevered into the lowermost screws with *in situ* benders. The middle screws were tightened last.

When there was splaying of the pedicles in a burst fracture, placing the rods resulted in narrowing of the interpedicular distance: the pedicles grasped the fractured middle column and when the rod was cantilevered into the lower screw, the intermediate screw and the middle fragment were pushed forward thereby reducing the retropulsed fragment. Consequently, we used the same technique regardless of the degree of separation of the pedicles.

No compression or distraction was needed to reduce the fracture as the middle column had been reduced and anterior vertebral height restored. After the instrumentation had been sited capsulectomy and decortication of the facets was undertaken and fusion achieved using a mixture of autograft and allograft. No discectomies or laminectomies were performed, regardless of the neurological status of the patient. Post-operatively, all patients were mobilised immediately as tolerated without bracing. In the first 12 patients (none with a neurological deficit) spinal cord monitoring was used: we did not observe any intra-operative changes. In the remaining patients, we were unable to use this owing to a change in the reimbursement policy.

Results

The mean time from injury to operation was 21.2 hours (8 to 100) for the HS group and 23.6 hours (6 to 120) for the LS group. For the entire study group, the mean operating time was 66.9 minutes (45 to 110) and mean blood loss 298.8 ml (140 to 550).

The mean LSS was 7.7 (7 to 9) in the HS group and 5.3 (4 to 6) in the LS group. Groups were similar for distribution of the fractures by level (Table I). There were no significant differences between the low and high score groups in respect of age, duration of follow-up, pre-operative SI measurement or pre-operative %ABC. The mean pre-operative SI was 19.6° (12° to 28°) over the whole study group. It was corrected to a mean of -1.8° (-5° to 3°) by the operation, and was seen at final follow-up to have deteriorated to a mean of 2.4° (0° to 8°). Although the maximum loss of correction appears to be 8° (in one patient only), this patient was overcorrected to -5 degrees intra-operatively. At the last follow-up the kyphosis was only 3° but represented an 8° loss of correction. There were no significant differences between groups regarding the evolution of the sagittal plane deformity (Table II).

Mean spinal canal narrowing was 34.5% (10 to 75) at presentation and 10% (0 to 30) post-operatively. It further improved to a mean of 3.9% (0 to 20) at final follow-up in the entire group and was similar for both groups (Table II) (Fig. 1e). A total of four patients (10.3%) had a neurological deficit. All of these underwent surgery within 24 hours of presentation: the neurological status of two (1 ASIA-B, 1D) remained unchanged, one (ASIA D) improved to ASIA E, and one improved from ASIA B to D.

None of the patients had a loss of correction of more than 10°. There were no failures of instrumentation and no patient required revision surgery for either reason (Fig. 1f).

Three patients had a superficial wound infection and were treated with parenteral antibiotics and antiseptic dressings. One patient had a post-operative radiculopathy due to the intraforaminal placement of a pedicle screw. The screw was subsequently re-sited, which resulted in complete relief of the patient's symptoms. One patient had a degree of post-operative coronal imbalance and required a second procedure. Full balance was obtained in all patients.

Discussion

McCormack et al[15] introduced the LSC to determine which fracture patterns would be appropriate for SSPI. The severity of injury was based on a points system, a higher point total (≥ 7 points) predicting SSPI construct failure and indicating the need for a longer construct. In our study, although all patients underwent SSPI+IS regardless of the severity of injury, the group of patients with LSS ≥ 7 were no different in terms of radiological outcome from the group of patients with LSC scores ≤ 6. Similar results have been reported in previous studies.[7,13] We think that the two major factors leading to this outcome in our series are the use of thick bicortical screws and full restoration of anterior vertebral height and the physiological curvature of the spinal column.

Although short segment instrumentation is not a new concept, authors have recently begun to report the use of an IS with SSPI. In 2008, Mahar et al[7] reported the results of SSPI+IS in nine patients with fractures of AO type A3,

Table II. Patient demographics, summary of radiological measurements and details of unpaired*t*-test comparison of load share classification (LSC) high score and low score groups. SD, standard deviation

	Total	High Score	Low Score	p- value
Number of patients	39	18	21	
Mean age (years)	35.1 (16 to 60)	38.9 (16 to 55)	34.3 (17 to 60)	0.217
Gender (male/female)	26/13	14/4	12/9	
Mean LSC	6.4	7.7	5.3	
Follow-up (months)	22.9 (12 to 36)	22.9 (12 to 36)	21 (12 to 34)	0.104
Sagittal index				
Pre-operative	19.6 (SD 4.3)	20.8 (SD 4.4)	18.5 (SD 4.1)	0.104
Post-operative	-1.8 (SD 3.1)	-2.2 (SD 2.77)	-1.4 (SD 3.55)	0.442
Correction %	109.8 (SD 17.8)	112.4 (SD 12.4)	107.5 (SD 21.2)	0.404
Last follow-up (months)	2.4 (SD 2.6)	2.3 (SD 2.6)	2.5 (SD 2.6)	0.835
Correction loss	4.3 (SD 2)	4.6 (SD 2.4)	4 (SD 1.6)	0.370
Anterior body height compression (%)				
Pre-operatively	41.9 (SD 9.7)	44.8 (SD 7.3)	39.4 (SD 10.8)	0.109
Post-operatively	4.6 (SD 5.7)	4.1 (SD 5.8)	4.5 (SD 5.75)	0.852
Correction %	90.8 (SD 11.8)	92.1 (SD 10.7)	89.7 (SD 12.5)	0.530
Last follow-up (months)	6.6 (SD 6.3)	7.2 (SD 6.5)	6.1 (SD 6.1)	0.623
Correction loss	2 (SD 4.1)	3 (SD 4.4)	1.1 (SD 3.74)	0.174
Canal narrowing (%)				
Pre-operatively	34.5 (SD 18.7)	37.7 (SD 18.4)	31.9 (SD 18.6)	0.347
Post-operatively	10 (SD 8.3)	8.3 (SD 7.4)	11.4 (SD 8.7)	0.258
Correction %	25.7 (SD 14.4)	29.3 (SD 13.6)	22.6 (SD 14.3)	0.152
Last follow-up (months)	3.9 (SD 5.9)	2.7 (SD 5.5)	5 (SD 5.9)	0.252
Remodelling	5.3 (SD 8.7)	5.5 (SD 8.1)	5.2 (SD 9.1)	0.912

followed up for 4.4 months, with a mean LSC of 6.1. The mean loss of kyphosis correction at final follow-up was 5.4°. Guven et al[14] studied the effects of screw incorporation into the construct at fracture level and reported successful results in 18 patients. Their mean follow-up was 50 months. Gelb et al[13] reported on the use of an IS in 20 (13 bilateral, 7 unilateral) of 27 patients. The highest loss of correction was in four of the remaining seven patients who did not have an intermediate screw. Korovessis et al[12] compared combined anterior and posterior surgery with SSPI and SSPI+IS for mid-lumbar burst fractures; 40 patients with a Type A3 burst fracture S (L2-L4) and LSC ≤ 6 were randomly selected. After a mean follow-up of 48 months, the authors concluded that SSPI+IS resulted in a similar correction of the short-term kyphosis and a better clinical outcome (as measured by Short Form-36 scores) when compared with combined surgery.

Biomechanical studies related to IS have been published. In the experimental cadaveric part of a study by Mahar et al[7] L2 burst fractures were mimicked in six intact spines. They found that segmental fixation, with pedicle screws inserted at L1-L2-L3, resulted in significantly greater construct stiffness than non-segmental fixation with pedicle screws inserted at L1 and L3. Wang et al[21] compared monoaxial and polyaxial IS in models of an unstable L3 burst fracture. Their results suggest that addition of intermediate screws significantly increases the stability of constructs with a decreased range of movement in flexion, extension, and lateral bending in both mono-IS and poly-IS groups. However, in the short-segment fixation group, mono-IS were more stable in flexion and extension than polyaxial-IS. In a cadaveric model, Baaj et al[22] tested T10-L4 specimens with an unstable three-column fracture simulated at the L1 level. Four constructs were tested as follows: one-above-one-below (short construct) with/without index-level screws and two-above-two-below (long construct) with/without index-level screws. Their results suggest that adding index-level pedicle screws to short-segment constructs improves stability, although it remains less than that provided by long-segment constructs with/without index-level pedicle screws.

In most burst fractures, the posterior column at the level of the fracture remains intact and provides additional points of fixation. In our study, we used polyaxial screws of 5 mm diameter and 30 mm to 35mm length as IS. The pedicle, rather than the vertebral body, contributes approximately 80% of the stiffness and 60% of the pullout strength.[23-25] Zindrick et al[26] reported no difference in pullout strength between similarly sized screws halfway or completely to the anterior cortex. They too reported that the more cortices are penetrated, the stronger the fixation.[26] We believe that longer screws extending to the anterior cortex do not provide any anterior support to the fractured vertebra, as the upper endplate and the anterior part of the body have already been disrupted. In addition, in highly comminuted fractures where the vertebral body is a 'bag of bones', insertion of a large diameter screw may cause distraction of the bone fragments and impede healing. With our technique, as the screw shaft occupied a very limited amount of the fractured vertebral body, reduction of the fragments was possible by creating tension around the anterior and posterior longitudinal ligaments. Using a polyaxial screw with an increased offset (compared with a monoaxial screw), we aimed to raise the fulcrum and increase the forward thrust at the fractured level, while reducing the rod onto the lower end vertebra (three-point bending and fixation principle). This forward thrust caused tensioning of both the anterior and posterior longitudinal ligaments, forcing them to act like splints: we were then able to restore the fractured vertebra to its original rectangular shape. We do not think that the risk of canal compromise is increased, because the pivot of the cantilever is the polyaxial head of the intermediate screw, not the fractured middle column. This is why compression occurs at the level of and posterior to the screw head and distraction occurs in all the structures that lie anterior to it.

In our opinion, opening the canal is unnecessary in patients with an incomplete neurological lesion. The stenosis is substantially the result of the kyphotic deformity rather than retropulsion of a fragment.[27] In a series of 95 fractures, Leferink et al[28] observed that only 2.4% of patients had a residual stenosis two years after surgery compared with 76.5% pre-operatively and 18.5% in the immediate post-operative period. By contrast, the origin of the syrinx responsible for the neurological deficit is at the apex of the local hyperkyphosis. Opening the canal is not devoid of risks (spinal cord injury, bleeding, post-operative haematoma) and in fact seems to increase the risk of non-union. Our findings show that the intermediate screw has no significantly negative effect on canal reduction and remodelling and although we did not open the canal in any patient, we saw no neurological deterioration.

We used hyperlordotic reduction in our patients. To achieve hyperlordosis, we did not perform any *in situ* bending of the rod but precontoured the rods and cantilevered them into the screws. We believe that hyperlordotic reduction directs the axial load more posteriorly than neutral or kyphotic reduction. The posterior structures are intact and can bear weight much better than the already disrupted anterior column. This load-sharing property of the posterior column has two advantages: first, a potential decrease in implant failure and second, a decrease in loss of correction as the vertebral body converts in time from a 'bag of bones' to a 'solid body' under tension (Fig. 1f). This is especially important during the first six months when most of loss of correction occurs.[7,29] This view is supported by the fact that we had almost no loss of correction or implant failure at final follow-up.

There are limitations to this study. The investigation was retrospective and the effect of hyperlordotic reduction on overall sagittal balance was not studied (we are currently working on this). In addition, the numbers are small when each thoracic or lumbar segment is individually evaluated and when subtypes of type-A are considered. The functional outcomes were not reported as they were affected by comorbidities and additional fractures of extremities.

The strengths of this study are: reporting of the largest number of patients; medium to long-term follow-up; when compared with other spinal literature; a very low rate of patient exclusion (2 of 41) due to insufficient follow-up and the reporting of hyperlordotic reduction at all levels for the first time.

In conclusion, hyperlordotic reduction and SSPI+IS is a safe and effective method of treating thoracolumbar burst fractures. This technique yields excellent radiological results with a very low rate of failure regardless of whether the fractures score high or low.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this study.

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