Retrospective analysis of treatment of thoracolumbar burst fracture using mono-segment pedicle instrumentation compared with short-segment pedicle instrumentation

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Abstract

Objective To investigate the safety and therapeutic effects of mono-segmental pedicle instrumentation (MSPI) in treating thoracolumbar burst fracture (AO classification: A3.1 and A3.2).

Methods A retrospective analysis was conducted on 60 cases with thoracolumbar burst fracture (AO classification: A3.1 and A3.2) between April 2005 and February 2010. Half of the 60 inpatients were treated with MSPI, and the other half was treated with short-segment pedicle instrumentation (SSPI). The mean operation time, blood loss, visual analog scale (VAS) and vertebral kyphotic angle before and after surgery were compared.

Results In the MSPI group, the mean operation time was 90 ± 25 min, and the blood loss at operation was 180 ± 62 ml. The vertebral kyphotic angles were $17.3^\circ \pm 9.3^\circ$ before surgery, $6.5^\circ \pm 6.5^\circ$ one week after surgery, and $9.5^\circ \pm 6.4^\circ$ for the latest follow-up. The VAS scores were 7.5 ± 1.4 before surgery, 2.5 ± 0.7 one week after surgery, and 1.4 ± 0.8 for the latest follow-up. In the SSPI group, the mean operation time was 101 ± 28 min, and the blood loss at operation was 203 ± 88 ml. The follow-up duration was 12–64 months. The vertebral kyphotic angles were $16.5^\circ \pm 9.1^\circ$ before surgery, $7.1^\circ \pm 6.9^\circ$ one week after surgery, and $7.5^\circ \pm 5.2^\circ$ for the latest follow-up. The VAS scores were 6.7 ± 1.5 before surgery, 3.0 ± 0.4

one week after surgery, and 1.1 ± 0.6 for the latest follow-up. There were no statistically significant differences between these two groups in the operation time, blood loss at operation, VAS score and vertebral kyphotic angle before and after surgery ($p > 0.05$). The post-surgical VAS scores and vertebral kyphotic angles were significantly decreased in both groups, compared to before surgery ($p < 0.05$).

Conclusions It is safe and effective to treat thoracolumbar burst fractures (AO 3.1 and AO 3.2) with MSPI. The mean operation time, blood loss at operation, post-surgical VAS and vertebral kyphotic angle of the MSPI group are similar, compared to the SSPI group. Further research is needed to find out whether therapeutic effects of MSPI are better than those of conservative treatment in these cases.

Keywords Spinal fractures · Fracture fixation · Mono-segmental pedicle instrumentation · Short-segment pedicle instrumentation

Background

The definition of thoracolumbar burst fracture was put forward by Holdsworth in 1963. A substantial axial loading force is responsible for a thoracolumbar burst fracture. Falls from a height, vehicle accidents and direct traumas are usual causes for the majority of thoracolumbar burst fractures. By definition, burst fractures are associated with some degree of canal compromise mostly resulting from retropulsion of bone fragments [1]. As a result of neural compression, patients suffering from thoracolumbar burst fracture frequently manifest neurologic deficits (medullary cone and equine caudal injury), approximately 50% according to some reports [2]. The patients suffered a lot

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and the financial burdens of their families and society were aggravated.

Despite continued controversy, most authors agree that neurologic impairment is an indication for operative decompression and stabilization of thoracolumbar burst fractures [3–6]. There were middle column injuries in thoracolumbar burst fracture, so a lot of surgeons thought that it was an unstable spinal fracture. According to the AO classification method, these fractures can be divided into three categories, partial burst (AO 3.1), burst-split (AO 3.2), and complete burst (AO 3.3). In the partial burst fracture (AO 3.1), there is a failure in the superior or inferior portion of the vertebral body, with the remaining section intact. If there is a sagittal split fracture through this remaining portion of the body, the injury can be classified as a burst-split (AO 3.2). In both types of fractures, the pedicles are intact. In complete burst fractures, both the end plates would show failure (AO 3.3) [7, 8]. Type A3.1 and A3.2 with more than 50% loss of anterior body height and significant regional kyphosis, or wedging ($>30^\circ$ at the thoracolumbar junction, or $>10^\circ$ in lumbar spine), are better treated by operation [9]. The optimal treatment remains controversial, as evidenced by the variety of surgical management options available. These include posterior reduction and decompression by indirect (ligamentotaxis) [10, 11] and direct posterolateral methods (costotransversectomy or transpedicular approaches) with short- or long-segment instrumentation, direct anterior decompression (with or without instrumentation), and combined antero-posterior approaches. The improved rigidity and stiffness of pedicle screw-based posterior spinal instrumentation systems have made short-segment pedicle screw instrumentation (SSPI) more reliable. After the development of the load-sharing classification (LSC) [12], more and more authors believed that on the condition of no severe anterior column defect, treatment of thoracolumbar burst fractures by SSPI will achieve clinical success [4, 5, 13–15].

Short-segment pedicle instrumentation has been widely used to treat thoracolumbar burst fracture (AO 3.1 and AO 3.2). During the SSPI procedure, screws are implanted into the pedicles adjacent to the injured one to fix the two adjacent vertebral bodies, which can easily cause adjacent segment degeneration and broken screws/rods. Hence, researchers have paid close attention to mono-segmental pedicle instrumentation (MSPI) with screws in fractured vertebrae in recent years due to its intact pedicles [16]. In the present study, a retrospective analysis was conducted on 60 cases with thoracolumbar burst fracture (AO 3.1 and AO 3.2) between April 2005 and February 2010, to evaluate the efficacy and safety of MSPI application in the treatment of thoracolumbar burst fracture (AO 3.1 and AO 3.2).

Methods and materials

Case materials

Thirty cases of thoracolumbar burst fracture (18 male, 12 female) treated by MSPI between September 2008 and February 2010 were included for analysis. Pre-surgical three-dimensional CT examination was performed to investigate pedicle and vertebral displacement. All patients were with unilateral end-plate injury, but the pedicles were intact. According to our experience, in the case of severe vertebral compression (3/5 vertebral body height loss), preoperative measurements revealed that the pedicle screw would definitely be inserted into the fractured part of the vertebrae, which in turn would affect the screw pull-out force and the fracture healing. Thus, we do not recommend treating such patients with MSPI. Cases of over-sized bone in the spinal canal and neurological deficit were excluded. The 30 patients were aged between 29 and 54 years, with an average age of 41.3 years. The most frequent fractured level was L1 (13 patients, 43%). Fractures of L2 accounted for 20% (6 patients). Fractures of T12 accounted for 20% (6 patients). T11 accounted for 13% (4 patients). Only one level was L3. The AO classification was A3.1 for 28 cases and A3.2 for 2 cases. All patients were assigned to ASIA E according to the American Spinal Cord Injury Association (ASIA) Impairment Scale (Table 1).

Thirty cases of thoracolumbar burst fracture (18 male, 12 female) treated by SSPI between April 2005 and September 2008 were included for comparison. Pre-surgical three-dimensional CT examination was also performed to make sure that all these 30 SSPI treated patients had similar intact pedicles, vertebral displacement, and vertebral height loss as those of the MSPI group. The 30 patients were aged between 30 and 53 years, with an average age of 40.2 years. The most frequent fractured levels were L1 (9 patients, 30%) and T12 (9 patients, 30%), T11 accounted for 20% (6 patients). L2 accounted for 16.7% (5 patients). Only one level was L3 (Table 2). Cases of over-sized bone in the spinal canal, severe vertebral compression and neurological deficit were excluded.

MSPI surgical method

With the patients under general anesthesia and in a prone position, pillows were put underneath the chest and the iliac to hang the abdomen in the air. The skin of the midline was incised to expose the fractured part from the bilateral lamina to the outer facet. Screw fixation was performed with screws inserted into the injured vertebral body. The insertion direction of screws can be adjusted using fluoroscopy. After that, screws were inserted into

Table 1 MSPI patients chart

Patient no.	Age (year)/ Sex	ASIA SCORE	Fracture level	Fracture type of AO-ASIF classification	Kyphotic angle (°)
1	29/M	E	L1	A3.1	10
2	32/M	E	L2	A3.1	11
3	40/F	E	T12	A3.1	30
4	51/M	E	T11	A3.1	11
5	38/M	E	L1	A3.1	11
6	42/M	E	L2	A3.1	12
7	33/F	E	L1	A3.1	11
8	41/M	E	L1	A3.1	11
9	51/M	E	L1	A3.1	18
10	50/M	E	T11	A3.1	29
11	36/F	E	T12	A3.1	31
12	49/F	E	T12	A3.1	32
13	43/M	E	T11	A3.1	13
14	44/M	E	L1	A3.1	12
15	29/M	E	L1	A3.2	10
16	42/F	E	L2	A3.1	10
17	50/F	E	L1	A3.1	12
18	36/F	E	T11	A3.1	31
19	37/M	E	T12	A3.1	34
20	48/M	E	T12	A3.1	30
21	44/F	E	L1	A3.1	13
22	43/M	E	L1	A3.1	10
23	54/F	E	L2	A3.2	31
24	40/F	E	T12	A3.1	32
25	41/F	E	L3	A3.1	11
26	42/M	E	L2	A3.1	11
27	32/M	E	L1	A3.1	11
28	31/M	E	L1	A3.1	10
29	45/F	E	L2	A3.1	15
30	46/M	E	L1	A3.1	10

the vertebrae adjacent to the injured endplate (if the broken endplate was the superior and the adjacent vertebra was the upper, or if the broken endplate was the inferior and the adjacent vertebra was the lower). It was difficult to use techniques including distraction of anterior column and in situ bending of the rods, because the distance between adjacent screws was too small. Indirect reduction of the fracture was achieved by the rod contouring, which was variably curved according to the expected angular correction. After reduction, the screws were tightly fixed. The incision was rinsed with saline. Allogeneic bones were implanted into the inter-laminar and facet joint zone, and negative pressure drainage was performed. After the surgery, patients were treated with analgesics or analgesia pump for 72 h. The drainage tube was removed after 48–72 h. Patients started to walk with TLS brace after 1 week. Fixation was removed after 1 year.

SSPI surgical method

The patient is placed in the same position, but the incision is longer than that of MSPI. The pedicle screws were inserted through pedicle, one level above and one level below the injured vertebra. Some reduction techniques were used, such as distraction of anterior and posterior column and in situ bending of the rods. After reduction, the screws were tightly fixed. After the surgery, patients were treated with analgesics or analgesia pump for 72 h. The drainage tube was removed after 48–72 h. Patients started to walk with TLS brace after 1 week. Fixation was removed after 1 year.

Follow-up

Posterior-anterior and lateral spine X-ray was performed before and 1 week after the surgery, as well as every 3 months. After 1 year, posterior-anterior and lateral spine X-ray was

Table 2 SSPI patients chart

Patient no.	Age (year)/Sex	ASIA SCORE	Fracture level	Fracture type of AO-ASIF classification	Kyphotic angle (°)
1	52/M	E	L1	A3.1	9
2	30/F	E	T11	A3.1	11
3	45/F	E	L1	A3.1	10
4	39/F	E	L2	A3.1	22
5	36/M	E	T11	A3.1	9
6	39/M	E	L1	A3.1	12
7	35/F	E	T12	A3.1	11
8	51/F	E	T11	A3.1	10
9	51/M	E	L2	A3.1	18
10	50/M	E	T12	A3.1	10
11	35/M	E	L1	A3.1	28
12	45/F	E	T12	A3.1	11
13	53/F	E	T11	A3.1	34
14	38/M	E	T12	A3.1	10
15	49/M	E	L1	A3.2	30
16	50/M	E	L2	A3.1	9
17	45/M	E	T11	A3.1	10
18	32/F	E	L1	A3.1	32
19	34/M	E	L2	A3.1	11
20	45/M	E	T12	A3.1	10
21	44/F	E	L1	A3.1	9
22	34/M	E	T12	A3.1	10
23	49/F	E	T11	A3.1	9
24	40/M	E	T12	A3.1	22
25	39/M	E	L2	A3.2	32
26	44/M	E	L3	A3.1	22
27	45/M	E	L1	A3.1	10
28	44/F	E	T12	A3.1	34
29	30/M	E	T12	A3.1	11
30	53/F	E	L1	A3.1	31

performed during the annual follow-ups. The vertebral kyphotic angle was measured. The operation time, blood loss, and pre- and post-surgical (1 week after surgery and the latest follow-up) visual analog scale (VAS) scores were recorded.

Statistical analysis

All data were shown as standard deviation ($\bar{x} \pm s$). Significance was assessed by paired Student's *t* test using SPSS 15.0 software (SPSS Inc., Chicago, IL, USA). A difference at $p < 0.05$ was considered statistically significant.

Results

Mono-segment fixation group

Screws were implanted into the pedicles without any difficulty. The operation lasted 75–125 min, with an average

Table 3 Operation time, blood loss, and drainage ($\bar{x} \pm s$)

Group	Operation time (min)	Blood loss (ml)	Drainage (ml)
MSPI	90 $\pm$ 25	180 $\pm$ 62	126 $\pm$ 25
SSPI	101 $\pm$ 28	203 $\pm$ 88	141 $\pm$ 38
<i>p</i>	>0.05	>0.05	>0.05

time of 90 min. The blood loss was 60–240 ml at operation, with an average of 180 ml (Table 3). Patients were monitored 12–26 months for follow-up evaluation, with an average of 13.2 months. All the patients were monitored for more than 12 months. The post-surgical (1 week after surgery, and the latest follow-up) VAS scores and vertebral kyphotic angles were significantly decreased, compared to before surgery ($p < 0.05$). The VAS scores and vertebral kyphotic angles did not show significant differences between the two post-surgical time points ($p > 0.05$) (Table 4). No neurological deficit or fixation-related complicating disease

Table 4 Efficacy of MSPI and SSPI ($\bar{x} \pm s$)

Group	Vertebral kyphotic angle (°)			VAS		
	Pre-surgery	1-week post-surgery	Latest follow-up	Pre-surgery	1-week post-surgery	Latest follow-up
MSPI	17.43 $\pm$ 9.3	6.5 $\pm$ 6.5 ^a	9.5 $\pm$ 6.4 ^a	7.5 $\pm$ 1.4	2.5 $\pm$ 0.7 ^a	1.4 $\pm$ 0.8 ^a
SSPI	16.5 $\pm$ 9.1	7.1 $\pm$ 6.9 ^a	7.5 $\pm$ 5.2 ^a	6.7 $\pm$ 1.5	3.0 $\pm$ 0.4 ^a	1.1 $\pm$ 0.6 ^a
<i>p</i>	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05

Compared to pre-surgery, ^a $p < 0.05$

was detected for any patient. Only one case of wound seroma was observed and resolved.

Short-segment fixation group

The operation lasted 80–150 min, with an average time of 101 min. The blood loss was 50–240 ml at operation, with an average of 200 ml (Table 3). Patients were monitored 12–64 months for follow-up evaluation, with an average of 34.6 months. The post-surgical (1 week after surgery, and the latest follow-up) VAS scores and vertebral kyphotic angles were significantly decreased, compared to before surgery ($p < 0.05$). The VAS scores and vertebral kyphotic angles did not show significant difference between the two post-surgical time points ($p > 0.05$) (Table 4). One case of broken screw was observed after 1 year. Following the removal of the broken screw, the vertebral kyphotic angle of the patient did not show increase in the next 2 years. In addition, one case of adjacent segment degeneration (intervertebral bone spurs) was observed, 36 months after surgery. Fixation was removed for all patients 1 year after surgery.

Comparison between MSPI and SSPI

The MSPI and SSPI groups showed similar mean operation time, blood loss at operation, post-surgical VAS and vertebral kyphotic angle (Table 4; $p > 0.05$). Typical case images are shown in Figs. 1, 2, 3, 4, 5, 6, 7, 8, and 9.

Discussion

The mechanical deficiency of SSPI and the advantage of MSPI

SSPI has been widely accepted as an advanced approach to treat thoracolumbar burst fracture since the first report by Roy-Camille [17]. The insertion of screws and rods into the vertebral bodies proximal and distal to the injured one can stretch the anterior and posterior longitudinal ligaments, and subsequently help to restore the injured vertebral body. However, because two motion segments of spine were

Fig. 1 Male patient (42 years old), admitted into the hospital with post-traumatic back pain for 2 h without neurological deficit, diagnosed as L2 fracture (AO A3.1). Pre-surgical lateral spine X-ray showing a vertebral kyphotic angle of 15°, 3 h after injury

Fig. 2 Male patient (42 years old), admitted into the hospital with post-traumatic back pain for 2 h without neurological deficit, diagnosed as L2 fracture (AO A3.1). Pre-surgical CT examination showed that the pedicles were intact after 3 days

Fig. 3 Male patient (42 years old), admitted into the hospital with post-traumatic back pain for 2 h without neurological deficit, diagnosed as L2 fracture (AO A3.1). Lateral spine X-ray taken 1-week post-surgery showing a vertebral kyphotic angle of 2°

Figs. 4, 5 Male patient (42 years old), admitted into the hospital with post-traumatic back pain for 2 h without neurological deficit, diagnosed as L2 fracture (AO A3.1). CT and lateral spine X-ray taken 3-month post-surgery showing the vertebral kyphotic angle is 2°

fixed, the long rod and high-force moment of SSPI can directly lead to high stress between the rods and the screws, broken rods and screws have frequently been observed in clinical practice. It has also been suggested that SSPI could easily induce loss of correction [18] and degeneration of adjacent segments [19].

To avoid the occurrence of complicating disease and to reduce surgical trauma and fixed segments, our hospital has been treating thoracolumbar burst fracture using the newly

Fig. 6 Male patient (42 years old), admitted into the hospital with post-traumatic back pain for 2 h without neurological deficit, diagnosed as L2 fracture (AO A3.1). Lateral spine X-ray taken 1-year post-surgery

developed MSPI technique since 2008. Our results have shown that the vertebral kyphotic angle decreased from pre-surgical $17.3^\circ \pm 9.3^\circ$ to post-surgical $6.5^\circ \pm 6.5^\circ$ for MSPI treated patients, and from pre-surgical $16.5^\circ \pm 9.1^\circ$ to post-surgical $7.1^\circ \pm 6.9^\circ$ for SSPI treated patients. The rectification of the vertebral kyphotic angle by MSPI was not significantly different from SSPI. This is probably because during MSPI, the stretching stress can be directly applied to the anterior and posterior longitudinal ligaments which are connected to the vertebrae on the injury side of vertebral bodies; whereas during SSPI, the stretching stress can only be indirectly applied to the longitudinal ligaments through a normal intervertebral space, which subsequently leads to attenuation of the stretching stress. Furthermore, MSPI only needs to fix one spinal segment, which utilizes shorter rods and lower force-moments compared to SSPI, and thus can reduce the risk of broken screws or rods. In our study, we did not observe any case of broken fixation in the follow-ups.

In our study, fixation was removed for all patients treated with either SSPI or MSPI. It has been suggested that removal of fixation might cause loss of vertebral kyphotic angle rectification in patients with complete vertebral fracture (AO A3.3). These results can be caused by vertebral body collapse resulting from insufficient bone implanted in the vertebral bodies, or by deteriorated local kyphosis due to irreparable intervertebral disc injury [20]. In our study, removal of fixation did not cause obvious loss of rectification of vertebral kyphosis, probably because we selected patients with thoracolumbar burst fracture (AO 3.1 and AO 3.2), and interlaminar bone implantation was conducted to prevent collapse of the intervertebral disc.

Fig. 7 Male patient (42 years old), admitted into the hospital with post-traumatic back pain for 2 h without neurological deficit, diagnosed as L2 fracture (AO A3.1). Lateral spine X-ray taken after taking the instrument away

Fig. 8 Male patient (42 years old), admitted into the hospital with post-traumatic back pain for 2 h without neurological deficit, diagnosed as L2 fracture (AO A3.1). The vertebral kyphotic angle is 2° and the bone is healed

In addition, the follow-up time of MSPI treated patients was as short as 12 months, which might also have made a contribution. Thus, long-term follow-up is required to determine whether vertebral kyphosis rectification can be affected by removal of fixation in MSPI treated patients.

Fig. 9 Male patient (42 years old), admitted into the hospital with post-traumatic back pain for 2 h without neurological deficit, diagnosed as L2 fracture (AO A3.1). CT scan taken 2-years post-surgery showing the laminar and facet of L1 and L2 were fused (marked by arrows)

The stability of pedicle fixation in injured vertebral bodies

Biomechanics studies have suggested that when pedicle screws are inserted to fix the spine, the pedicle provides at least 60% anti-withdrawal force and 80% axial stiffness, whereas vertebral cancellous bones only provide 20% anti-withdrawal force. Thus, the strength of the holding force of the pedicle screws is largely determined by the pedicles. Furthermore, since the pedicle screws are inserted into normal healthy bones, they move towards the uninjured endplate during the process of vertebral body rectification, and thus stress is applied to the healthy vertebral bone. Therefore, for AO A3.1 and A3.2 types of patients, the holding force provided by pedicle screws inserted through the pedicles of injured vertebral bodies can theoretically be close to that of normal vertebral bodies.

Past animal studies have revealed that compared to MSPI, SSPI showed statistically higher stability only in flexion activities [21], suggesting that the initial stability of MSPI is good enough. Our results showed that for MSPI patients, fixation was not destroyed during early post-surgical brace supported walking activities. Therefore, MSPI can be clinically used to treat spinal fracture.

Surgical indications

MSPI can be used to treat AO A3.1 and A3.2 types of patients with thoracolumbar burst fracture in the absence of neurological deficit. In any case, pre-surgical three-dimensional CT examination is required to determine the type of fracture and to insure unilateral end-plate injury, but the pedicles were intact.

For cases of over-sized bone in the spinal canal and neurological deficit in AO A3.1 and A3.2 patients, a previous study suggested that spinal cord decompression should be performed prior to MSPI treatment. In this study, only one case of loose screw was observed. This patient had to be operated again by removing the loose screws and long-segment fixation to correct the progressed kyphosis at last. However, in the same study, patients could not walk with a brace until 1 month after surgery [22]. Interestingly, in another study, patients without prior spinal cord decompression could walk as early as 5 days after surgery [23]. Because spinal cord decompression destroys the rear structure of the spine and reduces the spinal stability, we think that the initial stability of MSPI may not be good. Further biomechanical study will be required to verify our view.

For AO A3.3 type patients with serious spinal fracture, we thereby suggest that MSPI should not be used because of its collapsed vertebra.

In addition, MSPI cannot be used to treat patients with serious osteoporosis, because the screws cannot be held well.

Compared to SSPI, MSPI has less fixed segment and thus can reduce trauma, while providing similar stability. The length of the fixation can be limited to the injured area without compromising the result, which can help to preserve spinal mobility. Hence, MSPI can be used to treat thoracolumbar burst fracture (AO 3.1 and AO 3.2) without neurological deficit. However, until now, the surgical treatment of thoracolumbar fracture (AO A3.1 and A3.2) without neurological deficit is still controversial. Further research is needed to find out whether therapeutic effects of MSPI are better than those of conservative treatment in these cases.

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Conflict of interest None.

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