CLINICAL ARTICLE

J Korean Neurosurg Soc 40 : 249-255, 2006

Dorsal Short-Segment Fixation for Unstable Thoracolumbar Junction Fractures

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Objective : This study is to evaluate the efficacy of dorsal short-segment fixation in unstable thoracolumbar junction fractures.
Methods : The cases of 20 patients who underwent dorsal short-segment fixation were reviewed retrospectively. Clinical outcomes were analysed using Sonntag's pain level, work status, and neurological scale according to the modified Frankel classification. Radiological outcomes were analysed using Mumford's anterior body compression(%), canal compromise ratio, and Cobb's kyphotic angle.
Results : At the latest clinical follow-up (average=14.6 months), there were 19 (95.0%) in group I and 1 patient (5.0%) in II in pain level[35]. The postoperative work status were 17 (85.0%) in group I, 2 patients (10.0%) in II, and 1 patient (5.0%) in V. Surgery brought to improve the neurologic status. In success group (19 cases, 95%), the average canal compromise ratio was reduced from 0.57 (±0.07) to 0.05 (±0.08) ($P<0.05$), the average anterior body compression (%) was reduced from 41% (±17) to 18% (±14) ($P<0.05$), and the average preoperative kyphotic angle was 20.0° (±9.0), and corrected to 5.7° (±7.1) postoperatively, and progressed to 7.8° (±6.2) at the latest follow-up. There was a case of implantation failure in an elderly osteoporotic patient.
Conclusion : Although there are limitations in the patient number and follow-up period, the present study favors dorsal short-segment fixation for selective cases in unstable thoracolumbar junction fractures.

KEY WORDS : Unstable thoracolumbar junction fracture · Articulectomy · Dorsal reduction · Dorsal short-segment fixation.

Introduction

The thoracolumbar junction vertebrae make up the "hinge junction" of the thoracic and lumbar spine and are particularly vulnerable to traumatic injury. Non-operative management has been shown to be effective if there is minimal spinal canal compromise, intact dorsal elements, and no neurologic deficit[10].

Although surgical intervention is generally considered if the neurological deficits are progressive or imminent[38], the optimal treatment strategy for the full spectrum of all thoracolumbar junction fractures is still under debate. There are several surgical options in these injuries, for example ventral or dorsal approach, short- or multi-segmental fixation, bone graft or not, and so forth[1,2,17,22,23,32,37].

Ventral approach is available for adequate decompression and the ventral strut for axial loading, but requires extensive surgical procedure with morbidity of thoracostomy and may be necessary for staged dorsal procedure. Medical complications are relative contraindication[30]. Lateral extracavitary approach requires extensive muscle dissection and has difficulty to visualize the contra-lateral pedicle by unilateral approach.

Multi-segmental fixation can achieve firmer fixation, but may result in stiffness and discomfort.

The main advantages of the dorsal approach with short-segment fixation is to preserve motion segment, and to have the simplicity and the familiarity to the spine surgeon, but a recognized disadvantage is the difficulty in restoring the anterior column. Failure to restore the anterior column support can lead to secondary kyphosis, instability, pain, and late onset neurological deficit, depending primarily on the residual load transfer capacity of the fractured vertebral body[22]. This study is to evaluate the efficacy of dorsal short-segment fixation in unstable thoracolumbar junction fracture.

• Received : April 26, 2006 • Accepted : May 29, 2006
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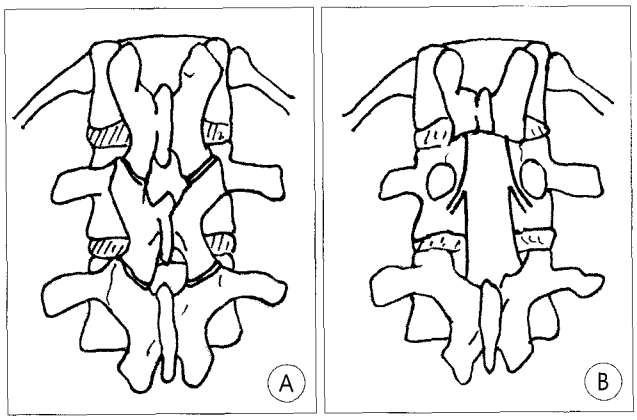

Fig. 1. Illustration showing the extent of dorsal decompression. A : Preoperative. B : Postoperative.

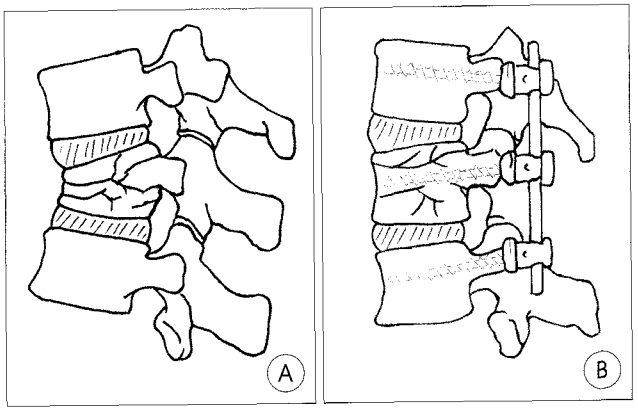

Fig. 3. Illustration of dorsal short-segment fixaion. A : Injured segment showing bursting fracture, canal compromise and kyphotic deformity. B : Dorsal short-segment fixation confined to a level above and below the injured segment including the injured segment.

Materials and Methods

This is a retrospective review of 20 patients with unstable thoracolumbar junction fractures managed by dorsal short-segment fixation. There were 12 males and 8 females. Their average age at the time of surgery was 37.3 years (range : 20~62 years). The majority of the injuries resulted from fall from a height (16 cases, 80.0%) and 4 cases (20.0%) from vehicle accidents. There were 18 cases (90.0%) in one level injury and 2 cases (10.0%) in two levels injury. Their injury levels were T12 in 5, L1 in 11, and L2 in 6 cases. The most recent clinical follow-up assessment was attempted and the average follow-up period was 14.6 months.

Indications for surgical instrumentation in this entire series included the presence of any one or more of the followings : presence of neurologic involvement caused by the fracture, kyphosis more than 20°, loss of vertebral body height by more than 50%, compromise of spinal canals, or any other instability which are based on the criteria of unstable thoracolumbar fracture by McAfee et al[21].

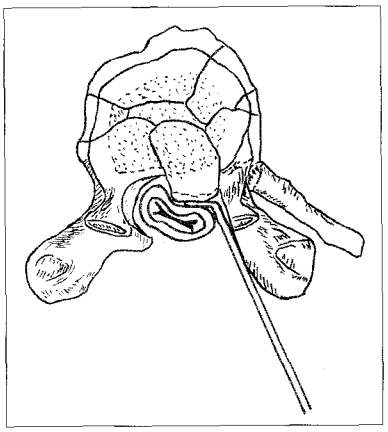

Fig. 2. Illustration of injured segment showing reimpaction of the retropulsed bony fragments anteriorly into the vertebral body using reverse-angled curet.

In highly comminuted fractures and severly midline retropulsed fragments (canal compromise ratio >0.70) with anticipated load sharing, we performed ventral approach with strut grafting. In cases of pedicle fracture(s), "two above and one below" pedicle screw constructs were performed. We excluded these cases in this study.

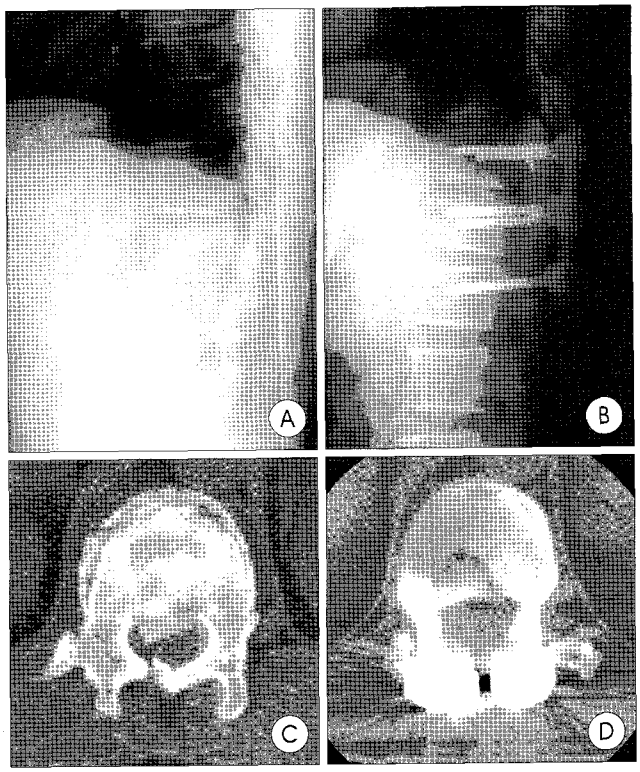

Fig. 4. A case of 36-year-old male patient with T12 bursting fracture. A : Preoperative plain radiograph. B : Postoperative plain radiograph showing dorsal short-segment pedicle screw fixation on T11, T12 and L1 at 7 months. C : Preoperative computed tomography(CT) scan showing apposition of bony fragments into the spinal canal with laminar impingement. D : Postoperative CT scan showing restoring the bony fragments into the original position.

Operations were performed by standard dorsal midline approach. In 13 cases of anterior canal compromise due to bone fragments into the spinal canal, wide bilateral total laminectomy of injured segment and partial laminectomy of adjacent upper segment so far as articulectomy were performed, according to circumstances partial pediclectomy was performed (Fig. 1),

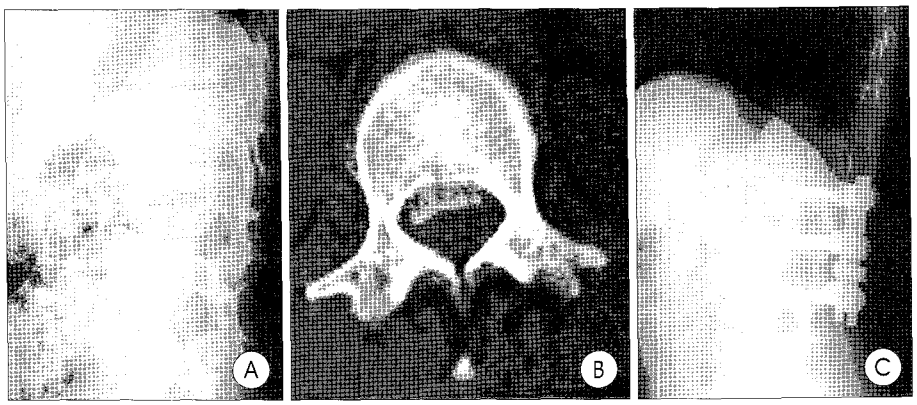

Fig. 5. A case of 26-year-old female patient with L1 bursting fracture. A : Preoperative plain radiograph. B : Preoperative computed tomography(CT) scan showing apposition of bony fragments into the spinal canal. C : Postoperative plain radiograph showing dorsal short-segment pedicle screw fixation on T12, L1 and L2 at 27 months.

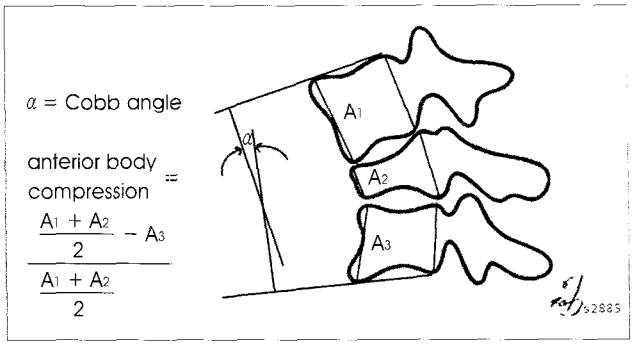

Fig. 6. Illustration of Cobb angle and formula used to measure anterior body compression using the formula by Mumford et al.[25] from plain radiograph.

then worked laterally, or infero- or supero-laterally to the thecal sac to dissect fragments off the cord and to reimpact bone fragments anteriorly into the vertebral body by using reverse-angle curet or small impactor (Fig. 2). There were 2 cases of dura repair for dorsal dural laceration. Fundamentally, the pedicle screw fixation was comprised on one level above and below the injured segment including the injured segment itself, if the pedicles were intact (Fig. 3). Correction of the kyphotic deformity and restoration of the body height were performed by this cantilever beam fixation system. After completion of decompression and fixation procedure, in-situ postero-lateral bone grafts obtained from the autogenous iliac, laminae and spinous of the patient, or xenograft were performed (Fig. 4, 5). Rigid orthosis were routinely used for 3 months after the operation.

Clinical and imaging follow up

We use three clinical parameters, the postoperative pain level using Sonntag's method[35], the postoperative work status, and the pre- and postoperative neurologic status according to the modified Frankel classification[3]. As radiological parameters, the canal compromise ratio was measured from preoperative and postoperative computed axial tomography, the anterior body compression (%) was calculated by anterior body heights of the injured vertebra and the non-injured, adjacent vertebrae above and below the injured level using the formula by Mumford et al.[25] (Fig. 6), and the kyphotic angle was measured between the superior end-plate of the upper and the inferior end-plate of the lower non-injured vertebra by Cobb's method from the preoperative, postoperative, and follow-up lateral views of the plain radiographs[36] (Fig. 6). The paired t-test for analysis by applying SPSS (ver. 11.0) program was performed and the p-value <0.05 was considered to be significant.

Results

Postoperative pain and work level

At the latest clinical follow-up, there were 19 patients (95.0%) in group I and 1 patient (5.0%) in group II in pain level according to Sonntag's method[35] (Table 1). The postoperative work status were 17 patients (85.0%) in group I, 2 patients (10.0%) in group II, and 1 patient (5.0%) in group V (Table 2).

Neurological status

According to the modified Frankel scale[3], preoperative neurological status were group E in 5 patients (25.0%), group Db in 2 patients (10.0%), group Da in 8 patients (40.0%), and group C in 5 patients (25.0%). No patient lost neural function after the operation. Surgery brought to improve the

Table 1. Postoperative pain level according to Sonntag's method

Group	Criteria	No. (%)
I	Pain free	19 (95.0%)
II	Mild pain, no medication	1 (5.0%)
III	Moderate pain, intermittent medication	
IV	Severe pain, continuous medication	
Total		20 (100%)

Table 2. Postoperative work status

Group	Criteria	No. (%)
I	Same or better work status	17 (85.0%)
II	Working but at a lower level	2 (10.0%)
III	Unable to work	
IV	Not working prior to operation	
V	Retired state prior to operation	1 (5.0%)
Total		20 (100%)

Table 3. Preoperative and postoperative neurological status according to the Modified Frankel Scale

Group	Criteria	Pre-operation No (%)	Post-operation No (%)
A	No neurological function		
B	Preservation of sensory		
C	Inadequate motor function	5 (25.0%)	
Da	Allowing ambulation with assistance	8 (40.0%)	
Db	Self ambulation with minor difficulty	2 (10.0%)	2 (10.0%)
E	Normal neural status	5 (25.0%)	18 (90.0%)
Total		20 (100%)	20 (100%)

Table 4. Preoperative and postoperative canal compromise ratio and anterior body compression (ABC %) according to Mumford's method

	Canal compromise ratio*	Anterior body compression (ABC%)†
	N=8/13	N=19 (Success group)
Preoperative	0.57±0.07	41%±17
Postoperative	0.05±0.08	18%±14

*,† $P < 0.05$

neurological status from group C to group E in 3 patients, from group C to group Db in 2 patients, from group Da to group E in 8 patients, from group Db to group E in 2 patients (Table 3).

Canal Compromise

Preoperatively all patients were measured the canal compromise ratio by using computed axial tomography. We pushed back the communited bony fragments into the original position by using reverse-angle curet or angled small impactor in 13 patients (65.0%). The average canal compromise ratio in 8 patients of them who were carried out postoperative computed axial tomography was reduced from 0.57 (±0.07) to 0.05 (±0.08) ($P<0.05$) (Table 4).

Table 5. Preoperative kyphosis and postoperative kyphotic correction

	Total (N=20)	Success Group (N=19)	Failed Case (N=1)
Preoperative (A)	19.7°±8.9	20.0°±9.0	14
Postoperative (B)	5.5°±7.0	5.7°±7.1	1
Follow up (C)	8.2°±6.3	7.8°±6.2	16
Initial correction (A-B)	14.2	14.3	13
Loss of correction (C-B)	2.7	2.1	15
Overall correction (A-C)	11.5	12.2	-2

Anterior Body Compression[24]

The average anterior body compression (ABC%) of all patients was corrected from 41% (±17) to 18% (±14) ($P<0.05$) in success group (Table 4).

Kyphotic Correction and Loss of Correction[1,24]

The average preoperative kyphotic angle of all patients was 19.7° (±8.9), and corrected to 5.5° (±7.0) post-operatively, and progressed to 8.2° (±6.3) at the latest follow-up. Their initial correction was 14.2°, loss of correction was 2.7°, and overall correction was 11.5°. The average preoperative kyphotic angle of success group (19 cases, 95%) was 20.0° (±9.0), and corrected to 5.7° (±7.1) post-operatively, and progressed to 7.8° (±6.2) at the latest follow-up. Their initial correction was 14.3°, loss of correction was 2.1°, and overall correction was 12.2° (Table 5)[1].

Complication and implant failure

There was no surgery related complication, but a screw pull-out with delayed kyphosis in an elderly osteoporotic patient with diabetes mellitus and internal malignancy. His initial correction was 13.0° and loss of correction was 15.0° at 3 months after the operation, which has not been further aggravating

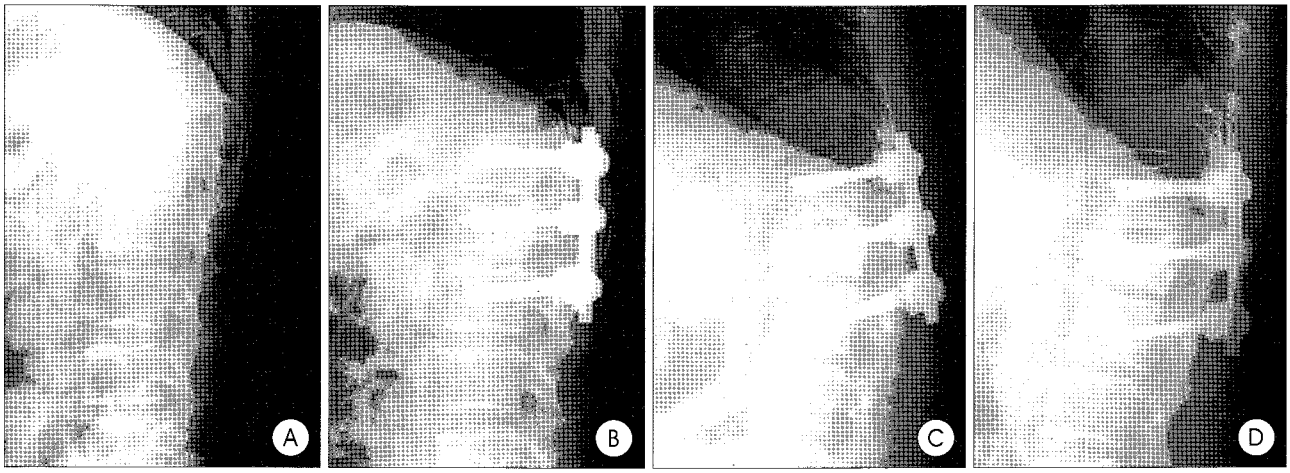

Fig. 7. A case of 62-year-old male patient with L1 bursting fracture. A : Preoperative plain radiograph. B : Immediate postperative plain radiograph showing segment pedicle screw fixation on T12, L1 and L2. C, D : Postoperative plain radiograph showing screw pull-out and delayed kyphosis at 8 month. C : flexion view. D : extension view.

up to 8 months (Table 5) (Fig. 7). We regarded it as a case of implant failure[22,23,32,37].

Discussion

The surgical goals for unstable thoracolumbar junction fractures are adequate decompression of neural element, restoration of vertebral body height and alignment, and mechanical stability, but there is still controversy in choosing operative procedure[1,2,8,17,22,23,32,37]. Multi-segmental fixation (instrumentation two segments above and below the fracture) can achieve relatively closer alignment to a normal spine and firmer fixation. The multi-segmental fixation is indicated for patients with complete cord injury, elderly patients, and patients with poor compliance to wear postoperative spinal brace[22,23,28], but cannot preserve the motion segments. Several reports suggested dorsal short-segment fixation as an efficient and safe method for the thoracolumbar fractures[15,17,18,28,29]. However, delayed as well as early failure, such as screw breakage, bending, loosening, pull-out, or delayed kyphosis had been reported to be 40~45% in early studies[1,7,23].

The loss of kyphotic correction

In general, the pedicle screw system resists both bending and axial loading, can be used to correct angulation deformity and restore the height as a cantilever beam fixation system. However, when the vertebral body is significantly compromised and associated with a considerable loss of height or abnormal angulation, the biomechanics of the system are altered significantly.

The changes in interbody height and angle cause the neural axis and instantaneous axial rotation(IAR) to be shifted posteriorly away from the injury and kyphotic angulation is inevitable. Therefore, the constructive ventral strut should be considered in the anticipated load sharing, such as highly comminuted fractures and severly midline retropulsed fragments. Needless to say, in the highly comminuted fractures and severly midline retropulsed fragments (canal compromise ratio >0.70) with anticipated load sharing, we performed ventral approach with strut grafting. Generally, the criteria as correction loss or implant failure is considered to be 10° or more and the critical period appears to be the 6 months after the procedure[22,23,32,37]. Lee et al.[18] reported 6 cases of implantation failure out of 48 patients who underwent dorsal short-segment fixation in thoracolumbar bursting fractures. They divided into two groups for thoracolumbar burst fractures; a group with screws on the injured vertebra and the other group without screws on the injured vertebra. The latter group showed poor initial correction as well as deterioration in the overall correction.

In our study, there was a case of loss of kyphotic correction, in an elderly osteoporotic patient, out of 20 patients over the latest follow up (Fig. 7). Lee et al's.[18] result is similar to ours. However, in our study, the pedicle screw fixation was included the injured segment itself as well as one level above and below it, if its pedicles were intact, which could be considered to reduce the failure rate. The failed cases, 2 in Lee et al's and 1 in ours, were in osteoporotic patients. Therefore, in the osteoporotic patients, certain principles should be considered, such as multiple site fixations, accepting lesser degrees of deformity correction, and avoiding ending the instrumentation within kyphotic segment[11]. Oertel J et al.[26] reported 3 cases of progressive kyphosis in 133 patients underwent surgery after removal of fixator and recommended the ventral approach in fractures with initial kyphotic deformation or wedge angle of 20° or more. However, besides the initial kyphotic angle, it is more reasonable to add other factors to choose ventral approach, such as the comminution of the fractured body, apposition of fragments and patient's status[22,28].

The apposition of bone fragments (Fig. 4)

There were 13 cases (65.0%) of canal compromise in our series. Preoperatively all patients were measured the canal compromise ratio by using computed axial tomography, their average ratio was 0.38 (± 0.24). We pushed back the communited bony fragments into the original position by using reverse-angle curet or small impactor in them after adequate decompression. The average canal compromise ratio in 8 patients of them who were carried out postoperative computed axial tomography was reduced from 0.57 (± 0.07) to 0.05 (± 0.08) ($P<0.05$) without any further aggravation of neurological status after the operation (Table 4).

Ligamentotaxis was previously thought to be dependant on an intact posterior longitudinal ligament, which would reimpact bone fragments into the vertebral body following operative distraction. In fact, the fibers necessary for reduction of these bone fragments originate in the annulus of the superior vertebra in the midportion of the end plate of the spine (Annulotaxis)[8]. Pitfalls to restore the apposed bony fragments by the dorsal approach are neural injury, incomplete decompression[8], and bleeding. However, partial laminectomy of the adjacent upper segment add to wide bilateral total laminectomy of the injured segment so far as articulectomy, according to circumstances partial pediclectomy, was available for working space to reimpact the bone fragments anteriorly. Profuse bleeding from the venous plexus can be avoidable by gentle procedure with applying a sheet of cottonoid and Gelfoam-Aviten packing.

The posterior comminution (Fig. 4)

In case of thoracolumbar fracture with associated laminar fracture, there is the possibilities of dorsal dural laceration, CSF

leakage or neural entrapment by impaction of the dural sac into the gap of the fractured lamina, so the dorsal approach is favored in that case. Kim[13] reported posterior dural laceration in 16 cases out of a total 36 patients with spinal bursting fractures during operation. In that study, the statistical analysis revealed significant associations of dural laceration with preoperative neurologic deficits, high grade spinal canal compromise, and comminuted fracture. He recommended that these patients should undergo posterior exploration of the spinal canal, extraction of neural elements, and repair of the lacerated dura before any spinal reconstruction maneuver.

In our series, there were 2 cases (10%) of dorsal dural laceration and 4 cases (20%) of laminar impingement on the spinal cord.

Less invasive anterior reconstruction

Up to now less invasive anterior column reconstruction technique has been developed to provide the ventral strut's role in unstable thoracolumbar junction fractures to avoid extensive surgery by some authors[4-6,15,27].

In the mid 1980s, Daniaux[4,5] proposed a new technique, transpedicular spongioplasty, as a relatively undemanding to augment the anterior column by autografting cancellous and cortical chip bones through the pedicle(s) into the vertebral body defect. However, this technique has not been able to prevent secondary kyphosis reliably in traumatic thoracolumbar fractures, as several authors had shown, largely due to aseptic bone necrosis of the grafted materials[1,16,19,38].

Oner FC et al[27] developed a technique to restore and augment the fractured anterior column through a transpedicular approach in 20 patients with unstable thoracolumbar fractures. They used Ballon-assisted-endplate-reduction(BAER) followed by vertebroplasty with calcium phosphate cement in combination with short-segment pedicle screw construct. In that study, there was no neurological complication. The average Cobb angle was corrected from 11° (±9.2) to -1.6° (±9.5). The average central body height increased from 66% (±10.7) to 81% (±10.4) of the estimated intact height. The average anterior vertebral body height increased from 71% (±14.9) to 92% (±10.3) of the estimated intact height. There was also promising cadaver study of augmented vertebroplasty in traumatic thoracolumbar fractures[27].

Oertel[26], Daniaux[4,5] and Oner's[27] dorsal instrumentation sites were limited on the above and below the fracture level, exclusive of the fractured segment[5,6]. On the contrary, our trial sites included the injured segment, if the pedicles were intact (Fig. 4, 5). Several authors demonstrated one stage posterolateral decompression and stabilization via the transpedicular route for unstable thoracolumbar fractures and metastatic vertebral tumors[9,12,14,34]. After achieving the canal decompression by wide laminectomy, articulectomy and pediculectomy, they removed all the retropulsed bony fragments and ventral column support was performed using cage(s)[9,14]. However, our decompression was attained not by removing the retropulsed bony fragments, but just reimpacting those anteriorly into the vertebral body, which would make the cord be less damaged and support ventral strut (Fig. 4, 5). With the short-segment pedicle screw constructs on above and below the injured segment including the injured vertebra itself, if the pedicles were intact, and just reimpaction the fragmented bones into the original position may participate in load sharing onto the injured vertebral body and preventing delayed kyphosis during the follow-up. Lee et al's.[18] data supports us. In-situ posterolateral bone grafts and postoperative rigid orthosis may be also important for providing stability, but there has been still some controversies[1,31].

Generally, the ventral constructs can be applied to provide load sharing to reduce the magnitude of the bending moment experienced by the hardware in flexion-compression[20]. However, the most reliable and least invasive technique to achieve a good realignment of the spine is with the use of pedicle screw construct[38]. But to restore ventral column is the utmost challenge of dorsal short segment fixation in unstable vertebral injuries[22,28]. Traditionally, the injured segment was excluded in the dorsal short-segment fixation for unstable thororacolumbar bursting fractures and the failure rate was reported highly[1,7,23]. Lee et al.[18] also reported that a group without screws on the injured vertebra showed poor initial correction as well as deterioration in the overall correction. However, our technique included on the injured segment, if the pedicles were intact, and performed reimpaction the protruded bony fragments into the original position, which may have gained time up to fusion and grant the stability without extensive surgical procedure, nor neurological aggravation in selective unstable thoracolumbar junction fractures. We think that the posterior communition may more justify the dorsal approach[13].

Conclusion

Although more follow-up periods and patients are needed to elute solid conclusion, the present study favors dorsal short-segment fixation for selective cases in unstable thoracolumbar junction fractures.

• Acknowledgement
This article was presented at the annual spring meeting of the Korean Neurosurgical Society in 2006.

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Commentary

The authors reported excellent results of short-segment fixation for thoracolumbar burst fractures especially in aspects of instumetation failure rate and kyphosis correction. Biomechanically short-segment pedicle fixation is a fixed moment arm cantilever beam fixation, and this type of fixation may result in construct failure at screw-rod interface due to significant load bearing. Disadvantages of short-segment pedicle fixation was early instrumet failure and kyphosis progression.

I agree to author's opinion that fixation including injured vertebra showed good results in kyphosis correction and less instrumet failure; biomecahnically stiffness is significantly increased by adding intermediate screw on injured vertebra. There are still controversy in outcome of short-segment fixation versus long-segment fixation. Although this paper showed exellent results in instrument failure rate and good kyphosis correction, some limitations are present due to short follow-up and small number of patients. We anticipate more papers to confirm the efficacy of short-segment fixation for spinal disorders.

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