Anterior D-rod and titanium mesh fixation for acute mid-lumbar burst fracture with incomplete neurologic deficits

A prospective study of 56 consecutive patients

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ABSTRACT

Background: Anterior decompression and reconstruction have gained wide acceptance as viable alternatives for unstable mid-lumbar burst fracture, but there are no mid and long term prospective studies regarding clinical and radiologic results of mid-lumbar burst fractures. **Materials and Methods:** An Institutional Review Board-approved prospective study of 56 consecutive patients of mid-lumbar burst fractures with a load-sharing score of 7 or more treated with anterior plating was carried out. All patients were evaluated for radiologic and clinical outcomes. The fusion status, spinal canal compromise, segmental kyphotic angle (SKA), vertebral body height loss (VBHL), and adjacent segment degeneration was examined for radiologic outcome, whereas the American Spinal Injury Association scale, the visual analog scale (VAS), and the employment status were used for clinical evaluation. **Results:** The patients underwent clinical and radiologic followup for at least 5 years after the surgery. At the last followup, there was no case of internal fixation failure, adjacent segment degeneration, and other complications. Interbody fusion was achieved in all cases. The average fusion time was 4.5 months. No patient suffered neurological deterioration and the average neurologic recovery was 1.3 grades on final observation. Based on VAS pain scores, canal compromise, percentage of VBHL and SKA, the difference was statistically significant between the preoperative period and postoperative or final followup ($P < 0.05$). Results at postoperative and final followup were better than the preoperative period. However, the difference was not significant between postoperative and final followup ($P > 0.05$). Thirty-four patients who were employed before the injury returned to work after the operation, 15 had changed to less strenuous work. **Conclusion:** Good mid term clinicoradiological results of anterior decompression with D-rod and titanium mesh fixation for suitable patients with mid-lumbar burst fractures with incomplete neurologic deficits can be achieved. The incident rate of complications was low. D-rod is a reliable implant and has some potential advantages in L4 vertebral fractures.

Key words: *Anterior lumbar fusion, internal fixation, lumbar burst fractures, mesh cage, neurologic deficit*
MeSH terms: *Lumbar vertebrae, fracture fixation, spinal cord compression, neurologic deficits*

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INTRODUCTION

Lumbar burst fractures are relatively infrequent as compared with thoracolumbar burst fractures. Literature mainly reports the management of thoracolumbar burst fractures, while there are few reports which discuss surgical options, functional outcome and benefits associated with lumbar burst fractures alone.[1,2] Although various therapeutic options are available in terms of conservative treatment and operative treatment,[1-3] it is generally accepted in the literature that operative intervention is the treatment of choice in many of these injures. The advantages of surgical treatment for lumbar burst fractures include decompression of the neural elements to facilitate neurological recovery, better correction of spinal deformity, fusion with rigid stabilization, salvage of vertebral motion segments, and prevention of

development of delayed deformities. However, the selection of the approach (anteriorly, posteriorly, or combined anteroposteriorly) for decompression and stabilization of lumbar burst fractures is controversial. Recently, favorable clinical results have been reported using anterior direct decompression of the neural elements and anterior instrumentation which allows fusion and fixation through the same single exposure.[4] But previously mentioned studies are mainly based on retrospective case series. To authors' knowledge, there was no mid and long prospective study regarding anterior approach treatment of mid-lumbar (L2–L4) burst fractures.

L1 burst fractures are usually treated as thoracolumbar fractures, whereas most of the L5 burst fractures are treated conservatively. In this study, we present a standard protocol for the operative treatment of mid-lumbar burst fractures with incomplete neurologic deficit using an anterior approach with anterior complex locking rod system (D-rod) and titanium mesh autograft fixation. We report the 5 year clinical and radiographic results of the surgical management.

MATERIALS AND METHODS

Study population
Approval from Institutional Review Board was obtained prior to the initiation of this study. An approved consent form was signed by each patient before any testing was performed. The inclusion criteria specified participants between the ages of 18 and 60 years, a single-level Denis type A, type B, or type C burst fracture of the lumbar spine (L2–L4) with incomplete neurologic deficits, presenting within 1-week after the injury and a load-sharing score[5] of 7 or more. The exclusion criteria involved major fractures of other sites and significant associated injury to any other major organ system requiring hospital admission and active management, pathologic or osteoporotic fractures, a history of previous spinal or abdominal operation or inadequate followup.

56 consecutive patients with a diagnosis of mid-lumbar (L2–L4) burst fracture with incomplete neurologic deficits were prospectively enrolled between March 2006 and September 2008 from the practice of three surgeons from three academic institutions. These patients were treated with anterior decompression, titanium mesh autograft, and internal fixation with D-rod. Among them, 39 were males and 17 were females. The ages ranged from a minimum of 18 years to a maximum of 59 years, with a mean of 33.4 years (standard deviation [SD], 8.8). The fracture levels were 21 L2, 18 L3, 17 L4. The cause of injury was either fall from a height or road traffic accident. Neurologically, nine patients had American Spinal Injury

Association (ASIA) grade B, 19 ASIA grade C, and 28 ASIA grade D before surgery. There were six patients with bowel or bladder dysfunction. According to the preoperative posterior-anterior and lateral radiographs, computed tomography (CT) scans and magnetic resonance imaging, the Denis classification and the "load-sharing classification" for comminution were used. All patients were followed up for at least 5 years.

Fixation system
Anterior complex locking rod system (D-rod) and titanium Mesh were provided by Double Engine Medical Material Company, China. D-rod included an anterior locking rod, a posterior distraction/compression rod, two adjustable transverse link bars and other accessory instruments [Figure 1], offering different size and length. All implants were manufactured using titanium alloy.

Surgical technique
All patients were operated by a left sided anterolateral retroperitoneal approach. The affected vertebral body was removed. After complete decompression, two bolts were placed before reduction of the fracture. Kyphosis was corrected using a spreader device applied to the heads of the two bolts. A titanium mesh cage filled with autogenous bone graft derived from the resected vertebral body was implanted into the defect created by the corpectomy. The distraction/compression rod is then applied over the bolts, and the nuts are placed. Next the locking rod and two locking screws were placed and tightened. Finally, two adjustable transverse link bars were placed between anterior rod and posterior rod and tightened.

Assessment methods
Preoperative radiographic and clinical evaluations were performed within 1-week of surgery and postoperative
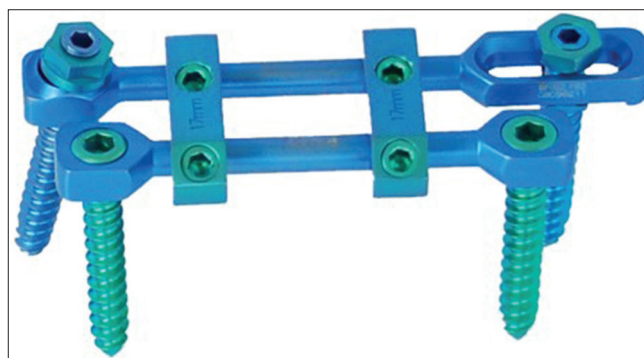

Figure 1: Top view showing the overall relation of the D-rod system. The design of the separated body of the D-rod system allows a locking rod to fix to the anterior side of the vertebral body. The locking rod has a smooth surface with a thickness of only 6 mm. With this system, it is not easy to damage important organs or blood vessels in front of the vertebral body

evaluations were performed at 3 months, 6 months, 12 months, and once a year later.

Radiographic evaluation

For radiographic evaluation, the segmental kyphotic angle (SKA) was obtained by measurement from one above to one below the fractured vertebra, according to the Cobb method. The percentage of vertebral body height loss (VBHL) was reported as fractions of anterior height between fractured vertebra and normal height of the adjacent vertebra below the fractured vertebra. The mid-sagittal spinal canal diameter at the injury level was compared with the average of the same diameter at one level proximal and one level distal to the injury and expressed as a percentage of narrowing. The fusion status was determined primarily using plain radiographs, combined with flexion/extension views and reconstructed CT scans when there was uncertainness of definite fusion. Adjacent segment degeneration (University of California at Los Angeles Grading Scale[6]) was also evaluated at the final followup.

For clinical evaluation, patients were administered a questionnaire on demographics, pain, function, use of analgesics, and employment status. All neurologic deficits were identified on initial evaluation and graded using the ASIA classification system. The recovery rate of back pain was quantified by the visual analog index (VAS), with 0 none and 10 worst possible pain. All perioperative and postoperative complications were recorded in the chart. The evaluations were performed independently by three authors on 3 separate occasions and in a blinded manner and the results were then averaged.

Statistical analysis

Statistical analysis, including mean values and SDs, was performed using SPSS software (SPSS, Chicago, IL, USA). Comparison between preoperative and postoperative data was done using the paired *t*-test. The size of test took bilateral $\alpha = 0.05$.

RESULTS

Perioperative data

The mean surgical time was 124 min (SD, 19), mean blood loss was 880 ml (SD, 380), and mean hospital stay was 9 days (SD, 1.4). There were no intra-operative complications of neurovascular injury and no neurological deterioration after screw insertion. There were two urinary tract infection and three superficial wound infection that were successfully treated with antibiotics. The other early postoperative complication included wound dehiscence in two patients, wound resuturing was done after debridement.

Radiological outcome

The patients were prospectively followed up for a minimum of 5 years with no cases lost during the followup period. Pre and postoperative images were available for all patients. Bone grafts in all patients fused, with a mean fusion time of 4.5 months (SD, 0.8); no nonunion, pseudarthrosis, internal fixation loosing, or rupturing was found at the final followup. None of the patients required either early or delayed supplemental posterior lumbar arthrodesis with instrumentation. Based on SKA [Figure 2], canal compromise [Figure 3] and VBHL, the difference was statistically significant between the preoperative period and postoperative period or final followup ($P < 0.05$) [Table 1 and Figure 4]. SKA, canal compromise and VBHL at the last followup changed slightly but not significantly compared with the postoperative period ($P > 0.05$). According to University

Table 1: SKA, canal compromise, percentage of VBHL and VAS pain scores (n=56)

Assessment methods	Preoperative period	Postoperative period	Final followup
SKA (°)	7.8±6.4	−10.1±5.5	−9.2±4.9
Canal compromise (%)	70±0.2	3±0.1	1±0.1
VBHL (%)	60.6±6.5	13.4±3.8	15.1±3.4
VAS pain scores (points)	8.8±0.9	2.8±1.3	2.6±1.1

SKA=Segmental kyphotic angle, VBHL=Vertebral body height loss, VAS=Visual analog scale
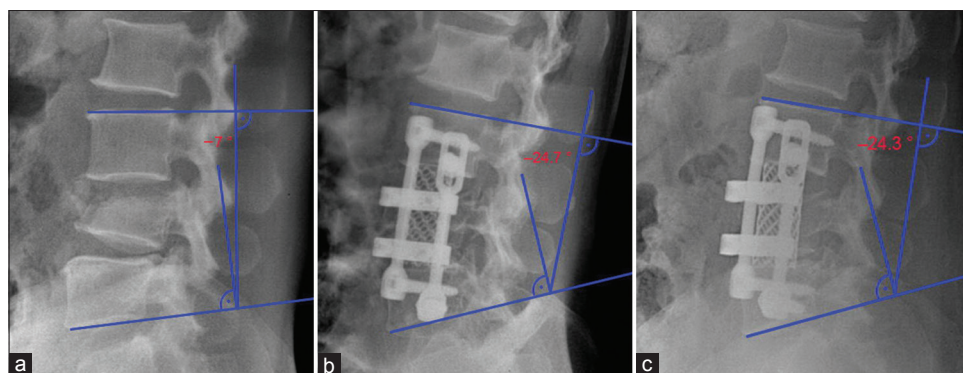

Figure 2: X-ray lumbar spine lateral view in a 42 year old woman showing L4 burst fracture. (a) Preoperative segmental kyphotic angle. (b) Anterior D-rod system stabilization was performed and kyphosis was reduced. (c) 25 months after D-rod system stabilization, slight loss of correction was seen

of California at Los Angeles Grading Scale criteria, at final followup, adjacent segment degeneration was not observed.

Clinical outcome

None of the patients had neurologic deterioration, abdominal contents injury, deep venous thrombosis pulmonary embolism or infection. Neurologically, ASIA grades 1 or 2 improved in all cases after surgery [Table 2]. The average neurologic recovery was 1.3 grades. Of 3 patients with sexual dysfunction, 2 returned to normal during the followup, the remaining one did not improve. Five of six patients with bowel or bladder dysfunction gradually returned to normal within half a

year. Only one patient with nerve root avulsion maintains the same neurology in the final followup. VAS pain scores demonstrated a significant variation between pre and postoperative or final followup ($P < 0.05$) [Table 1], and no patient with severe pain needed narcotic medications. 34 patients who had been working before injury returned to original work without restrictions, 15 patients changed to less strenuous work. The remaining 7 patients were unemployed.

Discussion

The surgical technique for reconstruction of L2–L4 burst fractures represents a difficult challenge for surgeons managing acute fractures, anterior, posterior and combined surgical approaches have specific advantages and disadvantages. In contrast to the thoracic spine, the critical anatomic consideration is the extreme flexion-extension mobility in the mid-lumbar area (L2–L4). Some authors suggest if surgery is chosen, a long fusion with distraction instrumentation should be avoided to conserve motion segments of the lumbar spine.[7] The "short segment" technique has become the most common technique in the operative treatment of thoracolumbar and lumbar fractures because of the advantages of decompression, fusion and fixation in one surgical sitting. Transpedicular decompression is a direct posterior technique,[8] but one with limited visibility of the anterior portion of the dural sac and with results that do not differ from those of indirect decompression. In the mid-lumbar, indirect decompression is not as successful because the technique depends on distraction and tensioning of the posterior longitudinal ligament. In addition, the posterior "short segment" technique is not entirely free of complications, including instrumentation failure, pseudarthrosis, infection, low back pain, and the need for late removal of implant.[9-11]

Table 2: Neurological function outcomes (ASIA grade)

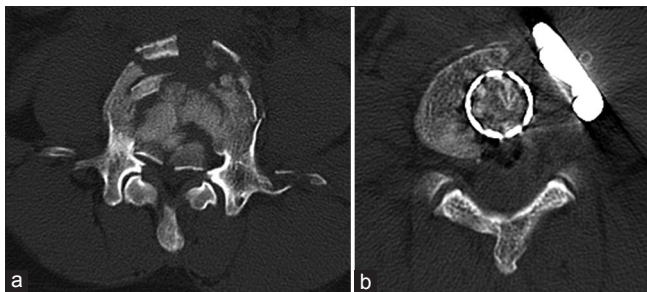| Preoperative period	Final followup				
	A	B	C	D	E
A	-	-	-	-	-
B	-	-	3	5	1
C	-	-	-	9	10
D	-	-	-	-	28

ASIA=American spinal injury association

Figure 3: A 38-year-old man who sustained an L3 burst fracture. (a) Preoperative computed tomography (CT) showing a severely narrowed spinal canal by the retropulsed bony fragments. (b) Postoperative CT demonstrated complete removal of the bony fragments in the spinal canal

Figure 4: (a) Preoperative lateral radiograph of lumbar spine of a 46-year-old man with a burst fracture of L3. American Spinal Injury Association grade C. (b) Preoperative anteroposterior view of patient showing increased interpedicular distance in L3 vertebra (c) Computed tomography scan showing significant retropulsion of body into the canal. (d) Postoperative lateral radiograph of patient demonstrates reduction of kyphosis with restoration of height. The canal has been decompressed. (e) Postoperative anteroposterior view of patient

Several authors reported a higher rate of implant failure ranging from 9% to 54% and the increase kyphosis from 3° to 12° after posterior "short segment" fixation due to lack of the construction supporting the anterior and middle column.[12-14] In an attempt to achieve a stiffer construct, within the limits of a "short segment" fixation, several technical measures have been described, including addition of cross-links,[15,16] "intermediate" screws at the fractured vertebrae.[15] In a prospective comparative study, Korovessis *et al.* found that although intermediate screws were inserted in the fractured vertebra, the resultant construct did not prevent the average 5° loss of correction at the final evaluation.[17] This leads some surgeons to advocate combined anterior and posterior approaches to increase stability and decrease failure. But combined anterior and posterior surgery is not an optimal treatment option for lumber burst fractures due to longer operative time, more blood loss, surgical morbidity and duration.[18] Some surgeons believe that combined approach is more suitable for serious unstable burst fractures with significant disruption of the posterior osteoligamentous complex or fracture-dislocation.

Anterior approach with corpectomy, structural bone graft and a lateral plate or rod fixation has been shown to be as effective as posterior surgery by directly reconstructing the weight-bearing anterior column and fusion.[17,19,20] Conceptually, the technique to treat such lumbar injuries as a single-stage anterior procedure could offer theoretical benefits such as improved canal decompression,[21] restoration of anterior load-sharing, fewer levels requiring arthrodesis,[22] restoration of sagittal alignment, and decreased surgical morbidity.[21] The anterior approach also avoids additional injury to the paraspinal muscles and disruption of their innervation, which is an important reason of low back pain after posterior surgery.[23] Long term loss of correction of 1°–4° after the anterior approach is reportedly less than that for the posterior approach.[24,25] In the setting of comminuted fractures within the middle lumbar spine, anterior column reconstruction is strongly recommended as the need to maintain biomechanical integrity and normal sagittal alignment is so important.[17,26] Several studies have shown that residual posttraumatic kyphosis, particularly in the lumbar spine, induces back pain not only shortly after surgery but after 10 years or more.[27-29] The current findings and review of literature suggest that from an anatomical standpoint, the ideal treatment of the more severely-crushed burst fractures is complete kyphosis correction with long term correction maintenance.[30] The authors of the present study consider it mandatory to correct posttraumatic kyphosis and maintain this correction in the lordotic lumbar spine to achieve improved functional outcome.

The indications of anterior corpectomy and fixation for acute thoracolumbar burst fracture includes:[31-33] more than 30% spinal canal compromise, more than 50% anterior cortex collapse, more than 20° kyphosis angle, neural injury of canal encroachment progressing and postoperative kyphosis deformity. However, it is lack of appropriate surgical indication for surgeons to choose surgical approach of lumbar burst fracture, the decision of surgical approach is based on the location of the fracture, the degree of vertebral destruction, any neurologic involvement, the degree of kyphosis, stability of the posterior column structures and surgeon's preferences. McCormack *et al.*[5] described the "load-sharing" classification and suggested that thoracolumbar and lumbar fractures with a point totals of seven or more for comminution, apposition of fragments, and kyphosis are suitable for short-segment anterior vertebrectomy, instrumentation and strut graft fusion. Parker *et al.*[34] showed that the load-sharing classification can help the surgeon to select "short-segment" fixation using the posterior approach for less comminuted injuries and the anterior approach for those more comminuted. The authors of the present study used the "load-sharing" classification with point totals of seven or more as the inclusion criteria.

This medium-term prospective study demonstrates reliable neurologic improvement of at least one ASIA grade and pain relief at the final followup. All patients appeared to have stable constructs at the latest followup and no patient developed pseudarthrosis. A short level of fusion was obtained with only two motion segments immobilized in all patients. Significant improvement in angulation was achieved postoperatively in this study with a mean preoperative 7.8° kyphosis correcting to a mean postoperative −10.1°. Loss of kyphosis correction at latest followup averaged 0.9° (5%), with overall sagittal angulation still remaining significantly improved from preoperative angulation ($P < 0.05$). Perioperative complications included two urinary tract infections and three superficial wound infections which were successfully treated with antibiotics. None of the patient required either early or delayed supplemental posterior lumbar arthrodesis with instrumentation. There were no intra-operative or late vascular injuries. Final clinical results, both pain relief and employment status, were gratifying and compare favorably with previous outcomes.[35]

Because the anatomy of the bifurcation of the great vessels and the necessity of retracting the common iliac artery to expose the disc, the L4–L5 level is most likely to be associated with vascular complication.[36,37] Kaneda noted that a larger percentage of pseudarthroses occurred with burst fractures of L4 (four of five patients).[22] The increased rate of pseudarthrosis at this level is most likely related to the

location of the fourth lumbar vertebral body and the shape of the fifth lumbar vertebral body which make instrumentation technically more demanding. Some authors suggest anterior instruments should not be used below L4 to avoid problems with the iliac vessels.[22] The design of separated body construct of D-rod allow locking rods to be adjusted freely to correct curvature of the lumbar spine, with particular attention to prevent contact with the overlying iliac vessels in the L5 area and decreased construct failure. This device permits distraction or compression as circumstances require, its versatility in screw placement allows for greater safety by avoiding internal structures at risk. Experimental data have demonstrated that devices offering variable and independent application of distraction and lordosis are more likely to achieve anatomic reduction.[38] The anterolateral load-sharing D-rod device with titanium mesh for lumbar burst fractures led routinely to solid fusion, without instrumentation failure and without the need for supplemental posterior spine stabilization. This conveys that D-rod has some potential advantages in patients with L4 lesion.

CONCLUSION

Good mid term clinical and radiologic evaluation results of anterior-only instrumentation and reconstruction with D-rod and titanium mesh for mid-lumbar burst fractures with incomplete neurologic deficits with a load-sharing score of >7 can be achieved in this study. While there are few studies report mid and long term clinical effects of this technique before. The bone fusion rate, lumbar stability, pain relief, and return to work were gratifying compared favorably with previous outcomes. The incident rate of relative complications from this technique is low.

Although this is a prospective study, the limitations of this study are the lack of a control arm and randomization. Further randomized controlled studies are needed to show the differences in clinical and radiologic outcomes between anterior approach and other approach in patients with mid-lumbar burst fractures.

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