Operative Treatment of Thoracolumbar Burst Fracture with or without Computer-Assisted Pedicle Screw(s) at the Fracture Level

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Abstract: Objection: The purpose of this study is to compare the clinical results of operative treatment of thoracolumbar burst fractures with or without computer-assisted pedicle screw(s) at the fracture level. The surgical treatment of thoracolumbar burst fractures with short pedicle screw instrumentation has good results in clinical situations but failure to maintain the sagittal plane correction has been reported by several authors. Several methods have been mentioned to reduce the high fixation failure rate in the treatment of thoracolumbar burst fractures with short pedicle screw instrumentation. Computer-assisted pedicle screw insertion in the fracture side is one of the methods and the success rates may be improved by inserting an additional screw at the facture level. **Methods**: Thirty-six patients (23 males and 13 females; mean age, 37.2 years; age range, 26-65 years) were treated with short posterior pedicle instrumentation with computer-assisted screw insertion at the fracture level in 17 cases (Group I) and without screw insertion in 19 cases (Group II). Segmental kyphosis and vertebral height were assessed by lateral view X-ray. Patients were thoroughly reexamined and the neurologic status, functional outcome and complications of both groups were assessed. **Results:** The average kyphotic angle before and after surgery and at latest follow-up were 16º, 2º, and 4º, respectively, in Group I and 17º, 3º, and 11º, respectively, in Group II. Mean anterior vertebral body height before and after surgery and at latest follow-up were 56%, 78%, and 75% of normal, respectively, in Group I and 54%, 75% and 63%, respectively, in Group II. Loss of kyphotic correction or vertebral height was more severe ($p<0.05$) and there was substantially more pain in Group II. No patients had an increase in neurologic deficit. Patients with neurologic deficit experienced improvement irrespective of treatment choice. Complications were relatively rare. **Conclusions:** There are high fixation failure rates associated with thoracolumbar burst fractures treated with short pedicle instrumentation. Computer-assisted pedicle screw insertion at the fracture level effectively reduces the fixation failure of thoracolumbar burst fractures treated with short pedicle instrumentation.

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1. Introduction

The goals of surgical treatment of unstable thoracolumbar fractures are early ambulation, correction of post-traumatic spinal deformity with and maintenance of the mechanical stability of the spine to prevent the late onset of deformity or neurologic deficit[1-5]. The capability of posterior pedicle devices to enhance stability is recognized. Several authors have reported good results with the use of pedicle screws in clinical situations, however, failure to maintain the sagittal plane correction was reported by several authors,[6-8] especially in traditional short-segment fixation[9,10]. Correction of post-traumatic spinal deformity with restoration of sagittal plane alignment and maintenance of mechanical stability of the spine has been claimed by most authors. Measurable kyphosis does not always herald clinical failure, but patients who had progressive kyphosis of more than 10º had substantially more pain than those who had little or no progression[7,11]. The purpose of this study was to compare the clinical results of operative treatment of thoracolumbar burst fractures with or without computer-assisted pedicle screw insertion at the fracture level.

2. Materials and Methods

Thirty-six patients with thoracolumbar burst fracture were reviewed retrospectively. There were 23 men and 13 women. The average age of the patients was 37.2 years (range, 26-65 years). The average follow-up period was 34 months (range, 29-53 months). The navigation system used in this study was the optoelectronic navigator (Vectar Vision, Brain LAB GmbH, Germany). The patients undergoing image-guided surgery with the device require preoperative spiral mode CT scans of the spinal segments to be instrumented. Image data were transferred to the navigator's computer and produce a three-dimensional image of the spinal segment.

During spinal navigation, patient registration was done to provide correlation between the operative anatomy and imaged anatomy displayed by the navigator. After successful registration, the navigation system can provide axial, sagittal, and coronal images of the fracture level (Fig.1) which was to insure accurate alignment for subsequent screw insertion. All the patients were surgically treated with limited posterior segmental fixation and posterolateral fusion using iliac crest bone graft. A short-segment construct with pedicle screws at one level above and below the fracture site with computer-assisted additional screw(s) at the level of the fracture (Fig. 2) was used in 17 patients, Group I, and no screws were used in the other 19 patients, Group II (Fig. 3). Pedicular placement was finished using anatomic landmarks and confirmed by plain intraoperative radiographs. Reduction was performed with all pedicle screws in place and computer-assisted 2 screws were placed at fracture level in the patients with no or mild neurologic deficits**.** We used an computer-assisted additional screw at the facture level in the patients with severe neurologic deficits. We fixed the overcontoured rods from the inferior pedicle screws down to the remaining pedicle screws, providing symmetric 3-volume lordotic reconstruction for further reduction of vertebral height and intracanal fragments. Indications for surgical stabilization included neurologic deficits, severe spinal instability (defined as kyphotic deformity >20°, canal compromise >50%, or loss of anterior vertebral body height >50%). Segmental kyphosis and vertebral height of burst fracture were assessed by lateral view X-ray[12]. The vertical height of each vertebral body and its adjacent disc were measured. Vertebral compression was measured directly at the affected level and reported as a percentage of normal which was determined by averaging the heights of adjacent segments above and below the fracture. Kyphosis was measured using the Cobb method. Computed axial tomography was performed on patients with burst fracture for the determination of canal compromise (Figs. 1, 2). Determination of canal compromise was made by direct measure of the midsagittal anteroposterior canal dimension at the injured level and the levels above and below the pedicle level. Then comparison was made using the averages or the corresponding dimensions measured at the levels above and below the injury level. The results of this comparison were reported as percent anteroposterior canal compromise at the injury area. Patients were thoroughly re-examined and the Frankel grade was recorded preoperatively, postoperatively and at follow-up. Patients were questioned for grading pain[12], which was defined as none, mild (requiring occasional narcotic medication and not interfering with daily activities); moderate (requiring occasional narcotic medication and interfering to some extent with daily activities), or severe (disabling pain or requiring frequent narcotic analgesics). All patients in our series began rehabilitation after application of the thoracolumbosacral orthosis and wore orthosis for at least 3 months.

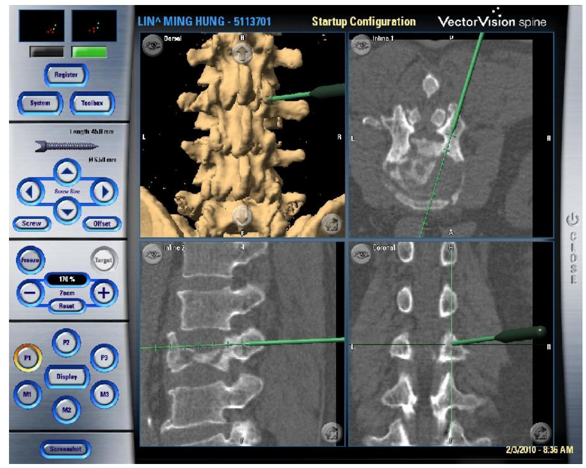

Fig. 1 After successful registration, the monitor can provide the axial, sagittal and coronal images of the fracture level which was to ensure accurate alignment for subsequent screw insertion.

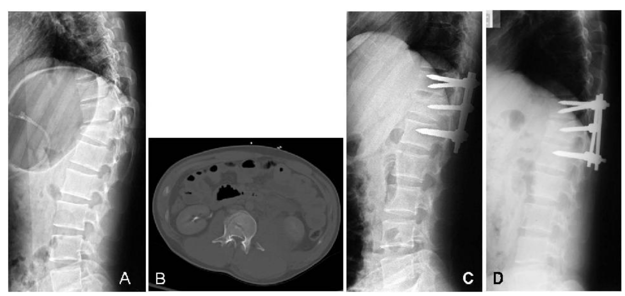

Fig. 2 (A) Preoperative roentgenogram of a 31-year-old male patient who sustained a T12 burst fracture with Frankel C neurologic deficit. The segmental kyphosis is about 28 degrees. (B) Preoperative CT scan image demonstrating a severe spinal canal encroachment by retropulsion of the fragments of the fractured vertebra. (C) Postoperative roentgenogram after short-segment transpedicular fixation with additional screw at the fracture level, segmental kyphosis is about 3 degrees with neurologic deficit improved to Frankel E. (D) Segmental kyphosis was maintained well at the final follow-up.

2.1 *Statistical analysis*

Data for preoperative and postoperative radiographic analysis were compared using Student's *t* test. Fisher's exact test was used to analyze the Frankel Scale and pain scale data.

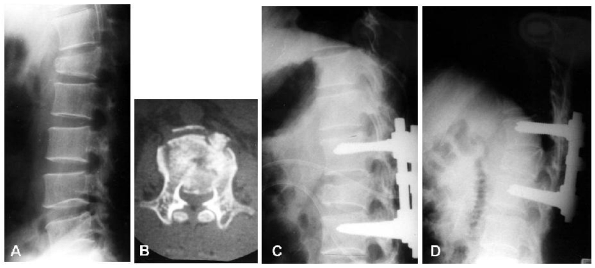

Fig. 3 (A) Preoperative roentgenogram of a 30-year-old male patient who sustained an L2 burst fracture without neurologic deficit. The segmental kyphosis is about 20 degrees. (B) Preoperative CT scan image demonstrating a significant spinal canal encroachment by retropulsion fragments. (C) Postoperative standing roentgenogram after short-segment transpedicular fixation without an additional screw at the fracture level, segmental kyphosis is about 4 degrees. (D) Segmental kyphosis was not maintained well, it was about 16 degrees at the final follow-up.

3. Results

Comparison of both groups with regard to radiographic review: The causes of injury included falling from a height (13 patients) and motor vehicle accidents (23 patients). The preoperative kyphotic deformity as measured according to Cobb's method was similar in both groups (Group I, 16.2±6.8º; Group II, 17.3±8.2º). Kyphosis correction after the operation was noted in both groups (Group I, 13.8º; Group II, 13.7º). Correction loss in Group I (2.3±1.8º) was much less than in Group II (8.1±6.7º) during follow-up ($p<0.05$) (Fig. 4). The average preoperative anterior vertebral height was similar in both groups (Group I, 56.1±13.4%; Group II, 54.2±14.8%). The average postoperative anterior vertebral height was 73.2±15.4% in Group I and 72.1±14.7% in Group II. During follow-up, anterior vertebral height was maintained well in Group I ($p<0.05$). The overall changes in anterior vertebral height preoperatively, postoperatively and during follow-up are presented in Figure 5.

Comparison of both groups with regard to pain status and neurologic outcomes: According to pain status, all of the patients in Group I and 71% of the patients in Group II had no pain or mild pain. No patients in Group I and 29% in Group II had moderate or severe pain ($p<0.05$, two-tailed Fisher's exact test). The patients with incomplete spinal cord injury showed neurologic improvement. Group I patients increased by an average of 1.5 grades on the Frankel Performance Scale, and Group II patients increased by an average of 1.4 grades. There were no statistically significant differences with regard to postoperative changes according to the Frankel Scale. No patients sustained an increase in neurologic deficit. Two patients (one in each group) had wound dehiscence on the 2nd day after the operation, but the wounds healed without any problem after secondary closure. Three patients had neurologic bladder with urinary tract infection, and improved after medical treatment. Two patients (Group II) removed the implant due to back pain.

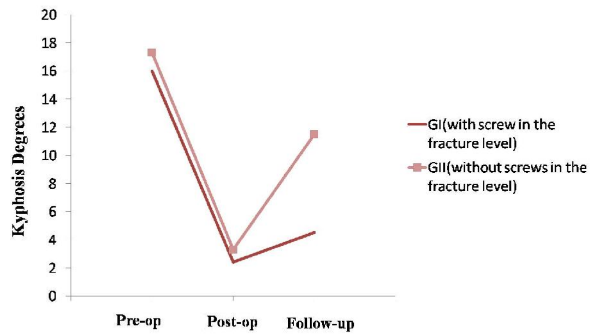

Fig 4 Kyphotic deformity decreased after surgery in both groups. Kyphotic deformity was maintained well in Group I, but loss of correction was significant ($p<0.05$) in Group II during follow-up.

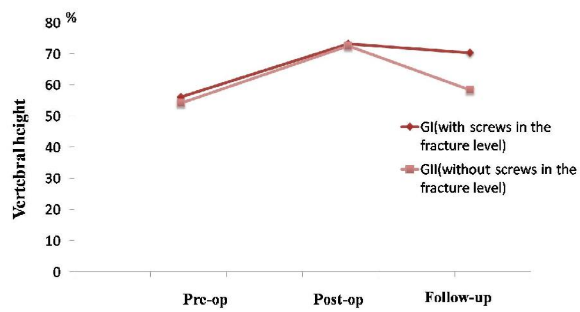

Fig. 5 Anterior vertebral height was maintained well in Group I during follow-up. Anterior vertebral height was decreased significantly in Group II during follow-up ($p<0.05$).

4. Discussion

The main benefit of surgical treatment of thoracolumbar fracture is that reduction and internal fixation of the injured spine allows early mobilization[3,8,13]. The other goals are 1) to decompress the neural canal by the direct[14-16] or indirect[6,17-19] method, especially in patients with neurologic deficits; 2) to prevent progressive deformity or further neurologic deterioration[4,20]. The short-segment fixation system limits surgical dissection and fusion to only 2 spinal motion segments, thus it can preserve more motion segments than long rod instrumentation. The surgical technique can provide symmetric 3-column lordotic distraction and make good initial kyphosis correction, but failure to maintain the sagittal plane correction has been reported by many authors[6,8,14], which is consistent with our findings that a high rate of loss of sagittal plane correction was associated with the short-segment fixation construct in our Group II patients.

Haher et al studied the effect of the 3 columns of the spine on the instantaneous axis of rotation in flexion and extension[21,22]. They demonstrated that the destruction of the anterior and middle columns moves the instantaneous axis of rotation posteriorly, thereby increasing its distance from the center of gravity. Anterior spinal instrumentation would place the instantaneous axis of rotation in the anterior aspect of the spine, thereby decreasing the moment arm to the center of gravity. A mechanical advantage would be obtained due to the decreased length of the moment arm. This means that reconstruction or augmentation of the anterior and middle columns may be necessary for sagittal maintenance[23-26], but anterior surgery is much more complicated in that it is associated with prolonged operation and hospitalization time, and increased morbidity and even mortality in the elderly[4,27]. Therefore, less invasive methods for vertebral body reduction and augmentation have been introduced[27-30]. However, serious drawbacks associated with the cement leakage and the high surgical technique demand was noted.

Posterior instrumentation is the most frequently used surgical treatment of thoracolumbar fractures because of the low morbidity and comorbidity, and surgeons' familiarity with the posterior approach compared with the anterior approach. Some authors have been using monosegmental fixation to treat thoracolumbar fractures and reported that this method has yielded good clinical results[31-33]. Muller et al[34] reported that disc space collapse is the main reason for correction loss after an operation and monosegmental fixation may not include all injured disc levels. Wei et al[33] noted that the difference in failure rate between monosegmental fixation and short-segment instrumentation is due to much more correction loss (6.38% vs 5.26%) for monosegmental fixation, although the difference was not significant. Two screws inserted at the fracture level after posterior instrumentation may be a handicap of anterior decompression if needed for patients with severe neurologic deficit. This is why we used the additional 2 screws at the level of fracture in patients with no or mild neurologic deficit and used one additional screw at the level of the fracture in patients with severe neurologic deficit who may need anterior surgical decompression if the neurologic deficit is not improving after a posterior operative procedure.

Many authors may be concerned about the safety and pullout strength of the pedicle screw at the fracture level. Computer-assisted surgery, using a CT-based navigation system, has been introduced successfully to add saftety[35,36] and accuracy to posterior procedures in spine surgery[37]. The navigation system can provide the accuracy in the placement of pedicle screws at the fracture level and it is safety in our study. Many authors[38] have reported that the pullout strength of the pedicle screw inserted into the fractured vertebral body is sufficient for the stability of construction. They have also reported that there is no difference in pullout strength between screws of similar sized inserted to a 50% depth versus to anterior cortex. Mahar et al[10] revealed that segmental fixation of burst fractures with screws at the level of the fracture can increase construct stiffness for axial tension stiffness, which offers improved biomechanical stability. It can also shield the fractured vertebral body from anterior loads and thereby reduce the high incidence of instrumentation failure and loss of kyphotic correction after pedicle screw instrumentation due to structural and mechanical deficiency of the anterior column after posterior operative indirect reduction of the fracture, which was demonstrated by this study.

Hashimoto et al[39] showed that initial canal compromise correlates with significantly increased risks of neurologic deficit. However, Dai et al[40] reported there was no statistically significant difference in the stenotic ratio of spinal canal or kyphotic deformity demonstrated in the patients with no neurologic deficit, with incomplete lesions, and with complete lesions. This is similar to our findings that the severity of neurological deficit could not be predicted, although what constitutes adequate canal clearance, which is supported by many authors, is still unknown[15,19,23]. The value of decompression of the spinal canal in spinal injury, whether anterior or posterior, is still controversial[19,38]. In the indirect method, lordotic distraction is the main force required for indirect posterior reduction. Clinically we found that the kyphosis correction is impressive and the improvement in Frankel subgrade was similar in both groups, but the maintenance of sagittal alignment was not adequate in Group II. Short posterior instrumentation may lead to early implant failure and to rekyphosis. A fixed kyphosis or a flat back deformity at the thoracolumbar or lumbar level may lead to pain, dysfunction, and in some cases, implant failure. The complication may necessitate a late revision and reconstruction of the deformed segment[7,9,11]. McLain et al[7] reported that patients who had major progressive kyphosis had more symptoms of pain and more severe symptoms than those who had little or no progression, which is consistent with our findings.

There are limitations to this study. One is that it was not a prospective randomized clinical trial and as such, is amenalle to biased and invalid results.[41] Another is the number of patients available was not large enough. The research team is currently considering increasing the patient sample size and arranging for a prospective randomized clinical trial.

In conclusion, there is a high fixation failure rate associated with thoracolumbar burst fractures treated with short pedicle instrumentation without screws at the fracture level. Computer-assisted pedicle screw insertion at the fracture level effectively reduces fixation failure, and the kyphosis correction and height restoration is maintained well. Although the neurologic outcomes were similar in both groups, posterior short instrumentation without pedicle screw insertion at the fracture level resulted in substantially more pain.

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