

Management of Late Posttraumatic Kyphosis With Anterior Z-Plate Instrumentation

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Abstract

Failed treatment of thoracolumbar spine fractures may lead to late posttraumatic kyphosis (LPK), and LPK treatment is challenging. The aim of this retrospective study was to investigate whether anterior reduction and Z-plate instrumentation constitute feasible treatment for LPK (>30 days after injury). Twenty patients who developed LPK after a thoracolumbar fracture were treated with the Z-plate anterior thoracolumbar plating system. Sixteen patients were followed for a mean of 35 months. Ten of 15 patients with a thoracotomy had persistent postthoracotomy pain. Mean back pain decreased significantly, from 9.2 before surgery to 4.1 after surgery (10 = worst pain ever experienced, 0 = no pain). Osseous union occurred in all patients. Postoperative loss of reduction of 4.9° kyphotic angle was recorded at follow-up. Anterior stabilization with the Z-plate is a technically feasible procedure in patients with LPK. Long-term postthoracotomy pain seems to be a significant problem in these patients.

Treatment of fractures of the thoracolumbar spine can be nonsurgical or surgical, depending on fracture type. Most fractures of the thoracolumbar junction are considered stable and do not require surgical intervention. Unstable thoracolumbar fractures, or fractures with severe deformities, often require surgical treatment. For these fracture types, stable, rigid instrumentation systems that allow reconstruction of the spinal column and early mobilization have replaced nonsurgical treatments.

In the past, however, initial treatment of thoracolumbar fractures was often inadequate. Failure of surgical and nonsurgical initial treatment of thoracolumbar spine fractures may lead to late posttraumatic kyphosis (LPK) with

incapacitating back pain and secondary neurologic deficits that can occur many years later.¹ Mechanisms of this complex spinal disorder include musculoskeletal dysfunctions due to kyphotic deformity and instability in the adjacent segments as well as neuropathic pain due to spinal canal stenosis, tethered cord syndrome, and syringomyelia.¹⁻⁷

LPK treatment remains difficult, and nonsurgical treatment of this spinal disorder is often unsuccessful. Because of its complex nature, LPK represents a challenging problem for spinal surgeons. Overall, the goals in revision surgeries do not differ from those in initial surgical procedures and include spinal canal decompression and reduction of posttraumatic deformity. However, these old fractures of the vertebral body are often irreducible by posterior distraction alone, as any delay in initial reduction of thoracolumbar fractures may lead to formation of scar tissue, fixed deformities, and callus formation. Although there is no consensus about the surgical treatment of LPK, some authors have pointed out that an anterior approach, including an osteotomy of the vertebrae or partial corpectomy, should be included in the surgical strategy.^{4,8-11}

In recent years, several anterior fixation devices have been developed: anterior thoracolumbar locking plate (ATLP), Armstrong plate, ASIF T-plate, Dewald-LDI system, Dunn device, Kaneda device, Kostuik-Harrington device, Olerud plate, Slot-Zielke device, Synthes plate, Texas Scottish Rite Hospital device, University anterior plating system, and Yuan plate.¹²⁻¹⁷ The array of devices indicates the difficulty in designing an anterior fixation device that features low risk for vascular injuries, high neurologic recovery, low rates of hardware failures, high fusion rates, compatibility with computed tomography (CT) and magnetic resonance imaging (MRI), high rigidity, ease of insertion, and the option to perform a reduction of kyphotic deformity (ie, distraction).

The Z-plate has demonstrated adequate stability for most loading situations.^{12,14,17,18} The low profile of this system is intended to prevent vascular complications and allow easy repair of the diaphragm. As a dynamic device, it allows distraction and reduction of kyphotic deformity as well as the ability to compress after bone grafting. The radius of curvature of the plate allows the plate to be closely applied to the curvature of the vertebral body. The titanium materials are CT- and MRI-compatible. Although the Z-plate was approved by the US Food and Drug Administration in 1993, few clinical studies have been conducted to evaluate its advantages and disadvantages.

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Table. Demographic Data and Clinical and Radiologic Outcomes

| Age (y) | Sex | Injury Level | Initial Treatment | Follow-Up (mo) | Back Pain* | | Postthoracotomy | Kyphosis (°) | | | Pain Relief? | Would Do It Again? |
|---------|-----|--------------|--------------------|----------------|----------------|---------------|-----------------|----------------|---------------|--------------------|--------------|--------------------|
| | | | | | Before Surgery | After Surgery | | Before Surgery | After Surgery | At Final Follow-Up | | |
| 47 | F | T8+T9 | Nonoperative | 13 | 10 | 0 | No | 8 | 0 | 0 | Yes | Yes |
| 53 | M | T11 | Nonoperative | 37 | 10 | 3 | No | 15 | 5 | 10 | Yes | Yes |
| 55 | F | T12 | Nonoperative | 42 | 9 | 9 | Yes | 25 | 10 | 16 | No | No |
| 62 | F | T12 | Nonoperative | 48 | 10 | 10 | Yes | 18 | 6 | 11 | No | No |
| 34 | M | T12 | Posterior fixation | 45 | 9 | 4 | Yes | 42 | 22 | 27 | Yes | Yes |
| 33 | F | T12 | Nonoperative | 36 | 9 | 5 | Yes | 21 | 10 | 14 | Yes | Yes |
| 32 | F | T12+L1 | Posterior fixation | 23 | 8 | 4 | Yes | 31 | 15 | 22 | Yes | Yes |
| 55 | M | L1 | Nonoperative | 48 | 10 | 2 | No | 18 | 7 | 12 | Yes | Yes |
| 43 | F | L1 | Nonoperative | 36 | 8 | 2 | Yes | 35 | 8 | 13 | Yes | Yes |
| 38 | M | L1 | Nonoperative | 34 | 8 | 3 | No | 26 | 11 | 16 | Yes | Yes |
| 58 | F | L1 | Laminectomy | 36 | 9 | 5 | Yes | 23 | 9 | 16 | Yes | Yes |
| 52 | F | L1 | Laminectomy | 24 | 10 | 6 | Yes | 19 | 8 | 15 | Yes | Yes |
| 45 | F | L2 | Nonoperative | 32 | 9 | 4 | Yes | 15 | 6 | 10 | Yes | Yes |
| 20 | M | L2+L3 | Posterior fixation | 17 | 8 | 4 | Yes | 35 | 15 | 23 | Yes | Yes |
| 44 | M | L2 | Nonoperative | 35 | 10 | 3 | No | 12 | 4 | 8 | Yes | Yes |
| 55 | M | L3 | Nonoperative | 55 | 10 | 2 | N/A† | 11 | 4 | 6 | Yes | Yes |

*Patients rated their pain on a visual analogue scale ranging from *worst pain ever experienced* (10) to *no pain* (0).

†No thoracotomy was performed in this patient.

The aim of this retrospective study was to investigate whether anterior reduction and Z-plate instrumentation constitute feasible treatment of LPK (>30 days after injury).

MATERIALS AND METHODS

Patients

Over a 5-year period, 20 patients (11 men, 9 women) with LPK were treated with anterolateral decompression and Z-plate stabilization.

Four of these 20 patients were excluded from this retrospective study. One patient, age 78, died approximately 36 months after surgery. For this patient's postoperative clinical course and consecutive follow-up visits, no major complications had been documented, and it was assumed the death was unrelated to the spinal procedure. Another patient could not be found for follow-up. Two men refused to take part in this study: One was gainfully employed and explained on the phone that he had experienced significant relief of pain and did not use any analgesics; the other was applying for worker's compensation and did not want to share information. These 2 patients had been followed for 12 months after surgery and were noted to have a fusion of the injured spinal segments at the final follow-up.

The remaining 16 patients (7 men, 9 women) were available for follow-up and were enrolled in the study. These patients were assessed by an independent examiner at a mean follow-up of 35 months (range, 13-55 months) on an outpatient basis. These patients' demographic data are summarized in the Table. Mean age at surgery was 45 years (range, 20-62 years). All patients had an old thoracolumbar fracture (>30 days after injury). Patients with fresh thoracolumbar burst fractures were not included in this series. Mean interval between initial injury and Z-plate instrumentation was 14 months (range, 1-42 months). Three patients included in this study had been treated with posterior stabilization and pedicle screw fixation at time of injury. Two patients were initially

treated with laminectomy and spinal canal decompression. Indications for anterior decompression and stabilization in this series included kyphotic deformity, progressive kyphosis, and persisting pain. Level of injury was within the thoracic spine (T8-T11) in 2 cases, at the thoracolumbar junction (T12-L1) in 10 cases, and within the lumbar spine (L2-L3) in 4 cases. Three patients had a 2-level injury.

Surgical Technique

The thoracolumbar junction was approached through the bed of the 10th or 11th rib, which required removal of this rib. After exposure and identification of the fractured vertebral body, corpectomy and reduction of the LPK were performed. An autogenous bicortical iliac crest bone graft was obtained through the same surgical incision. The bone graft was fitted into the bone defect using a press-fit technique. In addition, the resected rib was contoured and fitted into the bone defect. The implant was then applied. Accurate reduction and implant position were confirmed by intraoperative x-rays. A postoperative chest tube was used in all patients. After surgery, all patients were mobilized with a molded thermoplastic brace that they wore full-time for 4 months.

Clinical and Radiologic Evaluation

Demographic data and clinical preoperative data were obtained from patient charts and our electronic database. Patients were given a clinical examination by an independent observer on an outpatient basis and were administered a questionnaire on demographics, pain, function, use of analgesics, and employment status. Preoperative and postoperative pain scores were obtained on a visual analogue scale (VAS) consisting of a 10-cm line with one end anchored at *worst pain ever experienced* (10) and the other at *no pain* (0). Postoperative function was assessed by the Hannover Functional Ability Questionnaire for Measuring Back Pain-Related Functional Limitations (FFbH-R).¹⁹ This validated, short, self-administered question-

naire is used to assess functional limitations in activities of daily living. Its total score is expressed on a scale ranging from *minimal function* (0%) to *maximal function* (100%).

The Cobb method was used to measure kyphotic angle on lateral x-rays of the thoracolumbar junction. For this measurement, lines are drawn tangentially to the superior endplate of the superior vertebra and to the inferior endplate of the inferior vertebra. Perpendicular lines to these tangential lines construct the kyphotic angle. Fusion at the arthrodesis site was evaluated on plain x-rays and conventional tomograms, which were routinely obtained 6 months after surgery.

Statistical Analysis

Statistical analysis was done with SPSS 11.5 for Windows (SPSS Inc, Chicago, Ill). $P < .05$ was considered significant. The Wilcoxon signed rank test was used to compare preoperative and postoperative pain scores and kyphotic angles.

RESULTS

Three patients had complications recorded in this series. One woman with an incisional hernia needed a surgical repair. One patient with a superficial wound infection had it cleared with simple opening of the skin and subcutaneous tissue and intravenous administration of antibiotics. Another patient had a wound dehiscence successfully managed with surgical intervention. No hardware failures or vascular or neurologic complications associated with the procedure were recorded.

Clinical outcome data are summarized in the Table. Before and after surgery, all patients had normal sensorimotor function. Bowel or bladder dysfunctions were not recorded in this series. According to VAS scores, mean pain intensity decreased significantly, from 9.2 (range, 8-10) before surgery to 4.1 (range, 0-10) after surgery ($P < .0005$). Ten (66.7%) of the 15 patients who underwent thoracotomy with rib removal complained of significant postthoracotomy pain; for 7 (46.7%) of these 15 patients, postthoracotomy pain was the major complaint. Fourteen (87.5%) of the 16 patients reported some or complete relief of back pain, and 14 stated they would undergo the procedure again. Four (25%) of the 16 patients used analgesics regularly (>15 d/mo). Function was assessed with the FFbH-R.¹⁹ Mean function score was 64.2% (range, 0%-100%). At final follow-up, 7 patients were gainfully employed, 3 had applied for worker's compensation, 2 had retired because of physical disability, and 6 had retired after reaching retirement age (this total of 18 patients includes the 2 who gave employment status by phone but refused to participate in the study).

Osseous union occurred in all patients, as determined by plain x-rays and conventional tomograms, which were routinely obtained 6 months after surgery. Hardware failures and autograft displacement were not seen at final follow-up. Kyphosis was measured on lateral x-rays. Mean Cobb angle was 22.1° (range, 8°-42°) before surgery, 8.8° (range, 0°-22°) after surgery, and 13.7° (range, 0°-27°) at final follow-up, with a mean loss of correction of 4.9° (Figures 2A-2C). Kyphotic angle at final follow-up was significantly lower than before surgery ($P < .0005$).

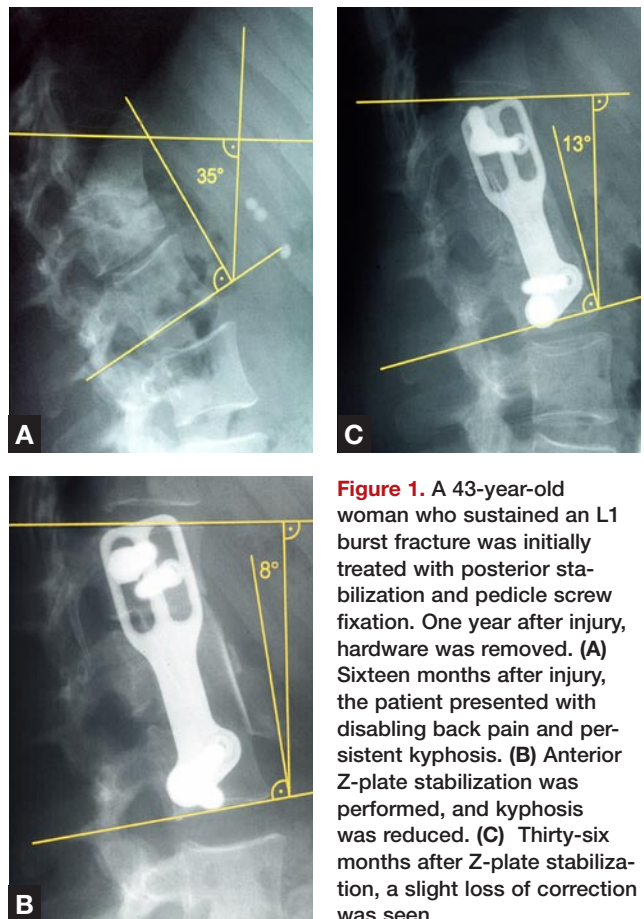


Figure 1. A 43-year-old woman who sustained an L1 burst fracture was initially treated with posterior stabilization and pedicle screw fixation. One year after injury, hardware was removed. (A) Sixteen months after injury, the patient presented with disabling back pain and persistent kyphosis. (B) Anterior Z-plate stabilization was performed, and kyphosis was reduced. (C) Thirty-six months after Z-plate stabilization, a slight loss of correction was seen.

DISCUSSION

Treatment of LPK with incapacitating back pain remains a common challenge for spinal surgeons. Many factors lead to the occurrence of this complex disorder:

1. Stable, rigid instrumentation systems that allow reconstruction of the spinal column and early mobilization have replaced nonsurgical treatment for certain fracture types. Before these systems were introduced, and before modern standardized surgical techniques were available, treatment was often inadequate by current standards.

2. Thoracolumbar fracture severity is sometimes underestimated. Fracture type can be misinterpreted, and biomechanical principles of the spine may not be respected. Initial nonsurgical treatment with recumbency and bed rest can become insufficient over the long term.

3. Although posterior stabilization with pedicle screw fixation of thoracolumbar fractures is widely used, many authors have reported unsatisfying results with respect to postoperative loss of correction after posterior pedicle screw fixation.²⁰⁻²⁹ Postoperative loss of correction may lead to LPK.

In acute management of thoracolumbar burst fractures, excellent results can be achieved with circumferential fusions. Combined anteroposterior procedures have an important role in LPK prevention. This approach can be used to maintain optimal correction and fusion after spinal fracture stabilization.^{24-26,30-34}

Residual kyphosis after spinal fracture stabilization may be a concern with respect to long-term functional outcome.²⁸ Potentially aggravating the condition are various musculoskeletal disorders, such as abnormal physiologic loads associated with instability and degeneration in the adjacent segments, compensatory thoracic hypokyphosis and lumbar hyperlordosis, spinal canal stenosis, and various neurologic disorders, such as radicular symptoms, myelopathy, posttraumatic thoracic syringomyelia, and tethered cord syndrome.¹⁻⁷ LPK, often unresponsive to nonoperative treatment, also challenges spinal surgeons. It is of paramount importance to address this problem as soon as possible to prevent chronic disabling back pain.

The literature includes many reports on treating thoracolumbar fractures but few on treating LPK, and data are limited. Some authors suggest a combined approach for LPK patients after unsuccessful treatment with recumbency and bed rest or inadequate surgery.^{1,4,11,35} An anterior approach becomes necessary for satisfying reduction results. This approach is required, along with osteotomy of the vertebrae or partial corpectomy, because callus formation of the vertebral bodies renders it very difficult to reduce posttraumatic deformity by posterior reduction and stabilization. After only 2 weeks, fractures of the vertebral body are often irreducible by posterior distraction alone. Therefore, any delay in initial reduction of thoracolumbar fractures may make an anterior procedure necessary.^{1,4-8-11} For this reason, anterior decompression with Z-plate instrumentation was used in this series to treat patients with LPK.

Cadaver studies have demonstrated the advantageous biomechanical properties of Z-plates,^{12,14,17,18} and clinical studies have shown excellent correction maintenance with Z-plate instrumentation.^{13,36} In most cases, postoperative loss of correction with progressive kyphosis is a common problem with spinal fracture stabilization; reported values range from 6° to 12°. ^{2,8,20,23-28,30,37,38} Progressive postoperative kyphosis may be a concern and may be associated with substantial residual pain.²⁸ In this context, the mean postoperative correction loss of 4.9° kyphotic angle noted in our series appears to be a satisfactory result. In particular, mean kyphosis at final follow-up was significantly less than it was before surgery—representing successful kyphosis reduction. Besides there being a relatively low postoperative loss of correction, there were no hardware failures, nonunions, or delayed unions in this study—further emphasizing the satisfactory *in vivo* stability of Z-plates. In some patients, however, residual kyphosis was as large as 27°. Although functional outcomes were satisfactory for most patients, abnormal physiologic loads, facet joint degeneration in adjacent segments, and compensatory lumbar hyperlordosis may be of concern in a study with longer follow-up.

In our series, clinical results regarding functional outcome, postoperative pain, use of analgesics, and employment status were satisfactory. There were no neurologic complications or any device-related impingement of neurologic structures in this patient group, and there were no

major complications of using the anterior approach. Anterior decompression and stabilization include a potential risk for vascular injuries, pneumothorax, sympathectomy, and retroperitoneal bleeding. Rod systems, in particular, are bulkier and have the potential to injure adjacent organs. Newer anterior stabilization systems, such as the Z-plate, ATLP, and University plate, are designed to decrease the profile of the implant, reducing the risk for complications related to the anterior stabilization and instrumentation. Therefore, we believe that the low profile of the Z-plate contributed to the good outcomes achieved in our series.

This study revealed that long-term postthoracotomy pain is a major problem for these patients. Although few objective data are available in the literature, the consensus is that postthoracotomy pain is common and may last for several months. Reporting on a series of 56 patients who underwent thoracotomy, Dajczman and colleagues³⁹ found that 54% had persistent postthoracotomy pain at a mean follow-up of 19.5 months. Therefore, in our series, it was not surprising that 46.7% of patients reported postthoracotomy pain as their chief complaint. This problem, which is most likely due to intercostal nerve damage and formation of localized neuromas,³⁹ must be considered when choosing an adequate procedure for spinal stabilization. In the future, minimally invasive, video-assisted thoracoscopic surgery may play a role in preventing postthoracotomy pain, as it has been shown to result in less postoperative pain, fewer pain medication requirements, improved postoperative shoulder girdle function, improved postoperative pulmonary function, and less morbidity after cardiothoracic procedures.⁴⁰⁻⁴⁵

Despite the promising results of LPK treatment with Z-plate stabilization in this study, anterior decompression and instrumentation performed as a 1-stage procedure have only limited indications in the treatment of fresh thoracolumbar fractures. Some authors have suggested anterior decompression and instrumentation as a 1-stage anterior procedure for the treatment of fresh thoracolumbar burst fractures.^{13,15,16,46-48} However, intact dorsal ligamentous structures and intact facet joints are important prerequisites for 1-stage anterior procedures. Posterior instabilities must be ruled out carefully before surgery. Therefore, we believe that the indications for 1-stage anterior procedures are limited.

CONCLUSIONS

Management of LPK is challenging. Good clinical and radiologic results can be achieved by anterior reduction and Z-plate instrumentation. Rates of correction loss and hardware failures are low. Long-term postthoracotomy pain may occur and may be a chief complaint.

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