Flexion-distraction injuries of the thoracolumbar spine: open fusion versus percutaneous pedicle screw fixation

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Object. Flexion-distraction injuries occur due to distractive forces causing disruption of the posterior and middle spinal columns. These fractures classically consist of a fracture line through the posterior bony elements; involvement of the posterior ligamentous complex is, however, common. Surgical treatment is often required for these unstable injuries to avoid neurological deterioration and posttraumatic kyphosis, and the surgery traditionally consists of an open posterior approach with instrumented fusion. Percutaneous pedicle screw fixation for these injuries, with the goal of minimal tissue disruption and preservation of normal anatomy while achieving adequate stabilization, has recently been reported in the literature, but to date, a direct comparative study comparing open and percutaneous fixation has not been reported. The authors report their experience treating these fractures with both techniques and review the available literature.

Methods. Patients with flexion-distraction injury who were treated between May 2003 and March 2013 were prospectively followed. American Spinal Injury Association scores and degree of kyphotic angulation were recorded at admission, discharge, and follow-up. Data regarding intraoperative blood loss and operative time were obtained from a chart review. Patients treated with open versus minimally invasive procedures were compared.

Results. The authors identified 39 patients who suffered flexion-distraction injuries and were treated at their institution during the specified period; one of these patients declined surgery. All had injury to the posterior ligamentous complex. Open surgical procedures with pedicle screw fixation and posterolateral fusion were performed in 27 patients, while 11 patients underwent minimally invasive pedicle screw placement. Overall, there was improvement in kyphotic angulation at the time of discharge as well as most recent follow-up in both the open surgery and minimally invasive surgery (MIS) groups. The authors found no significant difference in American Spinal Injury Association score or the degree of kyphotic angulation between the MIS and open surgery groups. There was a trend toward shorter operative time for the MIS group, and patients who underwent minimally invasive procedures had significantly less blood loss.

Conclusions. Minimally invasive percutaneous pedicle screw fixation appears to have similar efficacy in the treatment of flexion-distraction injuries and it allows for reduced blood loss and tissue damage compared with open surgical techniques. Therefore it should be considered as an option for the treatment of this type of injury.
(<http://thejns.org/doi/abs/10.3171/2013.6.FOCUS13176>)

KEY WORDS • flexion-distraction • Chance fracture • thoracolumbar • spine • minimally invasive surgery

FLEXION-DISTRACTION injuries occur due to distractive forces leading to disruption of the posterior and middle columns of the spine.⁵ These injuries are frequently associated with anterior column injuries such as compression fractures, often leading to further instability or kyphosis.²⁵ This fracture pattern was first classified by Chance, who originally described a flexion injury to the vertebrae resulting in disruption of the posterior arch system.³ These fractures classically consist of a fracture line through the spinous process, laminae, transverse

processes, pedicles, and into the vertebral body (Fig. 1), but involvement of soft tissues, such as the posterior ligamentous complex, is very common.^{1,15,22} The most common location for a flexion-distraction injury is around the thoracolumbar junction, although it can occur at any level of the spine.^{4,15} Flexion-distraction injuries account for 1%–16% of all thoracolumbar fractures, depending on the population examined.^{20,28}

Treatment of flexion-distraction injuries often requires surgical fixation and fusion. Although extension casting can be used for nondisplaced bony Chance fractures,¹ surgical treatment is often required if there is damage to the posterior ligamentous complex, as the associated ligaments heal poorly despite reduction and prolonged immobilization, and conservative management

Abbreviations used in this paper: AP = anteroposterior; ASIA = American Spinal Injury Association; IRB = institutional review board; MIS = minimally invasive surgery; TLICS = thoracolumbar injury classification system.

FIG. 1. Left: Midsagittal CT scan showing an L1 fracture involving the vertebral body and extending through the spinous process. Right: Sagittal CT scan showing an L1 fracture involving the vertebral body and extending through the pedicle posteriorly.

often results in significant kyphotic deformity and neurological deterioration.^{5,15} Moreover, extension bracing may be difficult for patients to tolerate, thus requiring surgical intervention.¹

Recently, minimally invasive techniques, such as percutaneous pedicle screw fixation, have become more routinely used. Percutaneous pedicle screw fixation has been shown to decrease blood loss, operative time, paraspinal muscle damage, and use of postoperative analgesics.^{12,22} Minimally invasive percutaneous instrumentation is an option, and it is particularly suitable for unstable fractures that do not require open reduction or open decompression of the neural elements. There have been relatively few reports of percutaneous pedicle screw fixation for flexion-distraction injuries in the literature, and reports thus far are limited to primarily bony injuries.^{1,22} This is likely due to the concern that ligamentous injuries heal poorly, thus necessitating bone grafting for fusion via open techniques. However, more recently, percutaneous pedicle screw fixation has been augmented with posterior fusion using allograft inserted after the placement of the rods.

We report our experience with the management of thoracolumbar flexion-distraction injuries with posterior ligamentous disruption over the past 10 years and compare open and percutaneous methods.

Methods

Under an IRB-approved research protocol, patients with flexion-distraction injury who were treated between May 2003 and March 2013 were followed prospectively. Neurological status was determined using the ASIA scoring system, which is based on the modified Frankel score,^{7,18} on admission as well as at each follow-up visit. The degree of kyphotic angulation, or Cobb angle, was measured from lateral radiographs using the rostral and

caudal intact endplates on admission, at discharge, and at each follow-up visit. The residual canal was based on the AP diameter of the canal at the site of injury, expressed as a percentage of the average AP diameter at the intact levels rostral and caudal to the level of the injury. Injuries were classified using the AO classification as well as the TLICS for thoracolumbar injuries.^{2,10,14,16,20,23,25,27,29} Total operative time, blood loss, and length of hospital stay were obtained via chart review from the surgeon's operative note, the operating room records, and the discharge summary. Results are summarized in Table 1.

Results

A total of 39 patients (30 male, 9 female) with flexion-distraction injury were treated at our institution between May 2003 and March 2013. Surgical management was recommended to all 39 patients, but one declined surgical treatment and was treated conservatively with external bracing. The average age of all 39 patients was 32 years (SD 18 years, range 14–85 years). The mechanisms of injury included 18 motor vehicle accidents, 9 falls, 3 motorcycle accidents, 3 ATV accidents, 1 sled-ding accident, 1 skiing accident, 1 bicycle accident, and 1 farming accident; in addition, 1 patient was struck by a car (as a pedestrian), and 1 patient was stuck by a falling tree limb. In all cases, noncontrast MRI demonstrated injury to at least some portion of the posterior ligamentous complex (Fig. 2). The levels of injury ranged from T-4 to L-2. The most commonly injured level was L-1 (12 cases). The average residual canal after injury was 94% (range 0%–100%).

Open surgical procedures with pedicle screw fixation and posterolateral fusion were performed in 27 patients

TABLE 1: Comparison of patients treated with MIS versus open procedures*

Variable	MIS	Open	p Value
no. of patients	11	27	
sex			
male	11	18	
female	0	9	
age (yrs)	40.1 ± 20.3	27.4 ± 15.3	0.4
ASIA score			
at admission	5†	4.41 ± 1.28	0.31
at follow-up	5†	4.56 ± 1.19	0.42
kyphosis (°)			
at admission	6.45 ± 3.43	9.85 ± 8.00	0.23
at follow-up	1.45 ± 7.98	6.26 ± 8.48	0.10
operative time (mins)	195 ± 42	257 ± 101	0.07
blood loss (ml)	93.6 ± 66.2	498 ± 415	0.003
no. of levels instrumented	3.8 ± 0.8	4.7 ± 1.2	0.08
hospital stay (days)	7.6 ± 3.8	11.2 ± 7.0	0.12

* Values represent numbers of patients or means ± SDs unless otherwise indicated.

† No SD is given because the score was 5 for all patients in the group.

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Fig. 2. **Left:** Midsagittal STIR MR image showing an L-1 fracture and highlighting the disruption of the posterior ligaments, including the ligamentum flavum and supraspinous ligament. **Right:** Midsagittal STIR MR image showing disruption of the ligamentum flavum, intraspinal ligament, and supraspinous ligament at T8-9.

(Fig. 3) and minimally invasive percutaneous pedicle screw fixation (MIS) without bony fusion was performed in 11 (Fig. 4). Twenty-four patients underwent fusion at least 2 levels above and 2 levels below the injured level. Construct length was based on the discretion of the operating surgeon, considering the level of fragmentation and comminution of the vertebral body (Fig. 5). Patients with associated fractures that compromised the anterior column support, such as burst fractures, were treated with longer-segment instrumentation. All but one of the surgi-

Fig. 3. Postoperative lateral (**left**) and AP (**right**) radiographs obtained after open T11-L3 posterolateral fusion with pedicle screw fixation of L-1 flexion-distraction injury.

Fig. 4. Postoperative lateral (**left**) and AP (**right**) radiographs obtained after MIS T8-10 pedicle screw fixation of flexion-distraction injury.

cally treated patients underwent surgery within 7 days of injury. The one patient whose surgery was delayed underwent surgery 15 days after injury as his condition was not stable enough until this point due to associated injuries, including traumatic brain injury and hemoperitoneum. Patients with incomplete spinal cord injuries all underwent surgical decompression within 24 hours of admission. No patient showed neurological deterioration prior to being cleared for surgery. The mean duration of follow-up was 18.5 months for the open group and 9 months in the MIS group. Patients treated with MIS procedures were significantly older (mean age 40.1 ± 20.3 years) than patients treated with open procedures (mean age 27.4 ± 15.3 years, $p = 0.04$).

The ASIA score was converted to a numerical system to aid in statistical comparison (1 = A, 5 = E). The average ASIA score at admission in the open surgery group was 4.41 (range 1-5, SD 1.28); all patients in the MIS group had ASIA scores of 5. The average ASIA score in the open surgery group improved to 4.56 at follow-up (range 1-5, SD 1.19). The between-groups difference was not significant at admission ($p = 0.31$) or follow-up ($p = 0.42$). The average kyphotic angulation at admission was 9.85° (range -12° to 25° , SD 8.00°) in the open surgery group and 6.45° (range 1° to 10° , SD 3.43°) in the MIS group (not significantly different, $p = 0.23$). The average kyphotic angulation improved to 6.26° (range -20° to 19° , SD 8.48°) in the open group and to 1.45° (range -9° to 18° , SD = 7.98°) in the MIS group, but the between-groups difference was not statistically significant ($p = 0.10$). The difference between the kyphotic angulation measured during the immediate postoperative period and at follow-up was not significant in either the open surgery ($p = 0.69$) or the MIS group ($p = 0.40$).

The total operative time averaged 195 minutes in the MIS group (range 139-280 minutes, SD 42 minutes) and 257 minutes in the open surgery group (range 132-479

Fig. 5. Midsagittal CT scan showing a flexion-distraction injury that has caused a fracture of the T-9 vertebral body extending posteriorly through the T-8 spinous process.

minutes, SD 101 minutes). There was a trend toward shorter operative times in the MIS group, but the difference did not achieve statistical significance ($p = 0.07$). The exact operative time was unavailable in 13 patients, all in the open surgery group. One patient underwent anterior cervical fusion for a separate injury during the same procedure, and this patient was omitted from the operative time analysis because the exact time of the thoracolumbar fusion could not be determined. The average blood loss was 93.6 ml in the MIS group (range 10–200 ml, SD 66 ml) and 498 ml (range 150–1500 ml, SD 415 ml) in the open surgery group. This difference was significant ($p = 0.003$). Intraoperative blood loss data were not available for 6 patients, all in the open surgery group. The patient who underwent anterior cervical fusion was again excluded from this analysis as the amount of blood loss from each procedure could not be determined. Although the average number of levels instrumented was

greater in the open surgery group, the between-groups difference did not achieve significance (MIS group mean 3.8 ± 0.75 , range 3–5 levels; open surgery group mean 4.7 ± 1.16 , range 2–7 levels; $p = 0.08$). The average hospital stay was 7.6 days (range 4–17 days, SD 3.8 days) for patients treated with MIS and 11.2 days for patients treated with open procedures (range 4–29 days, SD 7.0 days); this difference was not statistically significant ($p = 0.12$). The length of stay was often influenced by associated injuries.

Of our patients, 34 had TLICS scores of 7, 4 had a score of 10, and 1 had a score of 9. There was a mix of AO classifications, however, the most common was B1.2 injuries with the disruption of the posterior elements that was primarily ligamentous with an associated fracture of the vertebral body.

Surgical complications included a wound infection in 1 patient in the open surgery group with methicillin-sensitive *Staphylococcus aureus* that required 10 weeks of intravenous antibiotic therapy and 2 patients who required revision for misplaced pedicle screws—one of whom was in the MIS group. The patient who declined surgery has persistent back pain and progression of kyphosis from 8° on initial admission to 32° at the 5-month follow-up visit. The patient was again offered surgery at that time but again declined. He remained neurologically intact. Two patients underwent subsequent removal of their MIS instrumentation without complication after the healing of their injuries, thus eliminating any loss-of-motion segments. Neither patient has had subsequent progression of kyphosis following removal of the instrumentation. Although our follow-up period was relatively short, there were no cases of construct failure, kyphosis, or gibbus deformity.

Discussion

In 1948, Chance described a flexion injury to the vertebrae that resulted in a disruption of the posterior arch system.³ These fractures classically consist of a bony fracture line through the spinous process, laminae, transverse processes, pedicles, and into the vertebral body; however, involvement of soft tissues such as the posterior ligamentous complex is common.^{15,24} The most common location for flexion-distraction injuries is the thoracolumbar junction,⁹ which is consistent with our findings.

The management of flexion-distraction injuries often necessitates the use of posterior instrumentation and fusion, as conservative management may lead to kyphotic deformities or nonunions.^{5,15,26} These complications can in turn lead to pain or neurological deterioration.^{11,21} Conservative management of purely osseous injuries with extension casting or bracing may be attempted given their ability to heal compared with ligamentous injuries; however, this may be difficult for the patient to tolerate.^{1,13,22} The goal of surgical fixation includes stabilization of the spine, correction of focal kyphosis, prevention of progressive kyphosis, as well as decompression of neurological structures when appropriate.¹¹ Various surgical methods have been described for thoracolumbar flexion-distraction injuries.^{1,6,8} In 2004 Verlaan et al. performed a review of articles published between 1970 and 2001 that

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compared surgical techniques for traumatic thoracolumbar injuries.²⁸ The study population included 30 patients who had flexion-distraction injuries. The authors found that none of the surgical techniques that were used were able to maintain the corrected kyphotic angle, or Cobb angle.^{11,28} Many of the earlier studies used hooks and rods for posterior stabilization, devices that today have largely been replaced by the use of pedicle screws. In 2008, Joseph et al. evaluated 15 cases in which posterior stabilization using pedicle screws and rods was performed for the treatment of thoracic spine flexion-distraction injuries.¹¹ They found that the average kyphosis was improved from 19.6° preoperatively to 5.73° postoperatively, a statistically significant difference, and that the degree of kyphosis had increased to 7.87° at last follow-up, an increase that was not statistically significant. The average time to last follow-up was 16.1 months.¹¹ The authors suggest that thoracic flexion-distraction injury may be amenable to this single surgical approach in most cases.

In the past decade, percutaneous pedicle screw fixation has increased in popularity and the indications have expanded.^{1,17,19,22} The main advantage of percutaneous pedicle screws is reduction of soft tissue dissection and muscle damage, intraoperative blood loss, operative time, and requirement for postoperative analgesics.^{12,17,19,22} Percutaneous methods do not allow for direct decompression of neural elements; however they may allow for decompression of neural elements using ligamentotaxis via distraction maneuvers on the percutaneous screws. Prior reports of percutaneous pedicle screw fixation for the treatment of flexion-distraction injuries show promising results; however, they are primarily limited to bony Chance fractures.^{1,22}

Percutaneous approaches do not allow for posterolateral bone grafting in the traditional sense, but application of allograft around the screws can be possible using a nasal speculum or similar instrument. The use of bone grafting, however, has come into question when dealing with other fracture types, such as burst fractures.¹⁹ Because ligamentous healing in flexion-distraction injuries involving the posterior ligamentous complex is slower than bony healing, there has been a reluctance to use fixation techniques that do not include bone grafting and fusion.

To our knowledge, there have been no reports of percutaneous pedicle screw instrumentation for treatment of flexion-distraction injuries with a ligamentous injury component. As noted in our results, all patients in our series had disruption of the posterior ligamentous complex. There was a slight increase in kyphosis at follow-up in the MIS group, but this was not statistically significant when compared with the degree of kyphosis at admission or at discharge, or when compared with the degree of kyphosis in the open surgery group. Our average duration of follow-up in the MIS group (11.8 months) was similar to that in previously reported cases.^{1,22} Removal of instrumentation after healing of the injured segments is an option, and removal serves to preserve the patient's motion segments. In our practice, if a patient is not having postoperative pain, hardware failure, or prominence of their hardware, we usually feel that they would not benefit from an additional procedure to remove the instrumenta-

tion. If these problems do occur, a discussion is held with the patient regarding hardware removal. However, timing of instrumentation removal is less clear-cut in the cases of ligamentous injury than in cases of primarily osseous injury, but removal is not recommended prior to at least 1 year in the case of ligamentous injury. Two patients in our series opted for removal of the instrumentation. In our study population, patients treated with minimally invasive procedures had significantly less blood loss, a finding that is consistent with the literature.^{12,17,19,22} There was a trend toward reduced operative times with MIS procedures, although this did not achieve significance and could have been secondary to the trend of fewer levels instrumented in the MIS group. When dealing with osseous injuries, bony healing is more easily assessed using CT scans. Although promising, given the relative paucity of long-term data regarding MIS procedures as a treatment for flexion-distraction injuries, no definitive conclusions can be made; however, minimally invasive fixation should be considered as an option.

Conclusions

Flexion-distraction injuries involving injury to the posterior ligamentous complex should be treated operatively. Our experience, as well as the literature, shows that a posterior approach with instrumentation is sufficient to restore stability, correct deformity, and decompress the neural elements. Percutaneous pedicle screw fixation may be considered as an option in neurologically intact patients with flexion-distraction injuries where there is no need for neural decompression, even in the face of ligamentous injury. However, further studies are needed to assess the long-term outcome of patients treated with percutaneous pedicle screw fixation compared with traditional open instrumented fusion techniques.

Disclosure

Dr. Hitchon reports receiving support from DePuy Spine for clinical or research efforts not related to this study.

Author contributions to the study and manuscript preparation include the following. Conception and design: Grossbach, Hitchon. Acquisition of data: Grossbach, Hitchon. Analysis and interpretation of data: Grossbach. Drafting the article: Grossbach. Critically revising the article: Grossbach, Dahdaleh, Abel, Dlouhy, Hitchon. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Grossbach. Statistical analysis: Grossbach, Woods. Study supervision: Hitchon.

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Manuscript submitted April 15, 2013.

Accepted June 6, 2013.

Please include this information when citing this paper: DOI: 10.3171/2013.6.FOCUS13176.

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