Temporary Monosegmental Fixation Using Multiaxial Percutaneous Pedicle Screws for Surgical Management of Bony Flexion-Distraction Injuries of the Thoracolumbar Spine: A Technical Note

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Abstract:

Introduction: The efficacy of minimally invasive surgeries for thoracolumbar flexion-distraction injuries (FDIs) has been reported, but those surgeries were monosegmental fusion surgeries of two adjacent vertebrae with bone grafts or temporary fixations using percutaneous pedicle screws (PPSs) that were at least bisegmental. Our idea was to fuse the fracture itself, not to fuse the fractured vertebra with an adjacent vertebra or to stabilize the fractured vertebra by bridging rostrally/caudally adjacent intact vertebrae, specifically when the displacement is minimal. This study aimed to present the surgical techniques of reduction and temporary monosegmental fixation of neurologically intact thoracolumbar bony FDIs using multiaxial PPSs, which can minimize the surgical invasiveness and preserve all motion segments, as well as report three cases treated with this procedure.

Technical Note: When the fracture extended from the vertebral body to the spinous process at the same level, screws were placed into the fractured vertebra rostrally to the fracture along the rostral endplate, and the caudally adjacent vertebra was instrumented beyond the fracture line. When the fracture extended from the vertebral body to the spinous process of the rostrally adjacent vertebra, screws were placed into the fractured vertebra caudally to the fracture line, and the rostrally adjacent vertebra was instrumented. The kyphotic deformity was reduced through ligamentotaxis by using MPPSs in the rostral vertebra as rigid joysticks to apply direct buttress leverage to the rostral endplate. Intraoperative blood loss was minimal. The correction of kyphotic deformity and its durability were acceptable, and the segmental range of motion of the two affected vertebrae from flexion to extension was maintained after implant removal.

Conclusions: This surgery can act as the least-invasive option for the management of thoracolumbar bony FDIs to allow early ambulation without external bracing and to preserve all the motion segments.

Keywords:

flexion-distraction injury, Chance fracture, monosegmental fixation, percutaneous pedicle screw, minimally invasive surgery

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Introduction

The AO Spine thoracolumbar spine injury classification system classifies the classic “Chance fracture”[1] as type B1[2], a type of flexion-distraction injury (FDI) with a fracture line extending from the vertebral body to the spinous process of the same vertebra through the pedicles. When the disruption of the posterior tension band affects the intervertebral level osseously and/or ligamentously, the injury is classified as type B2 and is reportedly very common[3-5]. Neurologically intact patients with these bony FDIs used to be conservatively treated with a prolonged and uncomfortable body cast, which often resulted in kyphotic deformity or neurological deficit[3,4,6]. Accordingly, minimally invasive surgeries (MISs)

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Table 1. Demographic, Surgical, and Radiographical Characteristics of the Three Cases.

Case	Sex	Age (yrs)	AO type	Anatomical location of the fracture line	Fixation segment	Kyphotic angle of the fractured vertebral body			Segmental ROM[c] of the affected segment after IR [b]
						On admission	Immediately after surgery on the table	At the final follow-up after IR[b]	
1	M	66	B1	L1 body to L1 SP [a]	L1/2	15.25	13.21	14.68	6.81
2	F	17	B2	T12 body to T11 SP [a]	T11/12	13.04	4.83	6.01	4.50
3	M	22	B2	L1 body to T12 SP [a]	T12/L1	13.75	11.14	11.68	2.40

a) SP indicates spinous process

b) IR indicates implant removal

c) ROM indicates range of motion

for thoracolumbar FDIs have been proposed as an alternative treatment. However, those surgeries were monosegmental fusion surgeries of two adjacent vertebrae including the fractured vertebra with bone grafts[6-13] or temporary short-segment fixations using percutaneous pedicle screws (PPSs) which were at least bisegmental (1 level above and 1 level below the affected vertebra)[3,5,6]. Our idea was to fuse the fracture itself, not to fuse the fractured vertebra with an adjacent vertebra or to stabilize the fractured whole vertebrae by bridging rostrally/caudally adjacent intact vertebrae, specifically when the displacement is minimal. In this study, we describe, for the first time, the surgical techniques of reduction and temporary monosegmental fixation using multiaxial PPSs (MPPSs), which can minimize the surgical invasiveness and preserve all motion segments, as well as report three cases of neurologically intact thoracolumbar bony FDIs treated with this procedure.

Technical Note

The inclusion criteria for this procedure were as follows: (1) thoracolumbar bony FDIs classified as AO type B1 or B2[2], (2) all the endplates are intact, and (3) no neurological impairment.

Surgical technique

The patients were placed in the prone position with the thoracolumbar junction hyperextended on the operating table to indirectly reduce the kyphotic angulation of the fracture. In all cases, four total MPPSs (Viper2, DePuy Synthes) were placed into two adjacent vertebrae, including the fractured vertebra, under fluoroscopy control. The rostrally or caudally adjacent vertebra of the fractured vertebral body to be instrumented was selected on the basis of the anatomical location of the bony failure extending from the vertebral body to the spinous process as follows: (1) When the fracture extended from the vertebral body to the spinous process of the same vertebra (AO type B1), as in case 1 (Table 1, Fig. 1), MPPSs were placed into the fractured vertebra rostrally to the fracture line along the rostral endplate, and the caudally adjacent vertebra was selected to be instrumented beyond the fracture line as the opponent of the monosegmental fixation. (2) When the fracture extended from the vertebral body to the spinous process of the rostrally adjacent level (AO type B2), as in cases 2 and 3 (Table 1, Fig. 2), MPPSs were placed into the fractured vertebra caudally to the fracture line, and the rostrally adjacent vertebra was selected to be instrumented beyond the fracture line (Fig. 2 A).

Kyphotic angulation of the fractured vertebral body was corrected through ligamentotaxis as described in Fig. 3. Three patients underwent this procedure and started ambulation early from the day after surgery without external immobilization. The demographic characteristics of the patients, fracture types, and radiological measurements are summarized in Table 1. The cause of fracture was fall from a height in all cases. The mean operative time was 87 min (range, 75-95 min), and the estimated blood loss was 4.3 mL (range, 0-10 mL). Implants were removed within a year after surgery in all cases (mean, 9.7 months; range, 6-12 months). The kyphotic angle of the fractured vertebral body was measured as the angle made by the rostral and caudal endplates on the lateral radiographs. The mean correction was 4.28° (range, 2.04°-8.21°) after surgery, and the mean loss of correction was 1.06° (range, 0.54°-1.47°) at the final follow-up (mean, 15.7 months; range, 13-21), suggesting that the kyphotic angle of the vertebral body was maintained even after implant removal. Segmental range of motion (ROM) of the affected two vertebrae, defined as the difference in intervertebral angles from flexion to extension, was detected (mean, 4.57°; range, 2.40°-6.81°) after implant removal in all cases.

Discussion

Preservation of intact motion segments by limiting the number of instrumented segments always needs to be considered as a basic concept of MIS[14]. The least-invasive surgery in terms of the number of the instrumented segments is monosegmental fixation. Greenwald first reported monosegmental posterior fixation using Harrington rod or wiring with bone graft in five pediatric patients with lumbar FDIs, including purely ligamentous injuries and bony Chance fractures, in 1994[15]. Since this early trial, several studies have

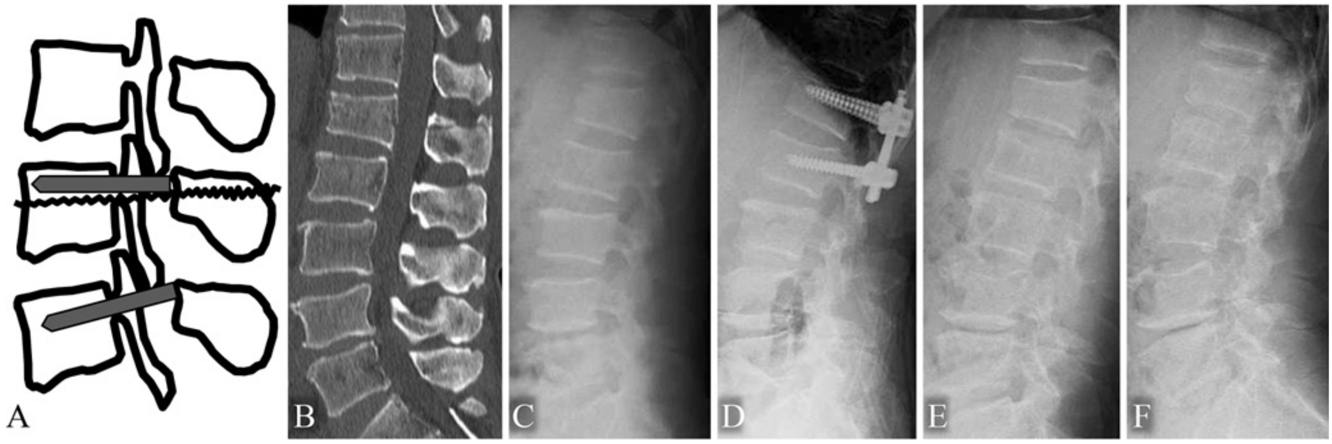

Figure 1. A 66-year-old man with a non-displaced AO type B1 fracture of L1 (Case 1 in Table 1). Schematic drawing of screw placement when the fracture extends from the vertebral body to the spinous process of the same vertebra (A), preoperative sagittal reconstruction of CT (B), preoperative (C) and immediately postoperative (D) lateral radiographs, and lateral radiographs following implant removal in flexion (E) and extension (F) at the final 13-month follow-up. MPPSs were placed into the L1 and the caudally adjacent L2 vertebrae (A and D). Correction of the kyphotic angle of the fractured vertebral body (from C to D) was 2.04°. Implants were removed at 11 months following surgery. Segmental ROM of the two affected vertebrae was maintained as 6.81° at the final follow-up (E and F).

CT, Computed Tomography; MPPS, Multiaxial Percutaneous Pedicle Screw

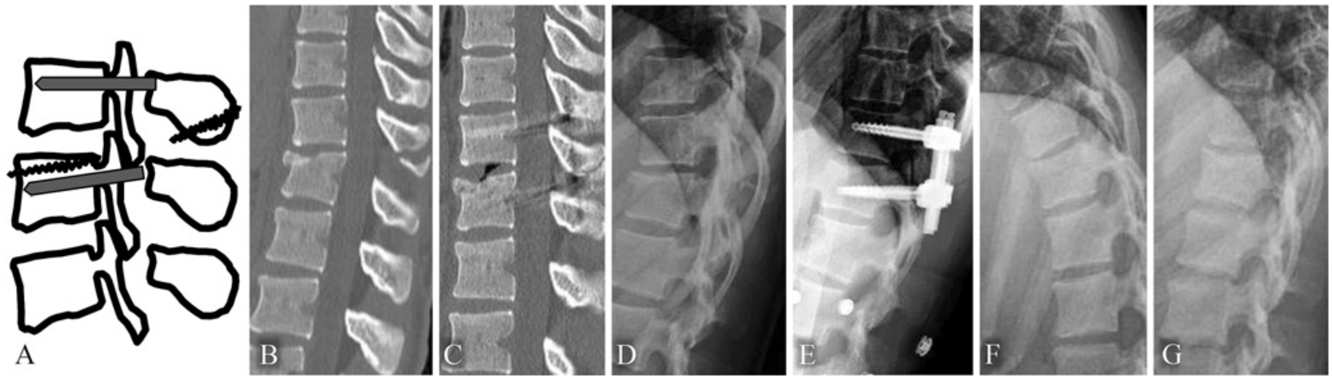

Figure 2. A 17-year-old female patient with a non-displaced AO type B2 fracture of T12 (Case 2 in Table 1). Schematic drawing of screw placement when the fracture extends from the vertebral body (T12) to the rostrally adjacent spinous process (T11) (A), preoperative (B) and postoperative (C) sagittal reconstruction of CT, preoperative (D) and immediately postoperative (E) lateral radiographs, and lateral radiographs following implant removal in flexion (F) and extension (G) at the final 21-month follow-up. MPPSs were placed into T12 and the rostrally adjacent T11 vertebrae (C and E). Correction of the kyphotic angle of the fractured vertebral body was 8.21° after the surgery (from D to E). Implants were removed at 6 months following surgery. Segmental ROM of the two affected vertebrae was maintained as 4.50° at the final follow-up (F and G).

CT, Computed Tomography; MPPS, Multiaxial Percutaneous Pedicle Screw

reported the radiological and clinical efficacies of monosegmental fusion surgery using pedicle screws for the treatment of thoracolumbar burst fractures[16-19], including FDIs[7-13]. However, it is debatable whether permanent immobilization is necessary[20-22], especially in young patients, even though the number of fused segments is only one[5]. Moreover, none of the previous studies have clearly described how the pedicle screws were inserted into the fractured vertebral body or how the other vertebra was decided to be instrumented as an opponent of monosegmental fixation to cope with different anatomical locations of fracture lines (i.e., AO type B1 and B2) in bony FDIs, whereas detailed criteria have been shown for the burst fractures depending on the damage of rostral or caudal endplate[10,16,19]. Our idea was to stabilize and fuse the fracture itself, not to fuse the fractured vertebra with an adjacent vertebra, specifically when the displacement is minimal. Hence, we described, for the first time, two different types of monosegmental instrumentation to stabilize two different types of fracture lines in AO type B1 (Fig. 1) and B2 (Fig. 2). In addition, we conducted temporary fixation using PPSs without fusion to preserve all motion segments and minimize surgical invasiveness into the soft tissue.

Spinal stabilization using PPSs is another strategy for

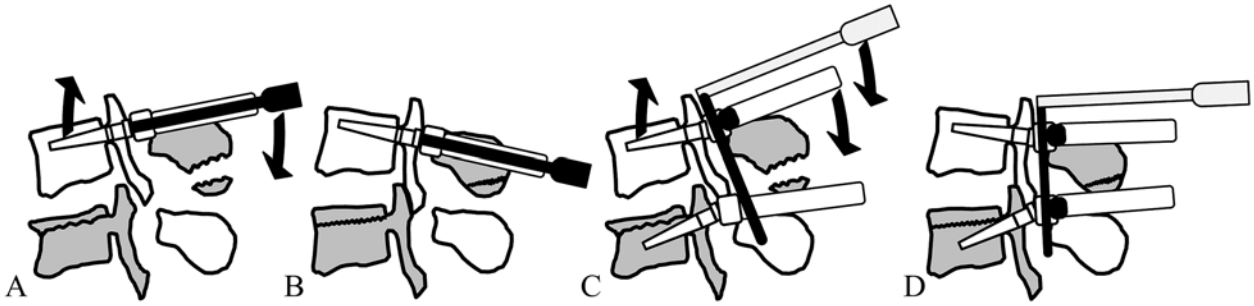

Figure 3. Schematic drawings showing how to correct the kyphotic deformity using MPPSs.
Step 1: Two MPPSs were first placed into the rostral vertebra. Because an MPPS can be used as a rigid joystick when its angular rigidity is locked with the screw drivers connected, the rostral endplate of the rostral vertebra was manipulated by direct buttress leverage of the locked MPPS (A). Then, the kyphotic angle of the fractured vertebral body was confirmed to be reduced through ligamentotaxis by handling the locked MPPSs (B).
Step 2: The screw drivers were disconnected, and the other two MPPSs were placed into the caudal vertebra. After the bilateral rods were applied, the angular rigidity of the MPPSs was locked with set screws, only in the rostral MPPSs (C). The caudal ends of the rods were intentionally lifted, leaving gaps at the bottom of the caudal MPPSs (C). The length of the gap was entirely dependent on the kyphotic angle, which was confirmed to be reduced in Step 1.
Steps 3: Kyphotic deformity was reduced in the same manner as described in Step 1 by handling the bilateral rod holders and the extenders connected to the locked rostral MPPSs (C), followed by the application of the set screws into caudal MPPSs to finalize the stabilization (D).
MPPS, Multiaxial Percutaneous Pedicle Screw

minimizing surgical invasiveness. Compared with conventional open surgeries, the percutaneous approach decreases intraoperative blood loss, operative time[23], length of hospital stay, postoperative infection rate, and postoperative visual analog scale[24,25]. Short-segment fixation using PPSs has also been applied to thoracolumbar FDIs[3,5,6] and was described as internal bracing, which may be a good option for neurologically intact patients who cannot tolerate external bracing for a long period[3]. However, the instrumented segments were at least bisegmental, except for one case report of monosegmental temporary fixation in a 12-year-old boy with a pure ligamentous lumbar FDI[26], which suggested its efficacy only for the management of ligamentous FDIs in adolescents with abundant healing potential. To the best of our knowledge, this is the first report of monosegmental fixation using PPSs for thoracolumbar bony FDIs.

To perform the correction of kyphotic deformity by using PPSs as joysticks, the angular rigidity of the screw head needs to be fixed (e.g., monoaxial screws or unitized multiaxial screws). However, when using fixed-angle screws, correction of the fractured vertebra is totally dependent on the screw trajectory and the rod alignment as the rods and fixed-angle screws are connected at a right angle. In addition, the percutaneous procedure can make the rod passage of fixed-angle screws more complex than in the conventional open procedures. Therefore, in the current technique, we used MPPSs because the screws need to be placed into the fractured vertebra with different trajectories, caudally or rostrally to the fracture line, based on the anatomical location of the fracture, and MPPSs reduce the difficulty of rod passage compared with fixed-angle screws. While making use of this advantage, the two rostral MPPSs were used as rigid joysticks: the angular rigidity of the bilateral rostral MPPSs was first locked after rod passage, and direct buttress leverage was applied to the rostral endplate[27]. Note that this correction was performed through the percutaneous procedures. Furthermore, when using fixed-angle PPSs, skin incision and muscle dissection might become greater unintentionally due to the profile of the screw head or the application of the reduction tool than when using multiaxial PPSs. This might decrease the less invasiveness of percutaneous procedure in part. Accordingly, we believe that multiaxial PPSs are more advantageous than monoaxial PPSs to be used in this technique.

In the current study, the correction of kyphotic deformity and its durability following implant removal were acceptable as internal bracing[3]. Segmental ROMs of the affected segments after implant removal were almost equivalent to previously reported values (3.92° at T11/12, 4.95° at T12/L1, 6.85° at L1/2) in people without significant spondylosis[28]. However, potential limitations of this procedure should be acknowledged. First, the benefits of implant removal remain unclear. Specifically, when posterior ligamentous injury is involved in adults, conventional open surgeries with bone graft should be considered since ligamentous healing is slower than bony healing, and bone grafting cannot be performed in the percutaneous procedure[5,6]. Second, it should also be noted that instrumentation using MPPSs might show larger correction loss of the kyphotic angle compared with the use of fixed-angle screws[29] in the management of thoracolumbar fractures, especially when the construct is short[30]. The mechanical rigidity of the screw head of MPPS might be insufficient to maintain the correction in some cases, depending on the magnitude of preoperative kyphotic angle of

FDI. Third, diminished bone quality (e.g., osteoporosis) may result in screw loosening[31] and correction loss. Postoperative external bracing (e.g., thoracolumbar orthosis) should be considered for early ambulation in osteoporotic elderly patients. These factors need to be further examined to elucidate the limitation of this monosegmental temporal fixation strategy.

Conclusions

Bony thoracolumbar FDIs with two different anatomical locations of fracture lines were treated with temporary monosegmental fixations using MPPSs to allow early ambulation without external bracing and to preserve all the motion segments. To the best of our knowledge, this article is the first to report the surgical techniques and the efficacy of this procedure, which can act as the least-invasive option for the management of neurologically intact patients with bony FDIs.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

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Author Contributions: K.F. designed the study, K.K., K.F., and T.F. performed analysis and interpretation, K.F., Y. T., and K.K. contributed to the provision of patients, K.K. wrote the manuscript, K.F., K.K., Y.T., T.F., and M.O. performed critical revision and final approval of the article.

Ethical Approval: We conducted this study in compliance with the principles of the Declaration of Helsinki. The study protocol was reviewed and approved by the Institutional Review Board of Saiseikai Yokohamashi Tobu Hospital (IRB No. 20200080).

Informed Consent: Informed consent for publication was obtained from all participants in this study.

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