INTRODUCTION

Burst fractures are compression fractures of the anterior and middle portions of the spinal column in which vertebral body fragments shift into the spinal canal. These fractures can cause neurologic complications and kyphotic deformity.

Patients with unstable burst fractures typically require surgery to relieve pain, to address neurologic deficits, and to stabilize the spine. Common surgical options include posterior approach, anterior approach, and combined anterior-posterior approach. Each technique has advantages and disadvantages. Then, the optimal approach remains controversial.

Some reports have described posterior reconstruction using pedicle screws, aiming to reposition canal-compromising fragments by ligamentaxis or remodeling of the canal. Posterior surgeries of this type for thoracolumbar burst fractures have reported satisfactory results in fractures involving mild instability. Conversely, McCormack et al. proposed that highly unstable spine fracture with load-sharing scores (LSS) ≥7 should be treated by anterior column reconstruction. For highly unstable thoracolumbar burst fractures, anterior decompression and reconstruction has been developed with a variety of anterior implant systems, which have achieved satisfactory results.

Currently, based on the biomechanical date, combined anterior-posterior approach can provide the most stable biomechanical stabilization of three columns for unstable thoracolumbar burst fracture. However, the extensive surgical procedures, including the anterior approach, may increase the morbidity, especially with traumatized thoracic or peritoneal cavities. Theoretically, stabilization of three columns through a posterior approach would avoid these risks, shortcomings, and facilitate rehabilitation. Recently, authors have re-
ported their experience with similar methods\textsuperscript{8).}

The aim of this study was to illustrate the technique of single-stage posterior subtotal corpectomy and circumferential reconstruction for the treatment of unstable thoracolumbar burst fractures with LSS ≥7 and to evaluate the radiographical findings and clinical outcomes of patients treated using this technique.

**MATERIALS AND METHODS**

**Patients**

Between February 2012 and February 2014, 16 patients with acute traumatic fractures at thoracolumbar junction were included in this prospective study.

All patients with load sharing scores ≥7 were treated with single-stage posterior subtotal corpectomy and circumferential reconstruction\textsuperscript{13,27,38).}

This study was conducted with approval from the Ethics Committee of our Hospital.

There were nine males and seven females with an average age at the time of operation of 54.8 years (range 23–73 years). The mean follow up period was 25 months (range 12–32 months).

Five patients suffered from T12 fractures, 10 from L1, 1 from L2. Neurologic deficit was assessed using The American Spine Injury Association (ASIA) impairment scale. The ASIA impairment scale was A in 1 patient, B in 2, C in 3, D in 4, and E in 6.

**Operative technique**

All procedures were performed using somatosensory evoked potential monitoring. Following endotracheal intubation, patients were placed in a prone position on a radiolucent operation table.

A posterior midline incision was made spreading from two or three levels above the fracture site to two or three levels below it, and subperiosteal dissection performed from the spinous process to the tip of the transverse process at all predetermined levels.

With C-arm guidance, pedicle screws were inserted two level below and above the fracture site or three levels in patients with severe osteoporosis or patients with translational or rotational injuries combined with posterior ligamentous complex disruption.

The single-stage posterior subtotal corpectomy was then performed (Fig. 1).

Posterior elements of the fractured level are removed. With dura mater on sight, both lamina of the fractured vertebra are completely removed. Facet joint of more severe injured side is then removed to reveal nerve root and dorsal root ganglions. Epidural veins and radicular veins are cauterized with bipolar forceps to avoid massive bleeding. These steps decompress the posterior aspect of the thecal sac. After that, for reduction of the segmental height, a rod is applied to the side of the vertebra with the facet joint still intact. Once these are done, the thecal sac can be easily retracted to provide better exposure of the posterior portion of the fractured vertebral body and the intervertebral discs. The thecal sac and nerve root are then gently retracted and protected with a nerve retractor. A subtotal corpectomy of the fractured vertebral body is performed with a high-speed drill and osteotome and curette leaving lateral and anterior vertebral body wall. The posterior wall, superior and inferior end-
plates of the fractured vertebral body are then broken down using a curved curette and the pieces are removed with pituitary. The discectomies are performed to provide sufficient space for cage. During this process, under fluoroscopy, a probe was used to check the depth of bone resection.

The appropriate size of cage is confirmed and the cage is pinned to the cage holder. The interior of the device is packed with resected local bone and allograft bone.

By gently distracting the thecal sac and nerve root, we insert a cage into the corpectomy cavity.

Using an impactor, the cage is shifted as necessary so that it is positioned exactly at the midline and in the anterior of the corpectomy cavity. Cage positioning can be monitored during all stages of implantation using posteroanterior and lateral fluoroscopy. Once proper placement is confirmed, additional bone graft tissue is packed around the cage and posterolateral sides of the column for the circumferential fusion.

Postoperatively, the patients were allowed out of bed using a customized thoracolumbar orthosis 24 hours after surgery. The orthosis was used for 3 months.

Radiologic evaluation and clinical assessments
Preoperative anteroposterior and lateral radiographic images were obtained to evaluate each fracture and degrees of segmental kyphosis. Computed tomography scanning and magnetic resonance imaging was done before surgery to assess for signal abnormalities in the spinal cord and other soft tissues (for e.g., indications of a tear in the interspinous or posterior longitudinal ligament).

The kyphotic angle was measured on lateral radiographs using the Cobb method. Regional angles (RAs) between the superior endplate of the vertebral body above the affected level and the inferior endplate of the vertebral body below the affected level were measured preoperatively, immediately after surgery, and at the final follow up (Fig. 2).

Radiologic assessment of fusion at follow up was based on the presence of trabecular bone bridging at the fracture site, or no motion (less than 3°) in lateral dynamic views (Fig. 3).

Surgical time, operative blood loss, functional improvement, and complications, including intraoperative and early postoperative events, were assessed by chart review. Clinical outcome was analyzed using a visual analogue scale (VAS) for back or radicular pain. The ASIA impairment scale for neurological deficit was used before surgery and at follow up.

Statistical analysis
The PACS system (π view®, Infinitt, Seoul, Korea) was used by two independent observers for the measurement. The intraobserver and interobserver agreement rate and k values were
obtained to check errors between 2 observers. For statistical analysis, the SPSS 17.0 was used and the p-value less than 0.05 were considered significant.

RESULTS

The interobserver agreement rate was 94% (mean k=0.75), and intraobserver agreement rate was 97% (mean k=0.81). The intraobserver and interobserver error analyses showed good agreement.

The average preoperative RA was 18.5±7.7 degrees (range, 7.7–35.2 degrees). Immediately after the operation, the average RA was -10.3±8.5 degrees (range, -30.1–3.5 degrees), and it was -9.2±8.0 degrees (range, -27.4–4.1 degrees) at the last follow up. The average correction angle was 28.9±13 degrees (range, 3.7–48.2 degrees). The difference in average preoperative and postoperative RA was statistically significant (p=0.024). No obvious correction loss was noted at the last follow up (Table 1).

The mean surgical time was 255 minutes (range, 185–300 minutes), with a mean intraoperative blood loss of 1073 mL (range, 700–2300 mL) (Table 2). Intraoperative complications included two dural tears, and one superficial wound infection. All dural tears were repaired primarily and did not result in adverse sequelae. The superficial wound infection successfully treated with debridement, primary closure over drains, and antibiotic therapy. There were no other severe complications.

The mean VAS of back pain decreased from a mean value of 6.6±1.0 (range, 5–8) preoperatively to 2±0.7 (range, 1–3) at the last follow up (p=0.001) (Table 2).

Some patients had an improvement in their neurological functions after surgery. The ASIA impairment scale was A in 1, B in 1, C in 1, D in 4, and E in 9 at the last follow up. The preoperative ASIA impairment scale was B in two patients, one of whom was restored to ASIA C. The preoperative ASIA impairment scale was C in three patients, these patients were restored to ASIA D or E. The preoperative ASIA impairment scale was D in four patients, two of whom were restored to ASIA E (Table 2).

All patients achieved bony fusion, which was confirmed based on the presence of trabecular bone bridging at the fracture site using radiographic evaluations including lateral dynamic views (Fig. 3).

DISCUSSION

The goals of surgical treatment for unstable thoracolumbar burst fractures are to restore vertebral body height, correct angular deformity, decompress neural tissue, allow rapid mobilization and rehabilitation, decrease the complications of prolonged immobilization, prevent development of progressive deformity with neurologic deficit, and limit the number of instrumented vertebral motion segments.

A large number of articles have been published describing techniques for the reduction and stabilization of these fractures, including posterior fixation, stand-alone anterior approach fixation, and combined anterior-posterior approach.

Each surgical treatment has advantages and disadvantages.

In practice, the management of each patient should be individually based on a variety of clinical and radiologic factors, including the presence of neurologic deficit, fracture type, location of the injuries, deformity angulation, residual canal diameter, vertebral body height and nonspine factors, such as age and medical comorbidities.

In cases of unstable thoracolumbar burst fracture with compression of neural elements or load sharing scores ≥7, anterior

| Case | Sex/age (yr) | Injury level | Follow up (months) | Regional kyphosis angle (degrees) |
|------|-------------|--------------|-------------------|----------------------------------|
|      |             |              |                   | Preoperation | Postoperation | Last follow up |
| 1    | M/71        | L1           | 38                | 7.5          | 3.7          | 4.2          |
| 2    | M/31        | L1           | 34                | 11.6         | 0.3          | 1.2          |
| 3    | F/72        | T12          | 33                | 14.0         | -7.3         | -6.2         |
| 4    | M/47        | T12          | 32                | 13.8         | -13.8        | -12.3        |
| 5    | M/50        | T12          | 30                | 18.3         | -11.3        | -9.6         |
| 6    | M/37        | T12          | 28                | 24.9         | -12.7        | -10.8        |
| 7    | M/70        | L1           | 27                | 11.3         | -6.3         | -5.6         |
| 8    | F/59        | L1           | 26                | 20.4         | -12.3        | -11.2        |
| 9    | F/69        | L1           | 24                | 23.6         | -13.0        | -11.6        |
| 10   | F/26        | L1           | 23                | 26.1         | -22.7        | -20.9        |
| 11   | F/73        | L1           | 22                | 24.0         | -2.2         | -1.1         |
| 12   | F/73        | L1           | 19                | 7.5          | -5.2         | -4.9         |
| 13   | M/49        | L1           | 18                | 22.0         | -17.2        | -17.0        |
| 14   | M/72        | T12          | 20                | 25.0         | -5.0         | -4.0         |
| 15   | M/55        | L1           | 22                | 35.0         | -10.0        | -9.9         |
| 16   | F/23        | L2           | 17                | 14.4         | -29.8        | -27.4        |
decompression with anterior instrumentation provides good exposure for direct decompression of the spinal canal, facilitates good reconstruction of the anterior and middle portions of the spinal column. Solely anterior approaches are indicated in cases where the posterior longitudinal ligament and posterior column is intact. However, the operative risk is higher than that associated with posterior approaches.

Traditionally the standalone posterior approach is the optimal in case of the posterior ligamentous complex injury, but it can only indirectly reduce a fractured vertebral body, and the means of augmenting the anterior column are limited. Reported loss of reduction caused by insufficient anterior column support with or without hardware failure is not uncommon. A combined anterior and posterior approach is the optimal for patients who have incomplete spinal cord damage, disrupted posterior ligamentous complex or translation injuries where anterior decompression or stabilization is required. Although the anterior approach provides good spinal cord decompression and allows for good vertebral column reconstruction, it may not resist further destructive flexion forces when the posterior ligaments have been rendered incompetent. Therefore, a combined surgical approach is appropriate for the purpose of reconstructing the tension bond.

Although the combination of anterior and posterior approach can provide the most stable biomechanical repair, the operation time, complication and morbidity rate might be apparently higher than that of the single approach. Recently, single-stage posterior corpectomy and replacement with various types of cage followed by pedicle screw instrumentation for unstable thoracolumbar burst fractures have been reported. Ayberk et al. and Sasani et al. have reported 8 and 14 cases of thoracolumbar burst fracture treated by the similar approach. The clinical outcomes were satisfied. They proposed that a single-stage posterior approach may be preferable to the combined anterior-posterior approach and that this procedure is associated with fewer complications than the traditional combined approach. Haiyun and Ozer reported a similar three-column reconstruction of thoracolumbar fracture above L2 through a single posterior approach with mesh cages and pedicle screws.

Using an expandable cage allows easier restoration of body height than use of a nonexpandable cage or strut bone. However, shortening reconstruction for unstable burst fracture with a shorter nonexpandable cage appears to offer two advantages: 1) the shorter nonexpandable cage can be easily inserted into the anterior part. By posterior compression, this maneuver did not affect the correction of kyphotic deformity. The shortening is from 0 to 5 mm (0–7.01%), which is within the safe range. 2) acute spinal column shortening within the safe range increases spinal cord blood flow, which is important for recovery of spinal cord function. Therefore, no significant difference was found between the biomechanical properties of expandable and nonexpandable cages. According to above reason, we used nonexpandable cage to reconstruct anterior and middle column in our cases.

Compared with stand-alone anterior or posterior approach,
single-stage posterior subtotal corpectomy and circumferential reconstruction can not only decompress the canal anteriorly but also decompress and repair neural elements posteriorly at same time. Anterior cage can significantly decrease the load over the posterior fixation system and avoid the loosening or fatigue fracture of screws, reduce the loss of the interbody height, prevent secondary kyphotic deformity. In addition, with the help of intact anterior longitudinal ligament and anterolateral wall of vertebral body that can form a protective band to strengthen the fixation against hyperextension and rotation force, single-stage posterior subtotal corpectomy and circumferential reconstruction can provide stiffer fixation mechanical.

However, our study is by no means suggesting that the single-stage posterior subtotal corpectomy and circumferential reconstruction should be the preferred treatment over other techniques; it is merely one of the surgical options. Our study had limitations, including a small sample size, a short follow up period in some of the patients, and the lack of a comparative study group. The more in-depth analysis and large number cases are needed.

CONCLUSION

The single-stage posterior subtotal corpectomy and circumferential reconstruction might be a safe and reliable surgical treatment option for unstable thoracolumbar burst fractures with load sharing scores ≥7. Because it provides effective circumferential spinal canal decompression in case of a neurologic deficit, complete kyphosis correction and maintenance of kyphosis correction, absence of risk carried by the anterior approach, facilitation of the placement of anterior and posterior fixation devices using only one approach, preservation of the anterior longitudinal ligament, repair of dural tears at the posterior side, less complications, and rigid enough biomechanical.

References

1. Acosta FI, Jr., Aryan HE, Taylor WR, Ames CP: Kyphoplasty—augment ed short-segment pedicle screw fixation of traumatic lumbar burst fractures: initial clinical experience and literature review. Neurosurg Focus 18: e9, 2005
2. Aebi M, Eiter C, Kehl T, Thalgott J: Stabilization of the lower thoracic and lumbar spine with the internal spinal skeletal fixation system. Indications, techniques, and first results of treatment. Spine (Phila Pa 1976) 12: 544-551, 1987
3. Akbarnia BA, Crandall DG, Burkus K, Matthews T: Use of long rods and a short arthrodesis for burst fractures of the thoracolumbar spine. A long-term follow-up study. J Bone Joint Surg Am 76: 1629-1635, 1994
4. Alanyaz A, Acaroglu E, Yazici M, Ozrun A, Surat A: Short-segment pedicle instrumentation of thoracolumbar burst fractures: does transpedicular intracorporeal grafting prevent early failure? Spine (Phila Pa 1976) 26: 213-217, 2001
5. Altay M, Özkurt B, Aktekin CN, Oztürk AM, Dogan O, Tahir AY: Treatment of unstable thoracolumbar junction burst fractures with short- or long-segment posterior fixation in magerl type fractures. Eur Spine J 16: 1145-1155, 2007
6. Alvine GF, Swain JM, Asher MA, Burton DC: Treatment of thoracolumbar burst fractures with variable screw placement or lisa instrumentation and arthrodesis: case series and literature review. J Spinal Disord Tech 17: 251-264, 2004
7. Andress HJ, Braun H, Helmerberger T, Schürmann M, Herleijn H, Harlt WH: Long-term results after posterior fixation of thoraco-lumbar burst fractures. Injury 33: 357-365, 2002
8. Aybek G, Orsveren MF, Altunald N, Tosun H, Seckin Z, Kilicarslan K, et al.: Three column stabilization through posterior approach alone: transpedicular placement of distractable cage with transpedicular screw fixation. Neurosurg Med Chir (Tokyo) 48: 8-14, discussion 14, 2008
9. Baker JK, Reardon PR, Reardon MJ, Heggeness MH: Vascular injury in anterior lumbar surgery. Spine (Phila Pa 1976) 18: 2227-2230, 1993
10. Bieri D, Lehrmann W, Ruedeck AH, Windolf J, Reger JM, Linkhart W: Factors influencing the quality of life after burst fractures of the thoracolumbar transition. Arch Orthop Trauma Surg 124: 461-468, 2004
11. Chang KW: A reduction-fixation system for unstable thoracolumbar burst fractures. Spine (Phila Pa 1976) 17: 879-886, 1992
12. Chen HH, Wang WK, Li KC, Chen TH: Biomechanical effects of the body augmenter for reconstruction of the vertebral body. Spine (Phila Pa 1976) 20: 187-E382-E387, 2004
13. Choi HJ, Kim HS, Nam KH, Cho WH, Choi BK, Han IH: Applicability of thoracolumbar injury classification and severity score to criteria of Korean health insurance review and assessment service in treatment decision of thoracolumbar injury. J Korean Neurosurg Soc 57: 174-177, 2015
14. Defino HL, Rodriguez-Fuentes AE: Treatment of fractures of the thoracolumbar spine by combined anteroposterior fixation using the Harms method. Eur Spine J 17: 187-194, 1998
15. Denis F: The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. Spine (Phila Pa 1976) 8: 817-831, 1983
16. Essex SI, Botsford DJ, Kostuik JP: Evaluation of surgical treatment for burst fractures. Spine (Phila Pa 1976) 15: 667-673, 1990
17. Gurtwitz GS, Dawson JM, McNamara MJ, Federer CE, Spergel DM: Biomechanical analysis of three surgical approaches for lumbar burst fractures using short-segment instrumentation. Spine (Phila Pa 1976) 18: 977-982, 1993
18. Haiyun Y, Rui G, Shucai D, Zhanhua J, Xiaolin Z, Kim J, et al.: Three-column reconstruction through single posterior approach for the treatment of unstable thoracolumbar fracture. Spine (Phila Pa 1976) 35: E295-E302, 2010
19. Hitchon PW, Torner J, Eichholz KM, Beeler SN: Comparison of anterolateral and posterior approaches in the management of thoracolumbar burst fractures. J Neurosurg Spine 5: 117-125, 2006
20. Jacobs RD, Casey MP: Surgical management of thoracolumbar spinal injuries. General principles and controversial considerations. Clin Orthop Relat Res (189): 22-35, 1984
21. Kaneda K, Taneichi H, Abumi K, Hashimoto T, Satoh S, Fujita M: Anterior decompression and stabilization with the Kaneda device for thoracolumbar burst fractures associated with neurological deficits. J Bone Joint Surg Am 79: 69-83, 1997
22. Kawahara N, Tomita K, Kobayashi T, Abdel-Wanis ME, Murakami H, Akamatsu T: Influence of acute shortening on the spinal cord: an experimental study. Spine (Phila Pa 1976) 30: 613-620, 2005
23. Kaya RA, Aydin Y: Modified transpedicular approach for the surgical treatment of severe thoracolumbar or lumbar burst fractures. Spine J 4: 208-217, 2004
24. Knop C, Fabian HE, Bastian L, Blauth M: Late results of thoracolumbar fractures after posterior instrumentation and transpedicular bone grafting. Spine (Phila Pa 1976) 26: 88-99, 2001
25. Lee GJ, Lee JK, Hur H, Jung JW, Kim TS, Kim SH: Comparison of clini-
cal and radiologic results between expandable cages and titanium mesh cages for thoracolumbar burst fracture. J Korean Neurosurg Soc 55: 142-147, 2014
26. Li KC, Hsieh CH, Lee CY, Chen TH: Transpedicle body augmenter: a further step in treating burst fractures. Clin Orthop Relat Res (436): 119-125, 2005
27. McCormack T, Karaikovic E, Gaines RW: The load sharing classification of spine fractures. Spine (Phila Pa 1976) 19: 1741-1744, 1994
28. Oskouian RJ Jr, Johnson JP: Vascular complications in anterior thoracolumbar spinal reconstruction. J Neurosurg 86 (1 Suppl): 1-5, 2002
29. Park WM, Park YS, Kim K, Kim YH: Biomechanical comparison of instrumentation techniques in treatment of thoracolumbar burst fractures: a finite element analysis. J Orthop Sci 14: 443-449, 2009
30. Parker JW, Lane JR, Karaikovic EE, Gaines RW: Successful short-segment instrumentation and fusion for thoracolumbar spine fractures: a consecutive 41/2-year series. Spine (Phila Pa 1976) 25: 1157-1170, 2000
31. Pfliugmacher R, Schleicher P, Schaeler J, Scholz M, Ludwig K, Khodadany-Klostermann C, et al.: Biomechanical comparison of expandable cages for vertebral body replacement in the thoracolumbar spine. Spine (Phila Pa 1976) 29: 1413-1419, 2004
32. Sasani M, Onzi AF: Single-stage posterior corpectomy and expandable cage placement for treatment of thoracic or lumbar burst fractures. Spine (Phila Pa 1976) 34: E33-E40, 2009
33. Sasso RC, Best NM, Reilly TM, McGuire RA Jr: Anterior-only stabilization of three-column thoracolumbar injuries. J Spinal Disord Tech 18 Suppl: S7-S14, 2005
34. Scrubba DM, Gallia GL, McGirt MJ, Woodworth GF, Garonzik IM, Witham T, et al.: Thoracic kyphotic deformity reduction with a distractable titanium cage via an entirely posterior approach. Neurosurgery 60 (4 Suppl 2): 223-230; discussion 230-231, 2007
35. Shang J, Ling XD, Liu YC, Liu W, Xiao XG, Yuan SH: Biomechanical effects of pedicle screw adjustments on the thoracolumbar burst fractures. Chin Med J (Engl) 126: 300-305, 2013
36. Tezeren G, Kuru I: Posterior fixation of thoracolumbar burst fracture: short-segment pedicle fixation versus long-segment instrumentation. J Spinal Disord Tech 18: 485-488, 2005
37. Tomita K, Kawahara N, Murakami H, Demura S: Total en bloc spondylectomy for spinal tumors: improvement of the technique and its associated basic background. J Orthop Sci 11: 3-12, 2006
38. Vaccaro AR, Zeiler SC, Hulbert RJ, Anderson PA, Harris M, Hedlund R, et al.: The thoracolumbar injury severity score: a proposed treatment algorithm. J Spinal Disord Tech 18: 209-215, 2005
39. Verlaan JJ, Diekerhof CH, Buskens E, van der Tweel I, Verbout AJ, Dhert WJ, et al.: Surgical treatment of traumatic fractures of the thoracic and lumbar spine: a systematic review of the literature on techniques, complications, and outcomes. Spine (Phila Pa 1976) 29: 803-814, 2004
40. Westfall SH, Akbarnia BA, Merenda TJ, Nauheim KS, Conners RH, Kaminski DL, et al.: Exposure of the anterior spine. Technique, complications, and results in 85 patients. Am J Surg 154: 700-704, 1987
41. Wood KB, Bohn D, Mehbod A: Anterior versus posterior treatment of stable thoracolumbar burst fractures without neurologic deficit: a prospective, randomized study. J Spinal Disord Tech 18 Suppl: S15-S23, 2005