The Surgical Outcomes of Spinal Fusion for Osteoporotic Vertebral Fractures in the Lower Lumbar Spine with a Neurological Deficit

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Abstract:

Introduction: Osteoporotic vertebral fracture (OVF) is the most common osteoporotic fracture, and some patients require surgical intervention to improve their impaired activities of daily living with neurological deficits. However, many previous reports have focused on OVF around the thoracolumbar junction, and the surgical outcomes of lumbar OVF have not been thoroughly discussed. We aimed to investigate the surgical outcomes for lumbar OVF with a neurological deficit.

Methods: Patients who underwent fusion surgery for thoracolumbar OVF with a neurological deficit were enrolled at 28 institutions. Clinical information, comorbidities, perioperative complications, Japanese Orthopaedic Association scores, visual analog scale scores, and radiographic parameters were compared between patients with lower lumbar fracture (L3-5) and those with thoracolumbar junction fracture (T10-L2). Each patient with lower lumbar fracture (L group) was matched with to patients with thoracolumbar junction fracture (T group).

Results: A total 403 patients (89 males and 314 females, mean age: 73.8 ± 7.8 years, mean follow-up: 3.9 ± 1.7 years) were included in this study. Lower lumbar OVF was frequently found in patients with lower bone mineral density. After matching, mechanical failure was more frequent in the L group (L group: 64%, T group: 39%; $p < 0.001$). There was no difference between groups in the clinical and radiographical outcomes, although the rates of complication and revision surgery were still high in both groups.

Conclusions: The surgical intervention for OVF is effective in patients with myelopathy or radiculopathy regardless of the surgical level, although further study is required to improve clinical and radiographical outcomes.

Level of evidence: Level III

Keywords:

osteoporotic vertebral fracture, surgical outcome, lumbar vertebral fracture, neurological deficit

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Introduction

Osteoporotic vertebral fracture (OVF) is the most common osteoporotic fracture, and the lifetime morbidity of OVF is over 30% for women[1,2]. Since the incidence of OVF increases with advancing age, the prevalence of this common fracture is expected to increase[3] as societies continue to age over decades.

The main symptom of OVF is back pain, and most patients can be treated conservatively[4]. However, 2% of in-hospital patients with OVF develop cord compression[5] and require surgical intervention to improve their severely impaired activities of daily living (ADL) with neurological deficits.

Many previous studies have reported the surgical techniques and outcomes of OVF with neurological deficits[6-15]. Most of these studies are case series at a single or small group of institutions, and studies with large sample sizes are scarce. There is one previous large-scale systematic review of 29 papers that included 596 OVF patients with delayed neurological deficits[16]. However, the majority of patients (93.8%) in that review had OVF at the thoracolumbar region (T10-L2). Therefore, the surgical outcomes of lower lumbar OVF with neurological deficits were not thoroughly discussed.

We aimed to investigate the postoperative functional and radiographic outcomes, as well as the postoperative complications, in patients who had fusion surgery for lower lumbar OVF with neurological deficits using a large sample size cohort.

Materials and Methods

Study design and setting

This was a retrospective multicenter study conducted at 28 university hospitals by the Japan Association of Spine Surgeons with Ambition. The study was approved by the institutional review board at each site. Inclusion criteria were patients who had neurological deficits due to vertebral collapse or non-union after OVF at T10-L5 and had undergone fusion surgery with a minimum follow-up of 2 years. We compared the radiographic and clinical outcomes between the patients with lower lumbar fracture (L3-5) (Fig. 1-a, b) and those with thoracolumbar junction fracture (T10-L2) (Fig. 1-c, d). Each patient with lower lumbar fracture was matched with two patients with thoracolumbar junction fracture by age, gender, and bone mineral density. After matching them, we divided the patients with lower lumbar fracture into the L group and those with thoracolumbar junction fracture into the T group, and same variables were compared between the two groups.

Patients with ankylosing spondylitis or diffuse idiopathic skeletal hyperostosis, back pain due to kyphotic deformity without any neurological deficit, or stand-alone vertebroplasty or kyphoplasty were excluded from this study. A datasheet was sent to each hospital, and spine surgeons were asked to fill in the datasheet with information as noted below.

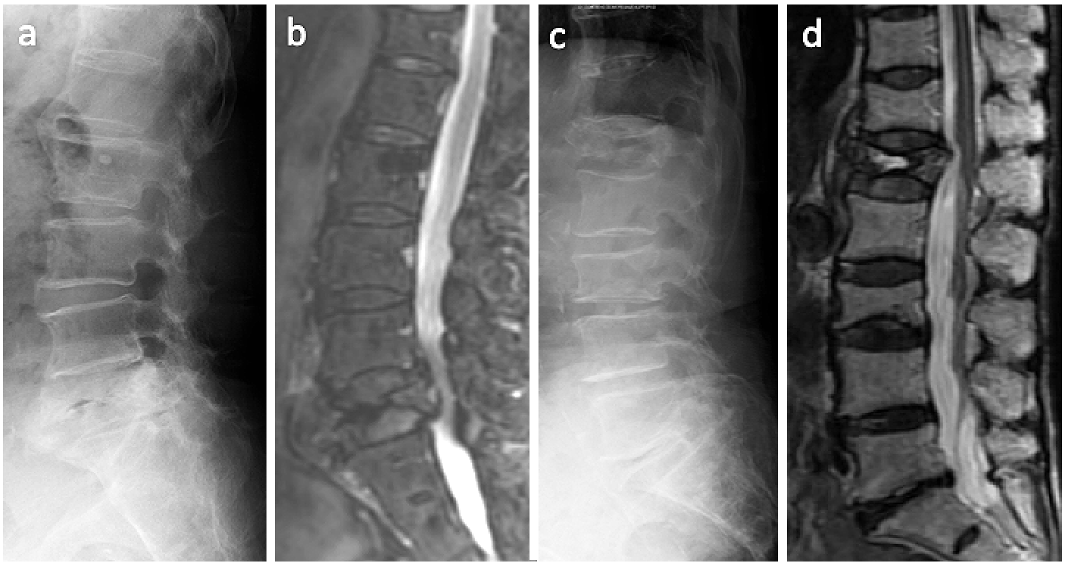

Figure 1. Image findings of representative cases of osteoporotic vertebral fracture (OVF).
a, b: Lower lumbar OVF. c, d: Thoracolumbar junction OVF.
a: Lateral radiograph showed L5 OVF with vacuum cleft with radiculopathy.
b: T2-weighted mid-sagittal magnetic resonance image showed L5 OVF with radiculopathy.
c: Lateral radiograph showed L1 OVF with vacuum cleft with myelopathy.
d: T2-weighted mid-sagittal magnetic resonance image showed L1 OVF with myelopathy.

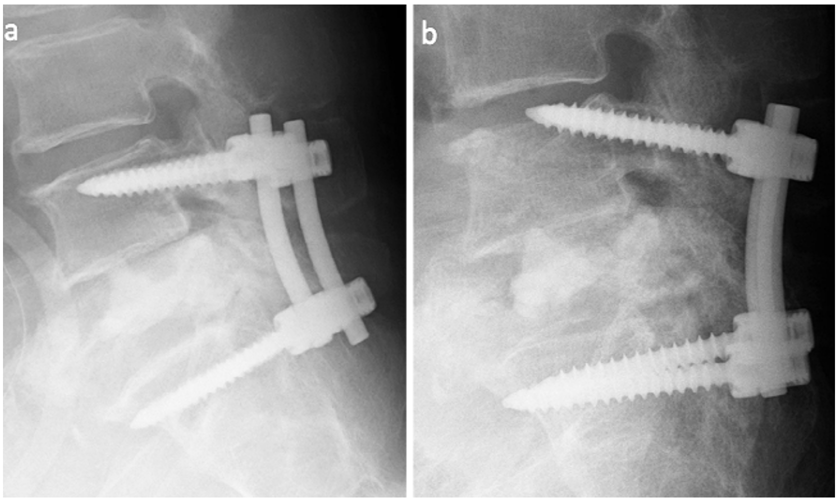

Figure 2. Radiographical examination of postoperative pedicle screw loosening.
a: Postoperative radiographical examination. b: Radiographical examination at final follow-up.
a: Lateral radiograph showed the posterior fixation surgery with vertebroplasty for L5 OVF.
b: Lateral radiograph showed loosening of bilateral L5 pedicle screws at final follow-up.

Variables

Variables such as age, gender, height, body mass index, bone mineral density, comorbidities, medication for osteoporosis, steroid intake, current smoking, and follow-up period were obtained from medical records.

Surgical information such as surgical approach (anterior, posterior, combined anterior and posterior), method of fixation, upper and lower instrumented vertebra (UIV and LIV), the number of fusion levels, estimated blood loss, and surgical time were collected.

Information on complications such as mechanical failure, newly developed vertebra fracture, and need for revision surgery during the follow-up period was collected. Mechanical failure was defined as a failure related to an implant within the fused vertebra at final follow-up (Fig. 2), such as loosening or backout of a pedicle screw, hook dislodgement, rod fracture, cage subsidence, and fracture at UIV or LIV. Pe-

Table 1. Demographic Data of 403 Patients.

	Lower lumbar (n=76)	Thoracolumbar junction (n=327)	P value
Age (y/o)	73.2±8.0	74.0±7.8	0.22
Gender (Male/Female)	17/59	72/255	1.00
Height (m)	1.50±0.10	1.52±0.08	0.05
Body Mass Index (kg/m^2)	22.2±4.5	22.7±4.5	0.24
Bone Mineral Density (g/cm^2)	0.59±0.21	0.65±0.21	<0.05
Comorbidities			
Diabetes Mellitus	21 cases (28%)	88 cases (27%)	0.89
Rheumatoid Arthritis	0 cases (0%)	8 cases (2%)	0.36
Parkinson's Disease	5 cases (7%)	19 cases (6%)	0.79
Medication of Osteoporosis	31 cases (41%)	132 cases (40%)	1.00
Steroid Intake	17 cases (22%)	34 cases (10%)	<0.01
Current Smoking	10 cases (13%)	44 cases (13%)	1.00
Follow-up period (months)	45.4±24.5	45.0±19.8	0.90
Perioperative complication	15 cases (20%)	62 cases (19%)	0.87
Surgical Time (min)	285±133	249±110	<0.05
Estimated Blood Loss (ml)	844±1260	629±1133	0.09

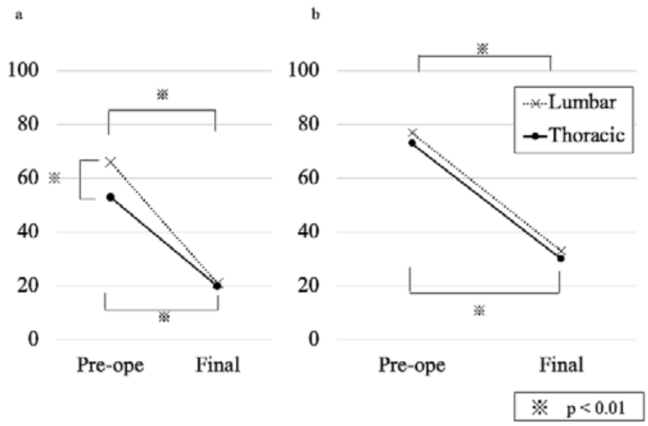

Figure 3. Clinical outcomes by the Visual Analog Scale (VAS) scores of all patients.
a: VAS scores of leg pain. b: VAS scores of low back pain.
a: The preoperative VAS score of leg pain was significantly higher in patients with lower lumbar fractures than in those with thoracolumbar junction fractures.
b: There was no significant difference in the preoperative VAS score of low back pain.
Both leg and low back pains improved significantly at final follow-up in both regions.

rioperative complications within 6 weeks after the surgery were also recorded.

Local kyphosis angle (LKA) was defined as the angle between the upper endplate of a proximal adjacent vertebra and the lower endplate of a distal adjacent vertebra of an affected vertebra. LKA was measured preoperatively, immediately after the surgery, and at final follow-up.

Clinical outcomes were evaluated preoperatively and at final follow-up with a visual analogue scale (VAS) score for low back pain and leg pain, Japanese Orthopaedic Association (JOA) score, and ADL. For the JOA score, only scores for subjective symptoms (9 points), clinical signs (6 points), and urinary bladder function (6 points) were included with a full score being 15 points. For ADL, patients were classified into the following six categories[17]: (1) bedridden; (2) wheelchair; (3) walking while holding on to wall or creep; (4) walking with a walker, bilateral canes, or one cane with support from others; (5) walking with a unilateral cane without any support; and (6) walking freely.

Statistical analysis

Means ± standard deviations were used to describe continuous variables and frequencies, and percentages were used to summarize categorical variables. Baseline demographics, preoperative scores, and surgical characteristics were compared using an independent *t*-test, a chi-squared test, or a Wilcoxon signed-rank test where appropriate. A p-value < 0.05 was considered statistically significant.

Results

Descriptive statistics

A total 403 patients (89 males and 314 females, mean age: 73.8 ± 7.8 years, mean follow-up period: 3.9 ± 1.7 years) at 28 university hospitals and affiliated hospitals were included in this study. Of these, there were 76 patients with lower lumbar fractures and 327 patients with thoracolumbar junction fractures. Table 1 summarizes the characteristics of all patients. Patients with lower lumbar fracture exhibited lower bone mineral density, a higher rate of steroid intake, and a higher preoperative VAS score of leg pain (Fig. 3). Surgical information revealed a longer surgical time and higher incidence of mechanical failure in patients with lower lumbar fractures.

After matching the patients, 73 patients with lower lum-

Table 2. Comparison of Demographic Data between 73 Patients in the L Group and 146 Patients in the T Group after Matching.

	L group (n=73)	T group (n=146)	P value
Age (y/o)	73.6±7.7	73.6±7.7	0.99
Gender (Male/Female)	17/56	33/113	1.00
Height (m)	1.50±0.10	1.52±0.09	0.09
Body Mass Index (kg/m^2)	22.5±4.6	22.3±4.0	0.72
Bone Mineral Density (g/cm^2)	0.59±0.20	0.62±0.16	0.35
Comorbidities			
Diabetes Mellitus	20 cases (27%)	38 cases (26%)	0.87
Rheumatoid Arthritis	0 cases (0%)	3 cases (2%)	0.55
Parkinson's Disease	4 cases (5%)	8 cases (5%)	1.00
Medication of Osteoporosis	27 cases (37%)	67 cases (46%)	0.25
Steroid Intake	17 cases (23%)	22 cases (15%)	0.14
Current Smoking	10 cases (14%)	19 cases (13%)	1.00
Follow-up period (months)	45.0±24.1	44.3±18.2	0.84
Perioperative complication	15 cases (21%)	29 cases (20%)	1.00

Table 3. Comparison of Surgical Methods between the Two Groups.

	L group (n=73)	T group (n=146)	P value
Fixation Methods			
Posterior	62 (85%)	133 (91%)	0.18
With Vertebroplasty	19 (26%)	69 (47%)	<0.01
With Interbody Fusion	3 (4%)	3 (2%)	0.40
W/O Vertebroplasty and Interbody Fusion	42 (58%)	64 (44%)	0.06
Anterior	1 (1%)	6 (4%)	0.43
Combined	10 (14%)	7 (5%)	<0.05
Surgical Time (min)	280±135	247±106	0.08
Estimated Blood Loss (ml)	708±647	693±1509	0.92
Number of Fused Vertebrae	3.4±2.2	4.2±2.0	<0.01

bar fracture were included in the L group, and 146 patients with thoracolumbar junction fracture were included in the T group. There was no significant difference in age, gender, height, body mass index, bone density, comorbidities, medication for osteoporosis, steroid intake, current smoking, and follow-up period (Table 2).

Comparison of surgical information between the two groups

Table 3 summarizes the surgical information of the two groups. Although there were no significant differences in surgical time (L group: 280 ± 135 min, T group: 247 ± 106 min; p = 0.08) and estimated blood loss (L group: 708 ± 647 ml, T group: 693 ± 1509 ml; p = 0.92) between the two groups, the number of fused segments was larger in the T group than that in the L group (L group: 3.4 ± 2.2, T group: 4.2 ± 2.0; p < 0.01).

There was no significant difference in the method of fixation. Most patients underwent a posterior fixation surgery in both groups (L group: 85%, T group: 91%). In terms of the methods combined with posterior fixation, the T group had vertebroplasty more frequently (L group: 26%, T group: 47%; p<0.01). By contrast, the L group had combined anterior and posterior fixation more frequently (L group: 14%, T group: 5%; p < 0.05).

Comparison of radiographical outcomes between the two groups

Preoperative LKA was lower in the L group (L group: 5.4 ± 15.7°, T group: 26.3 ± 15.9°; p < 0.001). LKA was significantly corrected after surgery (L group: −5.9 ± 14.0°, T group: 8.3 ± 11.3°), and collection loss was found at final follow-up in both groups (L group: −1.7 ± 13.8°, T group: 14.7 ± 13.7°) (Fig. 4). There was no significant difference in the mean correction loss of LKA (L group: 4.3 ± 9.4°, T group: 6.4 ± 8.2°).

Comparison of complications between the two groups

Mechanical failure was more frequently found in the L group (L group: 64%, T group: 39%; p < 0.001). There was no significant difference in the rate of perioperative complication (L group: 25%, T group: 27%), newly developed vertebral fracture (L group: 44%, T group: 37%), and revision surgery (L group: 19%, T group: 14%).

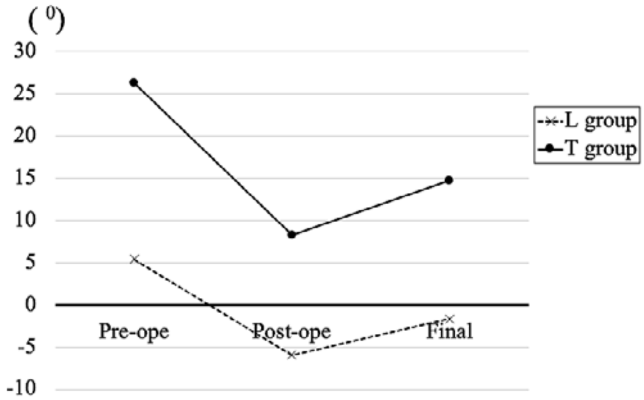

Figure 4. Radiographical outcomes by Local Kyphosis Angle (LKA).
There were no significant differences in the mean loss of correction of LKA between the L group and the T group at final follow-up.

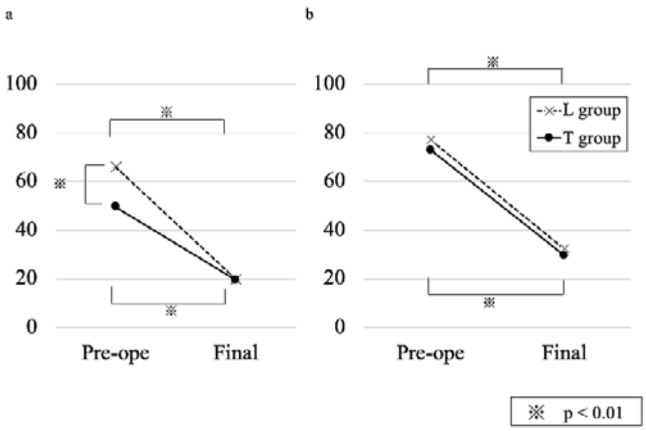

Figure 5. Clinical outcomes by the Visual Analog Scale (VAS) scores.
a: VAS Scores of Leg Pain. b: VAS Scores of Low Back Pain.
a: Preoperative VAS score of leg pain was significantly higher in the L group than that in the T group.
b: There was no significant difference in preoperative VAS score of low back pain.
Both leg and low back pains improved significantly at final follow-up in both groups.

Changes in clinical outcomes between the two groups

The preoperative VAS score of leg pain was significantly higher in the L group than that in the T group (L group: 66 ± 23, T group: 50 ± 23; $p < 0.001$), although there was no significant difference in the preoperative VAS score of low back pain (L group: 77 ± 19, T group: 73 ± 24; $p = 0.16$). Both leg and low back pain improved significantly at final follow-up in both groups (Fig. 5).

There was no significant difference in the JOA score preoperatively and at final follow-up. The JOA score improved significantly at final follow-up in both the L group (baseline: 4.6 ± 3.0, final: 9.9 ± 3.0, $p < 0.001$) and the T group

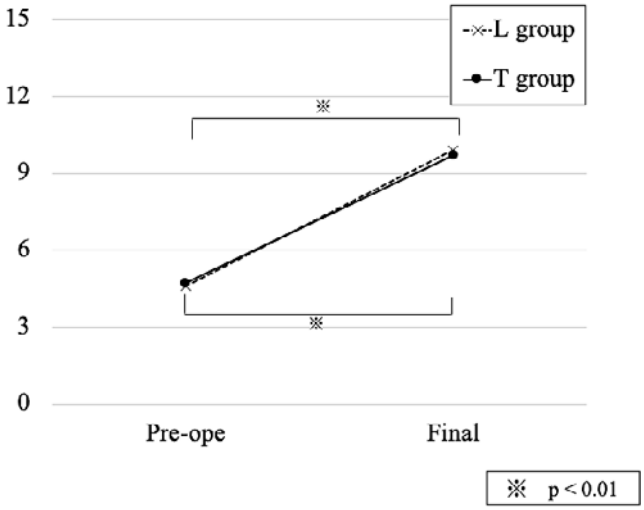

Figure 6. Clinical outcomes of surgery for Osteoporotic Vertebral Fractures, as evaluated by the Japanese Orthopaedic Association (JOA) score.
The JOA score improved significantly at final follow-up in both groups. There was no significant difference in JOA scores for the L group and the T group preoperatively and at final follow-up.

(baseline: 4.7 ± 3.6, final: 9.7 ± 3.2, $p < 0.001$) (Fig. 6).

Similarly, there was no significant difference in preoperative ADL between the two groups. The activities' score improved significantly at final follow-up in both groups analyzed by Wilcoxon signed-rank test (Table 4).

Discussion

In this study, we evaluated the surgical outcomes for OVF in the lower lumbar spine with neurological deficits. Previous reports revealed that OVF with neurological deficits frequently develop at the thoracolumbar junction area and that there are few patients with OVF in the low lumbar spine[6,11,15,16]. As a result, the surgical outcomes of lumbar OVF were still unknown. To the best of our knowledge, this is the first study to report the characteristics of surgical outcomes for lumbar OVF with a large sample size.

A previous biomechanical study indicated that peak mechanical loads were observed at the middle thoracic and thoracolumbar junctions during flexion-extension and stand-sit-stand[18]. In our study, bone mineral density was lower in patients with OVF at the lumbar spine than at thoracolumbar regions; however, the incidence of OVF at the lumbar spine was relatively low (19%). As the mechanical load to the lumbar spine is lower than to the thoracolumbar junction, higher energy might be needed to induce a lower lumbar spine fracture compared to a thoracolumbar junctional spine fracture, and this might be the reason for the lower frequency of OVF at the lower lumbar spine. In other words, OVF in the lumbar spine occurred frequently with patients with extremely low bone mineral density. Therefore, strict treatment for osteoporosis should be considered if lower lumbar OVF is observed.

Table 4. Clinical Outcomes of Surgery for Osteoporotic Vertebral Fractures, as Evaluated by Activities of Daily Living Score.

L group (n=73)	Preoperative	Final follow-up
1. Bedridden	10 (14%)	0 (0%)
2. Wheelchair	25 (34%)	5 (7%)
3. Walking while holding on to wall, creeping	19 (26%)	6 (8%)
4. Walking with walker, 2 canes, 1 cane with support	8 (11%)	44 (60%)
5. Walking with 1 cane without support	9 (12%)	0 (0%)
6. Walking freely	2 (3%)	18 (25%)

T group (n=146)	Preoperative	Final follow-up
1. Bedridden	16 (11%)	3 (2%)
2. Wheelchair	54 (37%)	8 (5%)
3. Walking while holding on to wall, creeping	23 (16%)	6 (4%)
4. Walking with walker, 2 canes, 1 cane with support	25 (17%)	80 (55%)
5. Walking with 1 cane without support	23 (16%)	0 (0%)
6. Walking freely	5 (3%)	49 (34%)

Comparison after matching revealed a higher incidence of postoperative mechanical failure in the L group. No previous studies have reported the characteristics of surgery for OVF in the lower lumbar spine. Posterior lumbar fixation without interbody cage is reported to be biomechanically insufficient, and pedicle screws are exposed to higher strain in cadaver study[19]. Posterior lumbar fusion without anterior support for unstable lumbar spondylolisthesis is reported to raise the possibility of progression of the implant loosening and loss of reduction and nonunion[20]. In this study, the high rate of mechanical failure in the L group may be due to the large number of patients (58%) who underwent posterior lumbar fusion without anterior support. Therefore, anterior support should be attempted in addition to posterior fusion for OVF at the lumbar spine to reduce postoperative mechanical failures. However, there are several unique problems in OVF that are distinct from those in degenerative lumbar disease, such as endplate deformation, greater range of motion, and low bone mineral density. These problems were reported as risk factors of mechanical failure, such as cage retropulsion and poor clinical outcomes of posterior fusion surgery for lumbar degenerative disease[21,22]. Thus, an appropriate cage or graft should be used for anterior support for lumbar OVF. Some studies reported favorable radiographic and clinical outcomes of lateral interbody fusion, corpectomy, or three-dimensional printed interbody cage[23-25]. Future study is warranted to reveal the best anterior support for OVF.

Neurological deficits due to thoracolumbar junction fractures may induce severe myelopathy such as paraparesis and bladder dysfunction, which definitely require surgical treatment in aged patients[6,11]. Several previous studies reported the safety and reliability of the surgery for OVF in the thoracolumbar junction region with a neurological deficit[7,8,10,13]. By contrast, OVF at the lower lumbar spine may induce radiculopathy, and necessity for the surgical treatment for radiculopathy is not as high as severe myelopathy. However, radiculopathy following OVF in the lower lumbar region is hard to treat conservatively compared to radiculopathy caused by lumbar degeneration[14,26]. Our study indicated that the JOA score and ADL improved in the L group and in the T group after the surgery. Therefore, the surgical intervention of OVF in the lumbar region is as effective as in the thoracolumbar junction region to improve the neurological deficit.

Our study revealed that the rate of complication and revision surgery indicated no difference between the two groups; however, these rates were still high in both regions. The complication rate after surgical treatment for OVF was reported to be 70% by Nguyen et al[12]. It is concluded that bone fragility was attributed to the high rate of complication[9]. However, several studies reported the effectiveness of preoperative use of teriparatide in spinal fusion surgery in osteoporotic patients to increase the fusion rate and to avoid the pedicle screw loosening[27-29]. Further strategies in both surgical procedures and treatments of osteoporosis are necessary to improve the surgical results for OVF in the lumbar and thoracolumbar regions.

Previous studies demonstrated that the correction loss rate of LKA after surgery for thoracolumbar OVF is comparatively high, from 43% to 88%[9]. In this study, the preoperative LKA was significantly lower in the L group; this may reflect the anatomical difference between lumbar and thoracolumbar region. However, there was no difference between the two groups in the degree of correction loss of LKA. In other words, although preoperative local alignment was different, the correction loss after the surgery was similar in both groups. Therefore, the correction loss of LKA should be considered in the surgical planning of OVF at the lumbar spine and at the thoracolumbar spine.

There are several limitations in this study. First, this was a retrospective study, and the evidence level is inevitably low as a consequence. Second, the indication for surgery and choice of a surgical method were determined at each institution. Third, we did not evaluate the details of the surgical methods in this study. Fourth, we did not evaluate whether the neurological deficit was myelopathy or radiculopathy and have details of fracture types such as central stenosis or foraminal stenosis. Future study is warranted to clarify the relation between the clinical outcomes of vertebroplasty and interbody fusion in each region.

To the best of our knowledge, this is the largest study to have investigated the surgical outcomes for OVF in the lumbar spine. We demonstrated that lower lumbar OVF was frequently found in patients with lower bone mineral density. Patients with lower lumbar OVF demonstrated radiculopathy, and anterior support should be provided in surgery for OVF in the lumbar spine to reduce postoperative mechanical failures. There was no difference in clinical and radiographical outcomes between OVF at the lumbar spine and that at the thoracolumbar spine, although the rate of complication and revision surgery remains high in both regions because of bone fragility. Therefore, we concluded that surgical intervention for OVF is effective in patients with myelopathy or radiculopathy regardless of the fractured level, although further study is required to improve clinical and radiographical outcomes.

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Author Contributions: Norihiro Isogai analyzed and wrote the manuscript, and all other authors participated in acquisition or analysis of data and drafting of the article. All authors have read, reviewed and approved the article.

Informed Consent: Informed consent was obtained from all individual participants included in the study.

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