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Efficiency of Distraction and Ligamentotaxis in Posterior Spinal Instrumentation of Thoracolumbar Retropulsed Fractures

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ABSTRACT

AIM: To compare the efficiency of distraction and ligamentotaxis in posterior spinal instrumentation of thoracolumbar retropulsed fractures according to the grade of spinal canal compression and fracture levels.

MATERIAL and METHODS: This study retrospectively reviewed 56 patients diagnosed with thoracolumbar fractures and significant fracture fragments retropulsed into the spinal canal who only underwent posterior instrumentation with distraction and ligamentotaxis, and compared groups according to the grade of spinal canal compression and fracture levels. The pre-and postoperative clinical outcomes were evaluated using Oswestry Disability Index and visual analog scale scores, and neuroimaging studies showed percentage of the spinal canal compression and fractured vertebral unit height.

RESULTS: A total of 34 male (60.7%), and 22 female (39.3%) patients with a mean age of 46.25 years was enrolled in study. The percentage of spinal cord compression reduced significantly from 40.2% preoperatively to 26.8% postoperatively (+13.4%). The vertebral unit height increased significantly from 25.20 ± 3.2 mm to 31.85 ± 2.6 mm (+6.65 ± 2.7). The absolute spinal canal compression reduction was higher for grade II fractures (1/3 to 2/3 compression) (+13.3%) than for grade I fractures (up to 1/3) (+7.9%). Greater widening was observed at L1–L2 level (+16.2%) than at T11–T12 level (+10.2%). Statistically significant differences were found between the two groups according to the grade of canal compression and fracture levels in the mean pre- and postoperative spinal canal compression reduction.

CONCLUSION: Indirect decompression techniques reduce retropulsed fragments, effectively improve the degree of spinal canal compression, and ensure safe laminectomy. The efficiency of distraction and ligamentotaxis after posterior spinal instrumentation correlated with the preoperative percentage of spinal canal compression and higher spinal canal area for fractures with a high preoperative stenosis.

KEYWORDS: Thoracolumbar retropulsed fractures, Distraction, Ligamentotaxis, Posterior spinal instrumentation, Indirect decompression

ABBREVIATIONS: ASIA: American Spinal Injury Association, **CT:** Computed tomography, **FVUH:** Fractured vertebral unit height, **MRI:** Magnetic resonance imaging, **ODI:** Oswestry disability index, **PLL:** Posterior longitudinal ligament, **SCA:** Spinal canal area, **VAS:** Visual analog scale

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INTRODUCTION

Surgical intervention in thoracolumbar fractures is required in the presence of neurological deficits, spinal instability, and vertebral dislocation. The fractured and retropulsed posterior vertebral wallin thoracolumbar burst fractures can cause neurological deficits during trauma or there after if bone fragments persist in the spinal canal (9,15,17).Two ways can be employed for neural decompression: direct or indirect. Direct decompression is performed by the resection of the compressing bone, ligaments, and disk material. However, indirect decompression techniques allow decompression of neural tissue without resection of the compressing fragments (8,18). Distraction and ligamentotaxis lead to an indirect reduction of the fracture fragments, resulting in the restoration of the corpus height, kyphosis correction, and canal widening. Ligamentotaxis tenses the posterior longitudinal ligament (PLL) during distraction (18). Numerous operative methods in the treatment of thoracolumbar retropulsed fractures suggest that there is still major conflict regarding optimal surgical management. This study aimed to assess the efficiency of distraction and ligamentotaxis in posterior stabilization of thoracolumbar retropulsed fractures according to the grade of spinal canal compression and fracture levels.

MATERIAL and METHODS

This study reviewed the data of 56 patients diagnosed with thoracolumbar fracture and significant fracture fragments retropulsed into the spinal canal at the Department of Neurosurgery at University of Health Sciences, Izmir Bozyaka Education and Research Hospital between January 2018 and November 2020. Patients who only underwent posterior spinal surgery for thoracolumbar fractures and spinal cord compression were included in the study, and those diagnosed with only compression fractures were excluded, as spinal cord compression was not seen. None of the patients had additional anterior stabilization. Preoperative magnetic resonance imaging (MRI) findings of all patients were carefully examined, and patients with PLL rupture were excluded from the study. Patients with free bone fragments and reverse fragments were excluded since it is considered a contraindication of using distraction and ligamentotaxis.

Clinical outcomes prior to surgery and at the final follow-up appointment were evaluated using Oswestry Disability Index (ODI) scale. Pain was assessed using the visual analog scale (VAS), ranging from 0 (no pain) to 10 (severe pain). Thoracolumbar radiography, thoracolumbar computed tomography (CT), and thoracolumbar MRI examinations were carried out before and after surgery. MRI was performed in all patients preoperatively. We evaluated all patients' MRI to determine whether the PLL was intact or not. If the PLL has ruptured, distraction could be dangerous due to tethering of neural structures. The percentage of the spinal canal compression at all fractured levels were calculated by measuring the spinal canal area (SCA) using axial CT scans, while the height of the fractured vertebral unit was evaluated using sagittal CT scans (Figures 1–4). Percentage of the spinal canal compression from CT scans calculated based on the formula (percentage of the spinal canal compression % = [SCA above + below fracture)/2−SCA fracture]/[(SCA above + below fracture)/2]× 100) suggested by Mumford et al. (12) was used to evaluate success of the surgical procedure. Spinal canal compression was graded on the preoperative axial CT scans into three groups: compression less than 1/3 of the normal (group I), compression between 1/3 and 2/3 (group II), and over 2/3 (group III) (16).

The height of the vertebral unit was measured from the bottom of the upper corpus to the bottom of the fractured corpus of the vertebra to elucidate the efficiency of ligamentotaxis. Thus, the fractured vertebral unit height included the sum of the measurement of the fractured corpus and upper disk height.

Written informed consent was collected from all patients, and this study was approved by the institutional ethics review committee at the University of Health Sciences Izmir Bozyaka Education and Research Hospital (Date: 30.12.2020, Issue No.10) in accordance with the World Medical Association Declaration of Helsinki and its most recent amendments.

Surgical Procedure

All surgeries were conducted by the same experienced surgeons at our hospital. All patients were positioned prone under general anesthesia. A midline skin incision was made, and the paravertebral muscles were detached bilaterally from the spinous processes to expose the laminae and pedicles. The fracture level was confirmed using fluoroscopy, and polyaxial screws were inserted through the pedicles bilaterally. Connecting caps were used to secure the rods within the heads of the pedicle screws. The caudal end of the construct was fixed, and distraction was applied throughout the fracture by a distractor as measured in the preoperative CT. This maneuver restored the vertebral body height, tensioned the annulus and PLL, and indirectly reduced any retropulsed fragments by ligamentotaxis. Then, the entire segment was locked in this lengthened position to maintain the corpus height. Laminectomy was performed safely when the SCA was enlarged after distraction.

Statistical Analyses

All statistical analyses were performed using the Statistical Package for Social Sciences software version 20. The Mann–Whitney U-test was used to compare the two independent groups, while the pre- and postoperative dependent variables (percentage of the spinal canal compression at the fractured levels, fractured vertebral unit height, and ODI scores of the patients) were compared using the Wilcoxon signed-rank test. A p-value ≤ 0.05 was considered significant.

RESULTS

This study included 56 patients diagnosed with thoracolumbar retropulsed fracture, including 34 men (60.7%) and 22 women (39.3%) with a mean age of 46.25 years (range, 18–74 years); they underwent surgery with posterior instrumentation alone. The mechanisms of injury were; fall from a height in 44 patients, and motor vehicle accidents in 12 patients. The preoperative

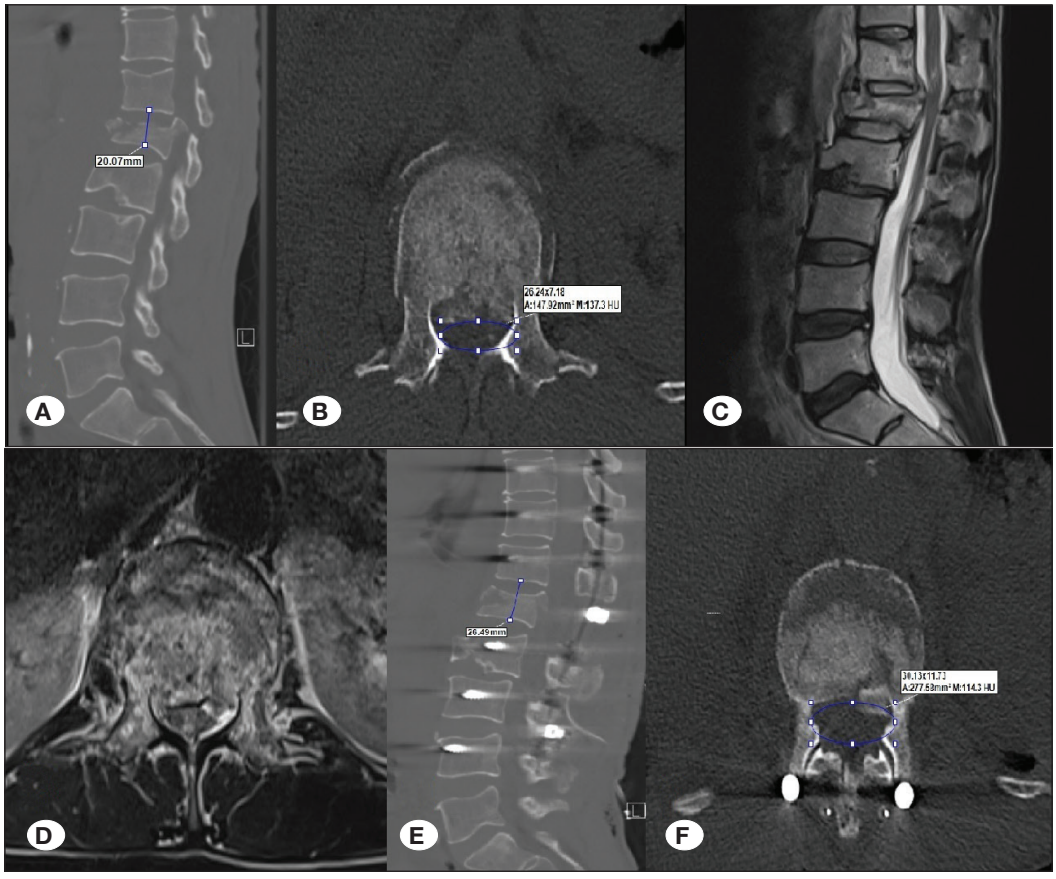

Figure 1: Preoperative sagittal computed tomography (CT) scan **(A)** showing the measurement of the fractured vertebral unit height, and axial CT scan **(B)** showing the spinal canal area at L1 burst fracture level. Preoperative sagittal **(C)**, and axial **(D)** T2W magnetic resonance images showing spinal cord compression. Postoperative CT scans after posterior spinal instrumentation with distraction and ligamentotaxis showing apparent increase invertebral unit height **(E)** and widening of the spinal canal **(F)**. The fractured vertebral unit height increased from 20.07 mm to 26.49 mm (+6.42 mm) **(A,E)**, and the percentage of spinal cord compression decreased from 42% to 24% (+18%) **(B,F)**.

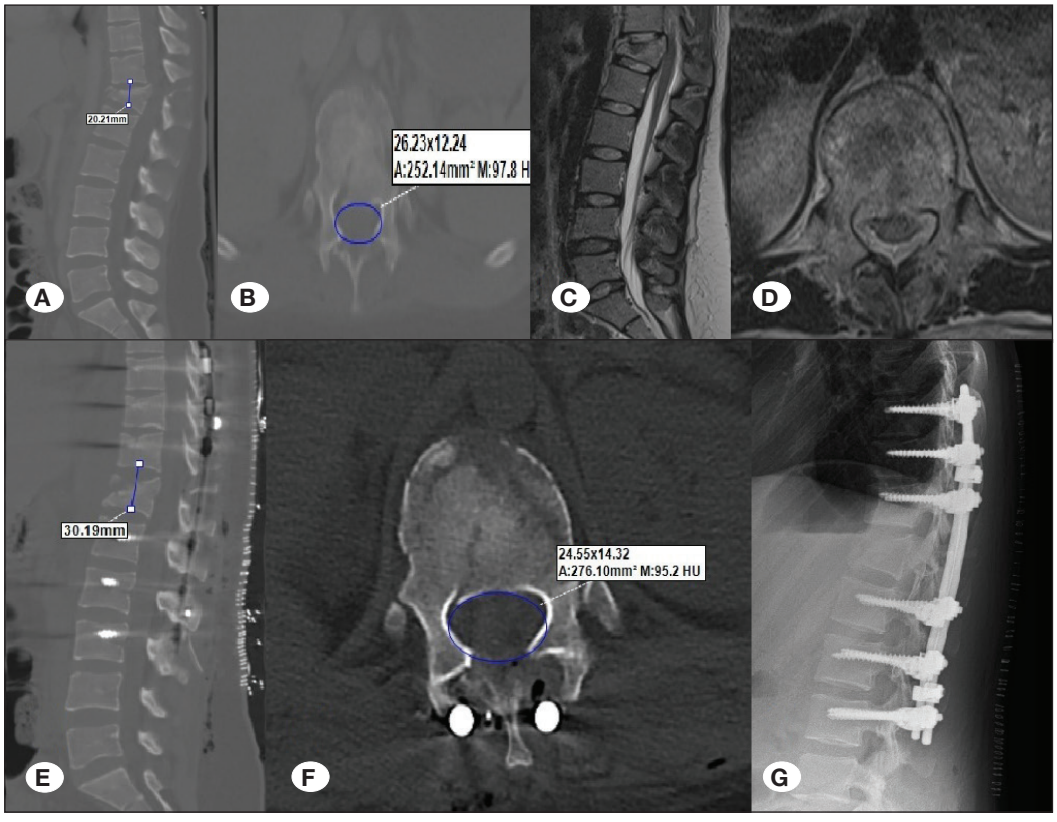

Figure 2: Preoperative sagittal **(A)** and axial **(B)** computed tomography (CT) scans and T2W sagittal **(C)** and axial **(D)** magnetic resonance imagings of T12 burst fracture with kyphotic angulation. Postoperative sagittal **(E)** and axial **(F)** CT images after distraction and ligamentotaxis showing kyphosis correction and expansion of spinal canal. Postoperative directradiography **(G)** after posterior instrumentation was performed. The distance from the T11 inferior end plate to theT12 inferior end plate increased from 20.21 mm to 30.19 mm (+9.98 mm) **(A,E)**, and the spinal cord occlusion reduced from 31% to 20% (+11%) **(B,F)**.

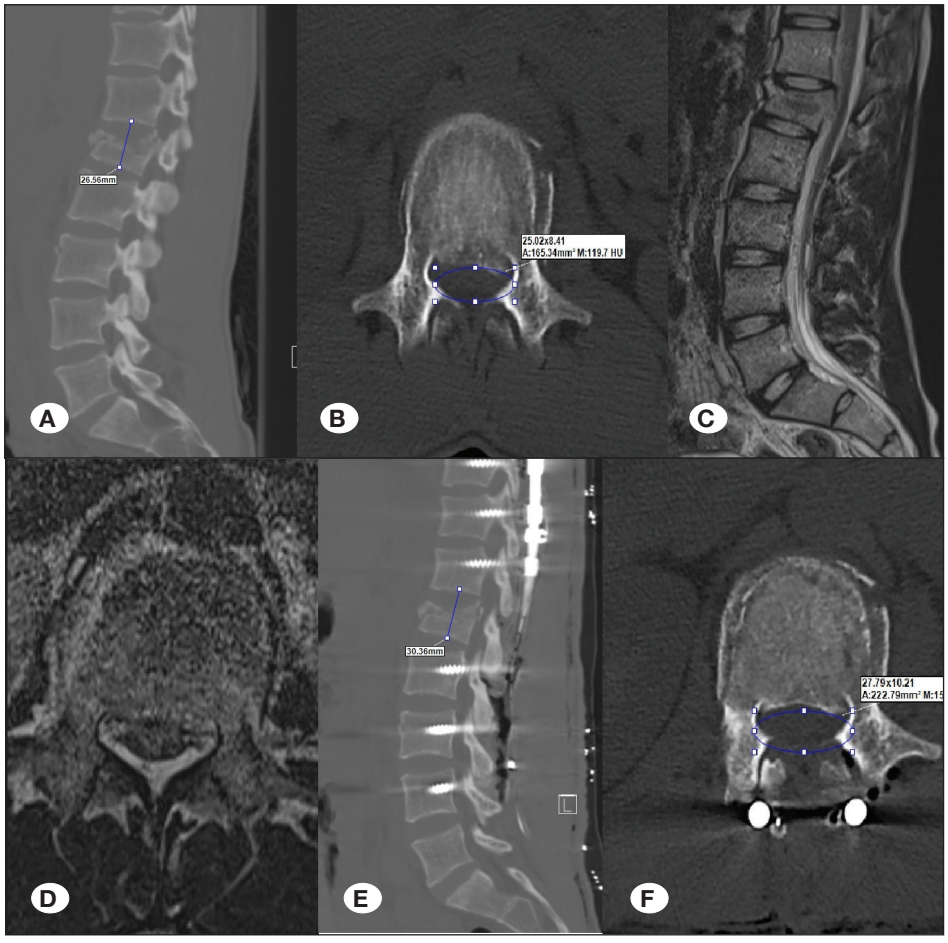

Figure 3: Distraction and ligamentotaxis in posterior instrumentation of L1 burst fracture. Preoperative sagittal **(A)** and axial **(B)** computed tomography (CT) scans, and T2W sagittal **(C)** and axial **(D)** magnetic resonance images showing spinal cord compression with the measurements. Postoperative sagittal **(E)** and axial **(F)** CT images showing the increase in the corpus height and decrease of the percentage of spinal cord compression at L1 fracture level. The fractured vertebral unit height increased from 26.56 mm to 30.36 mm (+3.80 mm) **(A,E)**, and spinal cord compression from 40% to 23% (+17%) **(B,F)**.

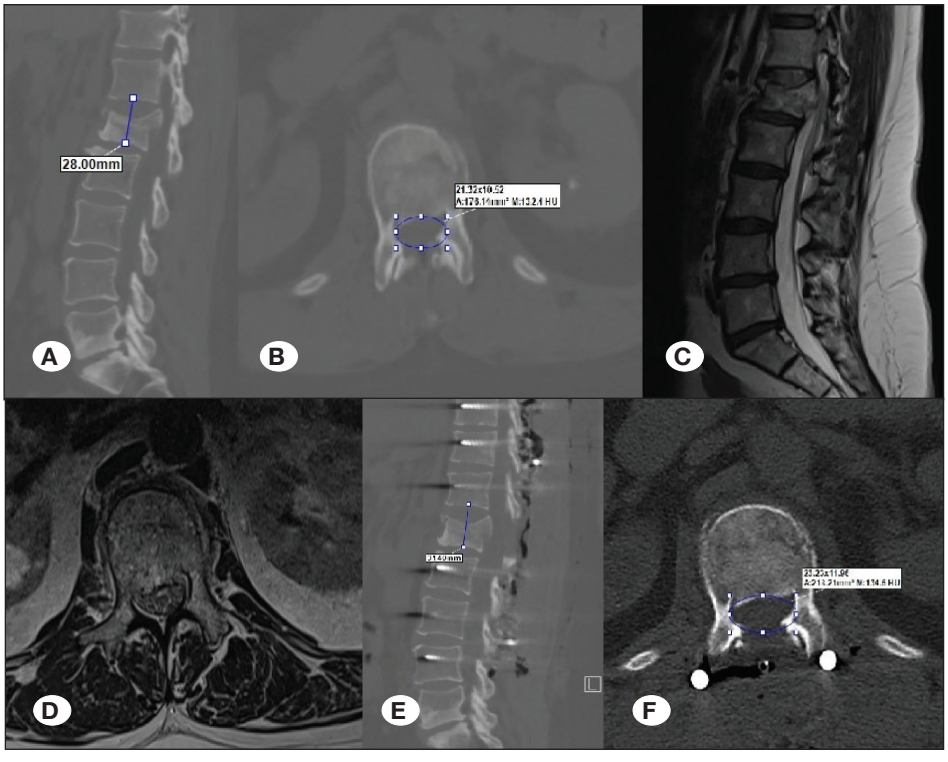

Figure 4: Preoperative sagittal **(A)** and axial **(B)** computed tomography (CT) scans, and T2W sagittal **(C)** and axial **(D)** magnetic resonance images **(C,D)** with fracture fragments from the posterior vertebral wall retropulse into the spinal canal. Postoperative sagittal **(E)** and axial **(F)** CT scans showing increased corpus height and canal widening after distraction and ligamentotaxis. 28.0 mm to 31.4 mm (+ 2.6 mm) **(A,E)**, and spinal cord occlusion from 36% to 22% (+14%) **(B,F)**.

neurological status was classified according to the scoring system of the American Spinal Injury Association (ASIA), and the scores were ASIA grade E in 32 patients, grade D in 12 patients, grade C in two patients, and grade B in four patients.

Fracture vertebra localizations and fracture types were determined according to AO spine classification of thoracolumbar fractures, with type A3 in 36 patients, type A4 in 14, and type C in six patients (Table I). Patients with AO spine type A1, A2, and B were excluded from our study since they had no posterior spinal canal compression. The fractures were at T11 in 4 patients, T12 in 12 patients, L1 in 28 patients, L2 in 6 patients, L3 in 4 patients, and L4 in 2 patients (Table I).

Clinical Evaluation

ODI scores significantly decreased in our study, with the average preoperative and postoperative scores being 76.3 ± 7.2 and 44.8 ± 5.4 ($p<0.05$), respectively. The VAS scores were 7.9 ± 1.3 preoperatively and 3.6 ± 1.9 at 2 months postoperatively.

Table I: Localization and Fracture Types*

Fracture type	A3	A4	C	Total
T11	3	1		4
T12	6	4	2	12
L1	21	3	4	28
L2	3	3		6
L3	1	3		4
L4	2			2
Total	36	14	6	56

**In accordance with AO Spine Thoracolumbar Fracture Classification.*

Radiographic Evaluation

The widening of the SCA was confirmed postoperatively. The average percentage of spinal cord compression decreased significantly from 40.2% preoperatively to 26.8% postoperatively (+13.4%, $p<0.05$). The average vertebral unit height increased significantly from 25.20 ± 3.2 mm to 31.85 ± 2.6 mm (+6.65 ± 2.7 mm, $p<0.05$).

The patients were divided according to the Wolter classification (16) into those with a spinal canal compression up to 1/3 (grade I), 1/3 to 2/3 (grade II), and over 2/3 (grade III). There were 18 patients in group I with canal compression up to 1/3. The spinal canal compression decreased 7.89%, while it was 13.3% in 33 patientsof group II (Table II). The decrease in both groups was significant ($p<0.05$). The absolute spinal canal compression reduction was higher for grade II fractures than for grade I fractures, and a significant difference was found between the two groups ($p<0.05$). The effects of ligamentotaxis were compared according to fracture levels. Greater widening was observed at the level of L1–L2 (+16.2%, $p<0.05$) than at the level of T11–T12 (+10.2%, $p<0.05$) (Table III). Asignificant difference was found in the spinal canal compression reduction between the two groups ($p<0.05$).

DISCUSSION

Distraction after spinal instrumentation contributes to the goal of spinal realignment by ligamentotaxis for complete and incomplete burst fractures. In burst fractures, the fracture fragments from the posterior vertebral wall retropulse into the spinal canal, commonly with the attachment of the PLL

Table II: Pre- and Postoperative Percentage of Spinal Canal Compression (PSCC) according to Wolter Classification. Preoperative Spinal Canal Area (SCA) Compression of up to 1/3 (Grade I), 1/3 to 2/3 (Grade II) and Over 2/3 (Grade III)

	Grade I (n=18)	Grade II (n=33)	Grade III (n=5)
Preoperative stenosis	27.39%	40.33%	76.6%
Postoperative stenosis	19.5%	27.0 %	46.2%
Widening (%)	+7.89	+13.33	+30.4
p (preoperative vs. postoperative)	**(p< 0.0001)**	**(p< 0.0001)**	(nevc)

Nevc: *Not enough valid cases.*

Table III: Pre- and Postoperative Percentage of Spinal Canal Compression (PSCC) according to Fracture Level

	T11-12 (n=16)	L1-2 (n=34)	L3-4 (n=6)
Preoperative stenosis	36.8%	43.6%	33.6%
Postoperative stenosis	26.6 %	27.4 %	24.8%
Widening (%)	+10.2	+ 16.2	+8.8
p (preoperative vs. postoperative)	**(p< 0.0001)**	**(p< 0.0001)**	(nevc)

Nevc: *Not enough valid cases.*

(13). Application ofa strong distraction tenses the PLL and leads to indirect reduction of the fracture fragments (7,10,11). Ligamentotaxis is most effective when the surgical intervention is performed within a few days after a trauma. Furthermore, ligamentotaxis is not efficient in patients with ruptured PLL, as an intact ligament is required for indirect reduction. Additionally, the ligamentotaxis procedure technique is should be considered contraindicated in patients with free bone fragments (the "reverse cortical sign" means that the fracture fragment is 180° inverted). In this case, reduction through distraction may cause the fragment to be displaced and may compress the dura (1,2,18). Several different indirect decompression procedures are utilizing the lumbar spine disc space, such as transforaminal lumbar interbody fusion, anterior lumbar interbody fusion, extreme lateral interbody fusion, and oblique lateral interbody fusion (18).

In the present study, we measured the SCA and calculated the percentage of spinal cord compression according to Mumford et al. to get an accurate measurement (12). The decrease in the average percentage of spinal cord compression was significant (+13.4%, $p<0.0001$). Using the same measurement method, Mueller et al. observed an average postoperative SCA increase of approximately +10% (from 29% preoperatively to 19% postoperatively) in 36 patients with distraction and ligamentotaxis in thoracolumbar burst fractures (1,11). Gertzbein et al. searched for the effect of ligamentotaxis in 25 patients with burst fractures using internal fixator (4). The overall percentage of preoperative compression dropped from 54% to 40% (+14%) postoperatively. Kuner et al. found an SCA stenosis reduction from 43% pre- to 25% postoperatively of approximately+18% in 56 patients (7). They found that large trapezoid-shaped fragments were difficult to reposition. Crutcher et al. demonstrated a 50% reduction in spinal canal stenosis of thoracolumbar burst fractures with posterior distraction instrumentation and ligamentotaxis (3). We also found that the increase in the average vertebral unit height was significant (+6.65%, $p<0.0001$). Infusa et al. noted in a cadaveric study that the greatest incremental change in the foraminal area was observed at 6 mm of distraction following pedicle screw instrumentation (5). Corpus height increase percentage and limits were not clearly stated in the literature; however, after examination of articles about this subject, the corpus height increase percentage was 20%–30% on average, but did not reach 40%–50% as a limit. Distraction will lengthen the construct; therefore, the rod needs to be cut a little longer than measured (15).

In the present study, the authors the patients according to the Wolter classification and found a significantly higher SCA increase for fractures with a high preoperative stenosis. These results were in line with previous studies (6,11,14). Mueller et al. determined that the reduction of SCA compression was higher for grade II fractures than for grade I fractures (11). Jeong et al. concluded that indirect decompression using PLL ligamentotaxis was a useful technique for patients with a high McCormack's classification score (6).

In the present study, the authors pre- and postoperative SCA stenosis widening according to the fracture level. The widening of ligamentotaxis between L1 and L2 was greater than that between T10 and T12. The SCA widening between L1 and L2 ranged from 41% preoperatively to 25% postoperatively (+16.2% widening, $p<0.0001$) in 34 patients, while a low but significant SCA widening between T10 and T12 was +10.2% ($p<0.0001$). Slight widening in some patients can be explained by the large trapezoid-shaped fragments which had resisted ligamentotaxis. The present results confirm the existing literature of showing the positive effect of ligamentotaxis (6,11). Neurological function was evaluated using the ODI scores in the current study, and a significant improvement was observed postoperatively.

Limitations

This study had several limitations. First, the retrospective study design may have led to selection bias, despite the fact that the same inclusion criteria were used for both groups. Second, the patient's habits, occupation, and comorbidities were not taken into consideration.

CONCLUSION

Indirect decompression techniques reduce retropulsed fragments and effectively improve the degree of spinal canal compression. Laminectomy could be performed safely when the SCA was enlarged after distraction. The authors concluded that the efficiency of distraction and ligamentotaxis after posterior instrumentation was correlated with the preoperative percentage of spinal canal compression; higher SCA increases for those fractures with a high preoperative stenosis.

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