Original Article
Clinics in Orthopedic Surgery 2024;16:863-870 • https://doi.org/10.4055/cios23387

Risk factors for Implant Failure in Thoracolumbar Fractures Treated with Posterior Long-Segment Instrumentation

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Background: Posterior long-segment instrumentation (PLSI) enables the stable repair of thoracolumbar fractures (TLFx) and is thus widely used. However, patients with highly unstable fractures may experience implant failure and related complications (e.g., pain and kyphosis) despite PLSI. Few studies have considered the implant failure rate and risk factors associated with PLSI for TLFx.

Methods: This study reviewed 162 consecutive patients with TLFx who underwent PLSI and completed > 1 year of follow-up between April 2011 and December 2019. Implant failure was defined as rod breakage, cap dislodgement, or screw breakage. Risk factors for implant failure were evaluated by multivariate regression analysis that included demographic, injury-related, and surgical factors.

Results: There were 15 cases (9.3%) of implant failure at the final follow-up (mean, 28.0 ± 18.0 months). Current smoker at the time of injury, fracture level, load sharing score, and anterior compression ratio (ACR) significantly differed between the implant failure and control groups (all $p < 0.05$). Multivariate logistic regression identified current smoker at the time of injury (adjusted odds ratio [aOR], 5.924; 95% CI, 1.405–24.988), mid to low lumbar fracture (aOR, 15.977; 95% CI, 4.064–62.810), and ACR (aOR, 1.061; 95% CI, 1.009–1.115) as predictors of implant failure.

Conclusions: This study demonstrated a high implant failure rate in patients with TLFx treated with PLSI. Smoking at the time of injury, mid to low lumbar fracture, and higher ACR were identified as significant risk factors for implant failure. These findings can help guide treatment decisions and improve patient outcomes in TLFx surgery.

Keywords: *Spine, Trauma, Thoracolumbar fracture, Implant failure*

There remains no consensus regarding the treatment of acute traumatic unstable thoracolumbar fractures (TLFx).[1)] Surgery is generally performed for patients who had neurological or mechanical instability, with the objectives of decompressing the spinal tract, restoring vertebral height and spinal alignment, preventing progressive kyphotic deformity and neurological damage, and providing early mobilization and rehabilitation for early ambulation and rehabilitation.[2)] Posterior long-segment instrumentation (PLSI) is generally regarded as the treatment of choice for patients with TLFx because of its better stability and correction.[1,3-7)]

PLSI is commonly used to fix the 2 segments of the vertebral body above and below the fractured vertebra. Regardless of this stable fixation, implant-related complications may occur; in some cases, additional anterior support or longer posterior instrumentation (≥ 3 levels above and below the fractured vertebra) is necessary. The use of PLSI ≥ 3 levels above and below the fractured vertebra has been advocated in patients with ankylosing spondylitis, with the goal of preventing implant failure (IF) and reduc-

Received November 29, 2023; Revised July 19, 2024;
Accepted August 7, 2024
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tion loss. In the highly unstable fracture dislocation that characterizes TLFx, a longer construct (covering ≥ 3 levels above and below the fractured vertebra) or the use of anterior support is often necessary to prevent implant-related complications.[8] However, such complications may arise in patients with TLFx when PLSI is performed in a manner other than the approach described above.[9]

To our knowledge, there have been few studies regarding IF rates and risk factors associated with PLSI for the treatment of TLFx. The purpose of this study was to determine the incidence, time of onset, type, and clinical outcomes of IF, along with associated risk factors, in patients who underwent PLSI for acute TLFx.

METHODS

The study was reviewed and approved by the Ethics Committee of Ajou University Hospital (IRB No. AJOUIRB-MDB-2021-272), and informed consent was waived.

Study Design and Setting

This study was based on a retrospective review of 465 patients who underwent surgical treatment for single-level unstable TLFx by high-energy trauma (fall, motor vehicle accident, and crushing by a heavy object) between April 2011 and December 2019 at a single tertiary hospital with a level 1 trauma center. TLFx was surgically treated if the thoracolumbar injury classification and the Thoraco-Lumbar Injury Classification and Severity (TLICS) score were ≥ 4. PLSI was performed in patients with severe comminution and a load sharing classification (LSC) score ≥ 6, AO type C fracture, or a thoracolumbar junctional fracture. Patients younger than 19 years or older than 65 years (n = 25) were excluded. Patients were also excluded if they had ankylosing spondylitis or diffuse idiopathic skeletal hyperostosis (n = 16), a history of scoliosis (n = 9), spinal surgery (n = 22), multilevel fracture (n = 52), short-level fixation (n = 30), combined anterior surgery (n = 53), and/or a follow-up duration of < 1 year (n = 96). Finally, 162 patients were included in the analysis (Fig. 1).

Baseline demographic data (age, sex, smoking status, body mass index [BMI], cause of injury), injury data (fracture level, AO fracture type, TLICS, LSC, bi-segmental sagittal Cobb angle [CA], anterior compression ratio [ACR], and the presence of any neurological deficit), and surgical data (time to surgery, laminectomy, and insertion of a transverse connector) were collected from medical records. BMI was divided into overweight/obese (BMI ≥ 23 kg/m^2) or not. The cause of injury was categorized as fall injury, traffic accident, or other. The fracture level was categorized as thoracolumbar junctional (T10–L2) and mid to low lumbar (L3–L4). The CA and ACR of the fractured vertebra were measured on lateral radiographs obtained with the patient in the supine position.[10] The ACR was determined by measuring the height of the anterior vertebra at the level of injury (AI) and at the nearest normal levels above (AA) and below (AB) the level of injury. The ACR (%) was calculated as AI / (AA + AB) / 2 × 100%. A smaller ACR was considered indicative of more severe vertebral height loss.[10] Neurological deficit included any sensory or motor deficit below the level of injury, including autonomic dysfunction such as bladder, bowel, and sexual dysfunction.

Surgical Technique

All surgeries were performed as soon as the patient's condition allowed. All operations were performed by 1 surgeon (HDL) using the same instrumentation system (CD Horizon Legacy, Medtronic Sofamor Danek). The screw size was chosen according to the vertebral size (in most cases, 6.5 × 45-mm screws and 5-mm titanium rods). Fracture reduction and indirect decompression of the spinal canal were accomplished via postural reduction, with rod contouring and the application of distraction forces before the screws were tightened. Total or partial laminectomy was performed according to the presence of neurological deficit and the presence of neural tissue compression on preoperative images. A transverse connector was applied according to the severity of posterior element disruption. After decortication of the laminae and facet joints, auto-iliac bone and allo-demineralized bone matrix and bone chips were applied to all instrumented levels.

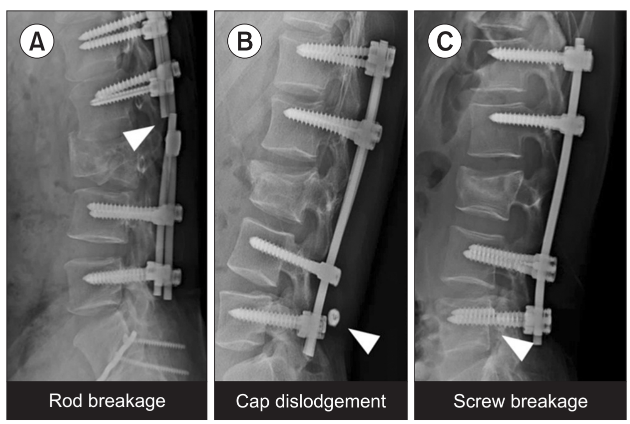

Fig. 1. Three subtypes of implant failure in posterior long-segmentation instrumentation for thoracolumbar fracture. (A) Bilateral rod breakage between the 2 middle screws. (B) Cap dislodgement at the most caudal segment. (C) Screw breakage at the most caudal segment.

All patients received a thoracolumbosacral orthosis for 3 months after surgery.

Evaluation of IF and Fusion

Radiographs acquired at routine 1-, 2-, 3-, 6-, and 12-month postoperative follow-up visits were reviewed to detect IF. Subsequently, the patients attended annual follow-up visits. In addition to the standard follow-up protocol, patients were admitted to the outpatient clinic if they experienced sudden pain or reported a clunking sound. IF was defined as rod breakage, cap dislodgement,[11,12] and screw breakage (Fig. 1). To differentiate infection, fever, complete blood count, C-reactive protein, and erythrocyte sedimentation rate were checked, and in all cases, there was no evidence of infection. Information regarding the timing of IF onset, the presence of acute pain, or subsequent revision surgery related to progressive kyphosis was also obtained from medical records. Progressive kyphosis was defined as a > 10° increase in the CA from the immediate postoperative visit to the final follow-up visit. Fusion was defined as a difference of > 5° in dynamic flexion extension on lateral radiographs taken at 6 months and 1 year after surgery, confirmed by the detection of a bone bridge on computed tomography scans.

Statistical Analysis

Chi-square tests (categorical variables) or independent *t*-tests (continuous variables) were used in univariate analyses to identify possible risk factors for IF. Multivariate logistic regression analyses were used to identify independent risk factors for IF. Variables eligible for inclusion in the multivariate models included variables that were significant ($p < 0.05$) in univariate analyses. The final model was evaluated for goodness-of-fit using the Hosmer-Lemeshow test, and collinearity was assessed based on the variance inflation factor. Data were analyzed using SPSS version 20.0 (IBM Corp.). In all analyses, $p < 0.05$ was considered indicative of statistical significance.

RESULTS

Baseline Characteristics (Table 1)

The mean age of the patients was 45.0 ± 12.8 years, and most patients were men (n = 111, 68.5%). The mean BMI was 23.5 ± 3.2 kg/m^2. There were 52 current smokers (32.1%). Fall from a height was the most common cause of injury (n = 84, 51.8%), followed by motor vehicle accident (n = 44, 27.2%), and other (e.g., crushed by heavy object) (n = 34, 21.0%).

Thoracolumbar and lumbar fractures were diagnosed in 137 patients (84.6%) and 25 patients (15.4%), respectively. AO type B2 was the most common fracture type (n = 136, 83.9%), followed by A4 (n = 22, 13.6%) and C (n = 4, 2.5%). The mean TLICS score was 6.8 ± 1.3, and the mean LSC score was 6.9 ± 1.3. The mean CA at injury was 10.3° ± 10.6°, and the mean ACR was 9%. Neurological deficit at injury occurred in 52 patients (32.1%).

The mean time to surgery was 2.6 ± 2.4 days from injury. Laminectomy was performed in 12 patients (7.4%), and a transverse connector was inserted in 48 patients (29.6%). In the immediate postoperative period, the mean CA was 5.1° ± 8.4°; at the final follow-up visit (mean, 28.0 ± 18.0 months), the mean CA was 10.2° ± 8.2°. Progressive kyphosis occurred in 15 patients (9.3%). Fusion was identified in 126 patients (77.8%) at 6 months after surgery and in 154 patients (95.1%) at 1 year after surgery.

Implant Failure

There were 15 cases of IF (9.3%). The clinical characteristics of these cases are provided in Table 2. The mean time of onset was 21.7 ± 11.5 months after surgery. IF was caused by rod fractures in 5 patients, cap dislodgement in 4 patients, and screw breakage in 6 patients. All rod fractures were unilateral and occurred on the right side, between the 2 middle screws. The mean time to rod fracture was 23.6 months after surgery (range, 13.3–39.8 months). All cap dislodgements involved the most caudal screws. One case of cap dislodgement was bilateral, and 3 cases were unilateral (on the right side). The mean time to cap dislodgement was 16.5 months after surgery (range, 8.9–26.5 months). Screw breakage occurred at the most caudal or second most caudal screw, either unilaterally (n = 5, 3 cases on the left side and 2 cases on the right side) or bilaterally (n = 1). The mean time to screw breakage was 23.5 months (range, 5.1–46.7 months).

Among the 15 patients with IF and the 147 patients without IF, fusion at 6 months after surgery was observed in 9 patients (60%) and 117 patients (79.6%), respectively, with no statistically significant difference between the 2 groups ($p = 0.103$). At 1 year after surgery, fusion was observed in 10 patients (66.7%) and 144 patients (93.5%), respectively, with a statistically significant difference ($p < 0.001$).

Among the 15 patients with IF, progressive kyphosis was identified in 3. Two patients had mild back pain that improved after 1 month of conservative treatment; these 2 patients exhibited no subsequent progression of kyphosis. The third patient had increased pain, despite 1 month of conservative treatment. The fourth patient had increased pain and kyphosis progression after 1 month and under-

Table 1. Baseline Demographic Data and Comparison of the Implant Failure and Control Groups

Variable	Total (n = 162)	Implant failure group (n = 15)	Control group (n = 147)	*p*-value
Age (yr)	45.0 ± 12.8	38.4 ± 13.7	45.7 ± 12.6	0.065
Male	111 (68.5)	12 (80.0)	99 (67.3)	0.393
BMI (kg/m^2)	23.5 ± 3.2	22.4 ± 2.8	23.6 ± 3.2	0.160
Current smoker	52 (32.1)	10 (66.7)	42 (28.6)	0.006*
Cause of injury				0.070
Fall from a height	84 (51.9)	12 (80.0)	72 (49.0)	
Motor vehicle accident	44 (27.2)	2 (13.3)	42 (28.6)	
Other	34 (21.0)	1 (6.7)	33 (22.4)	
Fracture level				< 0.001*
Thoracolumbar (T10–L2)	137 (84.6)	5 (33.3)	132 (89.8)	
Mid to low lumbar (L3–L4)	25 (15.4)	10 (66.7)	15 (10.2)	
AO fracture type				0.146
A4	22 (13.6)	4 (26.7)	18 (12.2)	
B2	136 (83.9)	10 (66.7)	126 (85.7)	
C	4 (2.5)	1 (6.7)	3 (2.0)	
TLICS	6.8 ± 1.3	7.1 ± 1.3	6.8 ± 1.3	0.449
LSC	6.9 ± 1.3	7.7 ± 1.1	6.8 ± 1.6	0.009*
CA at injury (°)	10.3 ± 10.6	5.8 ± 12.3	10.8 ± 10.4	0.146
ACR (%)	30.4 ± 19.0	42.7 ± 10.7	29.2 ± 20.2	0.090
Neurological deficit	52 (32.1)	7 (46.7)	45 (30.6)	0.335
Time to surgery (day)	2.6 ± 2.4	1.6 ± 2.5	2.7 ± 2.4	0.170
Laminectomy	12 (7.4)	3 (20.0)	9 (6.1)	0.085
Transverse connector	48 (29.6)	3 (20.0)	45 (30.6)	0.556

Values are presented as mean ± standard deviation or number (%).
BMI: body mass index, TLICS: Thoracolumbar Injury Classification and Severity Score, LSC: Load Sharing Classification score, CA: Cobb angle, ACR: anterior compression ratio.
*Statistically significant.

went revision surgery.

Comparison of IF and Control groups (Table 1)

Among the demographic factors, only current smoking at injury significantly differed between the IF and control groups, with an IF frequency of 19.2% vs. 4.5% ($p = 0.006$). Among the injury factors, the fracture level, LSC, and ACR significantly differed between groups. IF was more frequent in the mid to low lumbar fracture group than in the thoracolumbar junctional group (40.0% vs. 3.6%, $p < 0.001$). LSC was higher in the IF group than in the control group (7.7 ± 1.1 vs. 6.8 ± 1.6, $p = 0.008$); ACR was also higher in the IF group (42.7% ± 10.7% vs. 29.2% ± 20.2%, $p < 0.001$). Among the surgical factors, none were statistically significant (all $p > 0.05$).

Risk Factor for IF

Univariate analyses identified 4 variables significantly associated with IF ($p < 0.05$). Thus, current smoker at the time of injury, fracture level, LSC, and ACR were entered into the stepwise multivariate logistic regression analyses. There was no multicollinearity (all variance inflation fac-

Table 2. Clinical Characteristics of Patients with Implant Failure

No.	Age (yr)	Sex	BMI (kg/m^2)	Current smoking	Cause of injury	Fracture level	Fracture type	TLICS	LSC	CA at injury	ACR	Neurological deficit	Implant failure type*	Onset (day)
1	60	M	23.0		MVA	L4	A4	6	7	–29.46	0.445	○	R	22.9
2[†]	32	F	19.6	○	MVA	L2	B2	7	9	11.32	0.397		S	23.4
3	41	F	16.0		Fall	L3	B2	10	9	15.58	0.579	○	R	22.5
4	24	M	18.9	○	Fall	L3	B2	7	7	5.94	0.471		S	12.6
5	48	M	26.1		Fall	L2	A4	6	9	5.48	0.458	○	S	46.7
6	22	M	20.0	○	Other	L3	A4	6	7	–1.39	0.478		C	14.1
7	31	M	22.1	○	Fall	L2	B2	7	7	12.79	0.474		C	26.5
8	30	M	21.4	○	Fall	L3	B2	7	7	3.29	0.525		C	16.4
9[‡]	43	M	23.9	○	Fall	L3	C	10	7	8.2	0.575	○	R	13.3
10	61	F	24.7		Fall	L3	B2	10	9	4.65	0.466	○	S	17.9
11	42	M	23.7	○	Fall	L1	B2	10	9	22.66	0.241	○	R	39.8
12	32	M	25.8	○	Fall	L2	B2	7	6	13.64	0.219		S	35.1
13[†]	59	M	22.2	○	Fall	L3	B2	7	7	9.43	0.385		S	5.1
14	20	M	24.8		Fall	L4	A4	6	7	–8.68	0.311	Present	R	19.8
15	31	M	24.5	○	Fall	L3	B2	7	9	13.52	0.385		C	8.9

BMI: body mass index, TLICS: Thoracolumbar Injury Classification and Severity Score, LSC: Load Sharing Classification score, CA: Cobb angle, ACR: anterior compression ratio, MVA: motor vehicle accident.
*Implant failure type: R, rod breakage; S, screw breakage; C, cap dislodgement. [†]Patient had painful implant failure. [‡]Patient underwent revision surgery.

Table 3. Multivariate Logistic Regression Model of Implant Failure

Variable	Adjusted odds ratio	95% CI	*p*-value
Current smoker	5.924	14.05–24.988	0.015*
Mid to low lumbar fracture	15.977	4.064–62.810	< 0.001*
LSC	1.415	0.670–2.990	0.363
ACR	1.061	1.009–1.115	0.021*

LSC: Load Sharing Classification score, ACR: anterior compression ratio.
*Statistically significant.

tors < 10). The Nagelkerke R^2 was 0.44, and the *p*-value in the Hosmer and Lemeshow test was 0.986. Multivariate logistic regression identified current smoker at the time of injury (adjusted odds ratio [aOR], 5.924; 95% CI, 1.405–24.988), mid to low lumbar fracture level (aOR, 15.977; 95% CI, 4.064–62.810), and ACR (aOR, 1.061; 95% CI, 1.009–1.115) as predictors of IF (Table 3).

DISCUSSION

PLSI is a commonly used and generally safe surgical method for the treatment of TLFx. Nevertheless, IF after PLSI is not uncommon, although the incidence, risk factors, and prognosis of IF after PLSI have not been reported. In this study, among 162 patients with TLFx who underwent PLSI and completed > 1 year of follow-up, there were 15 IFs (9.3%). Three patients presented with acute pain, and 2 patients had an increase of > 10° in CA. Among these 2 patients with an increased CA, only 1 underwent revision surgery because of increased pain and kyphosis progression. Current smoker at the time of injury, fracture level, LSC, and ACR of the fractured vertebra significantly differed between the IF and control groups. Multivariate logistic regression analysis identified current smoker at the time of injury (aOR, 5.924; 95% CI, 1.405–24.988), mid to low lumbar fracture level (aOR, 15.977; 95% CI, 4.064–62.810), and ACR (aOR, 1.061; 95% CI, 1.009–1.115) as predictors of IF.

Many studies have concluded that short-segment fixation can yield good results in TLFx, but PLSI is the better approach in terms of kyphosis correction, based on its lower rate of reduction loss and its decreased risk of IF.[5,6,13-16] Among patients with short-segment fixation, the risk of IF ranges between 9% and 54%, consistent with reports in the past 15 years.[4,17] The risk of IF in PLSI is not well-defined and has mainly been investigated in small numbers of patients. In those studies, it was in the range of 0%–28%, which was less than the range in short-segment fixation.[4,6,15,18-21] Biomechanical studies and finite element analyses suggest that this result reflects the stronger stiffness of the long construct.[22] In our study, the IF rate of PLSI for TLFx was 9.3%.

The timing of IF after short-segment fixation has been examined, but little is known regarding IF in PLSI. Sodhi et al.[23] reported a median time to IF of 17 months (interquartile range, 12–28.2 months) after short-segment posterior fixation in patients with traumatic TLFx. Nearly one-quarter of the failures occurred within 1 year; > 90% of the failures occurred within 4 years after surgery. Waqar et al.[6] compared short- and long-segment posterior fixation in the treatment of thoracolumbar junction fractures; they found that the time to failure was 3–14 months after surgery, and all failures occurred in the short-segment posterior fixation group. The mean time to construct failure in our study was 21.7 ± 11.5 months after surgery (range, 5.1–46.7 months). Thus, the time until failure was longer in patients who underwent PLSI than in patients who underwent short-segment fixation. Additionally, the presence of fusion at 1 year after surgery was correlated with IF. Therefore, if fusion is not well achieved by 1 year, patients should be informed in advance about the risk of failure.

Various poor surgical outcomes after IF have been described, including a long-term loss of kyphosis correction and, in up to 50% of patients, moderate to severe pain.[24] A recent study revealed that pain occurred in approximately 25% of patients with IF after short-segment fixation, and secondary surgery or device removal was subsequently required.[23] However, some studies have shown that IF is not significantly associated with clinical symptoms.[25,26] Studies of clinical outcomes in patients treated with long constructs have been rare. In the present study, kyphosis progression occurred in 3 of 15 IF patients; only 1 patient developed kyphosis, and their pain did not improve despite conservative treatment. In contrast, among patients treated with the long construct, IF is delayed; this allows soft tissues (e.g., the posterior ligament complex) to heal sufficiently, thus considerably reducing the incidences of IF and other serious complications.[27]

Smoking is widely known as a risk factor for non-union in fracture.[28] One component of cigarettes, nicotine, is known to inhibit the differentiation of osteoblasts and the synthesis of collagen.[29] In spine fusion, smoking is also recognized as a risk factor for pseudoarthrosis, which is attributed to smoking lowering bone density and adversely affecting tissue nutrition due to worsening microcirculation.[30] In the current study, current smoking was strongly associated with IF. Therefore, for current smokers, more stable fixation should be considered during surgery to prevent pseudoarthrosis, and the higher risk of complications should be explained to the patient before surgery.

Fracture severity as a risk factor for IF in patients with vertebral fractures has also been examined. The LSC score is widely used as a representative index of fracture severity. It is calculated by scoring the extent of comminution present on computed tomography sagittal images, the degree of displacement present on axial images, and the degree of reduction in radiographs. In early studies, the IF rate was high in short-segment fixation patients with an LSC score > 6, but studies in the past 10 years have shown a weak correlation between LSC and IF.[31,32] In the present study, the LSC score differed between the IF and non-failure groups, but risk factor analysis did not reveal a significant difference. Among the factors related to fracture severity, ACR was more closely related to IF. Previous studies have also identified the degree of the vertebral body's wedge angle before surgery as a major risk factor for re-collapse in trauma patients.[33] This association suggests that the degree of comminution of the anterior column, rather than the degree of overall comminution of the vertebral body, has a greater influence on the risk of IF.

Fracture level as a risk factor for IF was not determined in previous studies, whereas our study identified mid to low lumbar fracture as a risk factor for IF. Although the IF rate in PLSI is reportedly near 0%, most of the fractures have been thoracolumbar junctional fractures.[4,18-20] Among patients who underwent surgical treatment of low lumbar fracture, the complication rate was high and hardware failure reached 29%.[34] A lumbar fracture is a high-energy fracture, which causes severe and unstable damage to surrounding soft tissue that increases the risk of IF. Additionally, the lumbar region has a large range of motion, such that fatigue may accumulate, eventually resulting in IF.[35]

The high IF rate after lumbar fracture surgery suggests that greater attention is needed regarding fusion. Although simple fixation surgery without fusion using a percutaneous approach was recently introduced,[36] surgeons should note that early failure with severe anterior column collapse can occur in patients undergoing long-segment fixation at the lumbar level. McCormack et al.[3] recommended long segment fusion or reinforcement of the anterior column for patients with an LSC score ≥ 7. Anterior fusion may be better in the mid to low lumbar region because the risk of failure during long-segment posterior fixation is high in such cases. This approach may also preserve a greater segmental range of motion.

Our study has several limitations. First, the retrospective design may have led to bias. To minimize this risk, we attempted to include consecutive patients who met the inclusion and exclusion criteria. Second, it was difficult to determine the exact time of IF, although patients were instructed to visit the hospital rapidly if they experienced pain. Additionally, the patient's neurogenic status may also influence IF. However, due to limitations in the data, we were unable to determine the impact of the severity of neurology on IF. Finally, because patients who underwent anterior surgery were excluded, the actual incidence of IF may have been underestimated.

In our study, the IF rate in patients with TLFx who underwent PLSI was 9.3%. Smoking at injury, mid to low lumbar fracture, and higher ACR were identified as risk factors for IF. Our results suggest that the possibility of IF should be considered when performing long segmental fixation in mid to low lumbar fractures.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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REFERENCES

1. Reinhold M, Knop C, Beisse R, et al. Operative treatment of 733 patients with acute thoracolumbar spinal injuries: comprehensive results from the second, prospective, internet-based multicenter study of the Spine Study Group of the German Association of Trauma Surgery. Eur Spine J. 2010; 19(10):1657-76.
2. Saglam N, Dogan S, Ozcan C, Turkmen I. Comparison of four different posterior screw fixation techniques for the treatment of thoracolumbar junction fractures. World Neurosurg. 2019;123:e773-80.
3. McCormack T, Karaikovic E, Gaines RW. The load sharing classification of spine fractures. Spine (Phila Pa 1976). 1994; 19(15):1741-4.
4. Altay M, Ozkurt B, Aktekin CN, Ozturk AM, Dogan O, Tabak AY. Treatment of unstable thoracolumbar junction burst fractures with short- or long-segment posterior fixation in magerl type a fractures. Eur Spine J. 2007;16(8):1145-55.
5. Tezeren G, Kuru I. Posterior fixation of thoracolumbar burst fracture: short-segment pedicle fixation versus long-segment instrumentation. J Spinal Disord Tech. 2005;18(6):485-8.
6. Waqar M, Van-Popta D, Barone DG, Bhojak M, Pillay R, Sarsam Z. Short versus long-segment posterior fixation in the treatment of thoracolumbar junction fractures: a comparison of outcomes. Br J Neurosurg. 2017;31(1):54-7.
7. Girardo M, Masse A, Risitano S, Fusini F. Long versus short segment instrumentation in osteoporotic thoracolumbar vertebral fracture. Asian Spine J. 2021;15(4):424-30.
8. Ikuma H, Takao S, Inoue Y, Hirose T, Matsukawa K, Kawasaki K. Treatment of thoracolumbar spinal fracture accompanied by diffuse idiopathic skeletal hyperostosis using transdiscal screws for diffuse idiopathic skeletal hyperostosis: preliminary results. Asian Spine J. 2021;15(3):340-8.
9. Aly TA. Short segment versus long segment pedicle screws fixation in management of thoracolumbar burst fractures: meta-analysis. Asian Spine J. 2017;11(1):150-60.
10. Lee HD, Jeon CH, Moon SW, Chung HW, Park KH, Chung NS. Radiological risk factors for neurological deficits after traumatic mid and low lumbar fractures. Spine (Phila Pa 1976). 2020;45(21):1513-23.
11. Agrawal A. Pedicle screw nut loosening: potentially avoidable causes of spine instrumentation failure. Asian Spine J. 2014;8(2):224-6.
12. Petscavage-Thomas J, Ouyang T, Bible J. Spine fixation hardware: an update. AJR Am J Roentgenol. 2020;215(3):534-44.
13. Li J, Liu L. Comparison of short-segment versus long-segment fixation for the treatment of thoracolumbar burst fracture: a meta-analysis. Int J Clin Exp Med 2017;10(2):1750-62.
14. Lee SH, Pandher D, Yoon K, Lee S, Oh KJ. The effect of postoperative immobilization on short-segment fixation without bone grafting for unstable fractures of thoracolumbar spine. Indian J Orthop. 2009;43(2):197-204.
15. Moon MS, Choi WT, Moon YW, Kim YS, Moon JL. Stabili-

sation of fractured thoracic and lumbar spine with Cotrel-Dubousset instrument. J Orthop Surg (Hong Kong). 2003;11(1):59-66.

16. Alhashash M, Shousha M. Minimally invasive short-segment anteroposterior surgery for thoracolumbar osteoporotic fractures with canal compromise: a prospective study with a minimum 2-year follow-up. Asian Spine J. 2022;16(1):28-37.
17. Jindal R, Jasani V, Sandal D, Garg SK. Current status of short segment fixation in thoracolumbar spine injuries. J Clin Orthop Trauma. 2020;11(5):770-7.
18. Sapkas G, Kateros K, Papadakis SA, Brilakis E, Macheras G, Katonis P. Treatment of unstable thoracolumbar burst fractures by indirect reduction and posterior stabilization: short-segment versus long-segment stabilization. Open Orthop J. 2010;4:7-13.
19. Ugras AA, Akyildiz MF, Yilmaz M, Sungur I, Cetinus E. Is it possible to save one lumbar segment in the treatment of thoracolumbar fractures? Acta Orthop Belg. 2012;78(1):87-93.
20. Formica M, Cavagnaro L, Basso M, et al. Which patients risk segmental kyphosis after short segment thoracolumbar fracture fixation with intermediate screws? Injury. 2016;47 Suppl 4:S29-34.
21. De Iure F, Lofrese G, De Bonis P, Cultrera F, Cappuccio M, Battisti S. Vertebral body spread in thoracolumbar burst fractures can predict posterior construct failure. Spine J. 2018;18(6):1005-13.
22. Wu Y, Chen CH, Tsuang FY, Lin YC, Chiang CJ, Kuo YJ. The stability of long-segment and short-segment fixation for treating severe burst fractures at the thoracolumbar junction in osteoporotic bone: a finite element analysis. PLoS One. 2019;14(2):e0211676.
23. Sodhi HB, Savardekar AR, Chauhan RB, Patra DP, Singla N, Salunke P. Factors predicting long-term outcome after short-segment posterior fixation for traumatic thoracolumbar fractures. Surg Neurol Int. 2017;8:233.
24. Kim HJ, Yang JH, Chang DG, et al. Proximal junctional kyphosis in adult spinal deformity: definition, classification, risk factors, and prevention strategies. Asian Spine J. 2022;16(3):440-50.
25. Ituarte F, Wiegers NW, Ruppar T, Goldstein C, Nourbakhsh A. Posterior thoracolumbar instrumented fusion for burst fractures: a meta-analysis. Clin Spine Surg. 2019;32(2):57-63.
26. Yamato Y, Hasegawa T, Yoshida G, et al. Revision surgery for a rod fracture with multirod constructs using a posterior-only approach following surgery for adult spinal deformity. Asian Spine J. 2022;16(5):740-8.
27. Yang JS, Liu JJ, Liu P, et al. Can posterior ligament structure be functionally healed after anterior reduction and fusion surgery in patients with traumatic subaxial cervical fracture-dislocations? World Neurosurg. 2020;134:e243-8.
28. Smolle MA, Leitner L, Bohler N, Seibert FJ, Glehr M, Leithner A. Fracture, nonunion and postoperative infection risk in the smoking orthopaedic patient: a systematic review and meta-analysis. EFORT Open Rev. 2021;6(11):1006-19.
29. Scolaro JA, Schenker ML, Yannascoli S, Baldwin K, Mehta S, Ahn J. Cigarette smoking increases complications following fracture: a systematic review. J Bone Joint Surg Am. 2014;96(8):674-81.
30. Macki M, Syeda S, Rajjoub KR, et al. The effect of smoking status on successful arthrodesis after lumbar instrumentation supplemented with rhBMP-2. World Neurosurg. 2017;97:459-64.
31. Kim GW, Jang JW, Hur H, Lee JK, Kim JH, Kim SH. Predictive factors for a kyphosis recurrence following short-segment pedicle screw fixation including fractured vertebral body in unstable thoracolumbar burst fractures. J Korean Neurosurg Soc. 2014;56(3):230-6.
32. Filgueira EG, Imoto AM, da Silva HE, Meves R. Thoracolumbar burst fracture: McCormack load-sharing classification: systematic review and single-arm meta-analysis. Spine (Phila Pa 1976). 2021;46(9):E542-50.
33. Jang HD, Bang C, Lee JC, et al. Risk factor analysis for predicting vertebral body re-collapse after posterior instrumented fusion in thoracolumbar burst fracture. Spine J. 2018;18(2):285-93.
34. Formby PM, Wagner SC, Pisano AJ, Van Blarcum GS, Kang DG, Lehman RA. Outcomes after operative management of combat-related low lumbar burst fractures. Spine (Phila Pa 1976). 2015;40(18):E1019-24.
35. Park WM, Choi DK, Kim K, Kim YJ, Kim YH. Biomechanical effects of fusion levels on the risk of proximal junctional failure and kyphosis in lumbar spinal fusion surgery. Clin Biomech (Bristol, Avon). 2015;30(10):1162-9.
36. Ko S, Jung S, Song S, Kim JY, Kwon J. Long-term follow-up results in patients with thoracolumbar unstable burst fracture treated with temporary posterior instrumentation without fusion and implant removal surgery: follow-up results for at least 10 years. Medicine (Baltimore). 2020;99(16):e19780.