

Treatment of thoracolumbar fractures by temporary posterior instrumentation with selective fusion schemes

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Abstract

Objective: This retrospective study investigated the clinical and radiographic outcomes following temporary transpedicular posterior instrumentation between two cohorts of patients with thoracolumbar fractures (TLF) who underwent selective or bi-segments intervertebral articular process fusion.

Materials and Methods: Patients with TLF who underwent the temporary posterior fixation with selective fusion (**Group SF**), or bi-segments fusion (**Group BF**) were studied. Superior intervertebral articular process and interlaminar fusion were performed in Group SF, whereas in Group BF, the patients underwent bi-segments fusion in both superior and inferior articular processes, as well as interlaminar fusion. We measured the distal and proximal intervertebral mobility, regional kyphotic angle, and vertebral height before and after surgery in both groups. Greenough Low-Back Outcome Score was used to assess the clinical outcomes.

Results: Sixty-five patients with TLF from T12 to L2 fractures were enrolled in the study period: 23 patients in the Group SF and 22 patients in the Group BF. All the patients experienced fracture healing (mean follow-up time: 19.7 months). The mean postoperative functional outcomes were 65.0 ± 2.0 points for the Low-Back Outcome Score in the Group SF and 65.2 ± 1.8 for the Group BF. A progressive regional kyphotic angle was observed with time regardless of fusion but was not significantly different between the two groups. There was a statistical difference between unfused inferior proximal adjacent and inferior distal adjacent segment regardless of fracture segments.

Conclusion: The strategy of selective fusion is reported to be useful for the treatment of patients with TLF. The motion in the un-fused and adjacent segment could be better regained after instrumentation removal in the selectively fusion group.

1. Background

Fractures of the thoracolumbar junction and upper lumbar spine (T12–L2) are common injuries as a result of high-energy trauma with potentially devastating consequences including pain, neurological injury, and loss of function[1]. The main strategy of surgical treatment for thoracolumbar fractures (TLF) has been neurologic decompression, anatomic reduction, stabilization, and fusion[2, 3]. However, the best treatment and surgical indications of TLF, especially for the fusion procedure are still controversial [4-6]. Fusion generates definite immediate benefits and late stability, such as vertebral body height loss beyond 40%, an abnormal signal in the intervertebral disc, and rupture of the inter-spinal ligament[7]. Although the fusion of mobile segments solves the problem of instability, it restricts the movement of the spine. As adopted by reconstructive surgery of spine trauma, the protection of mobile segments is possible by restricting the number of fusion segment[8, 9]. In the present study, patients who suffered from unstable TLF with kyphotic angle above 20 degrees and vertebral body height loss more than 40% were enrolled. Typically, the fused schemes are performed in both superior and inferior articular processes[10, 11]. As a result, we proposed the selective fusion schemes for TLF with the superior intervertebral articular process

and interlaminar fusion, regardless of bi-segments fusion. This approach aimed at post-operative, preservation of spine motion, stabilization of fracture, and restoration of spinal alignment. In order to validate the effectiveness of selective fusion schemes, we compared the regional kyphotic angles, intervertebral mobility to the fractured segment, and the distal adjacent segments following temporary posterior fixation in TLF patients who underwent either selective (superior) intervertebral articular process or bi-segments (superior-inferior) articular process fusion.

2. Methods

2.1 Patient Population

The institutional review boards at two trauma centers (grade III-A) approved this retrospective clinical investigation. All the participants were over 16 years old, and their written informed consent was obtained. Data from 102 patients who were diagnosed with TLF at two-grade III-A hospital (spinal trauma centers) were retrospectively reviewed between January 2011 and January 2018. Fractures were classified according to the AO classifications of TLF as follows:

The **inclusion criteria** were: 1) A1-A3-B1 and B2 AO type TLF from T12 to L2 fractures with one injured spinal segment. 2) TLF with kyphotic deformity > 20 degrees, loss of vertebral body height by more than 40%, and posterior ligamentous complex disruption. 3) The injured spinal segment with only injured upper endplate or corresponding abnormal intervertebral disc signal. 4) Fractures without or partial neurological deficit.

The **exclusion criteria** were: 1) Patients who suffered severe neurological deficits, and required laminectomy for neural decompression. 2) Fractures that involved more than one vertebrae. 3) Patients with severe osteoporosis. 4) Patients that did not receive hardware removal after fracture healing.

From 102 reviewed cases, 37 patients were excluded because of the exclusion criteria and incomplete radiographic data. Sixty-five patients with fractures of the thoracolumbar junction (45 male, 20 female, 17-58 years old) were enrolled in this study. They were all surgically stabilized with the transitory and transpedicular posterior instrumentation, involving the injured vertebrae above and below the fractured vertebrae with superior intervertebral articular process fusion or superior-inferior articular process fusion. Thus, the patients were divided into two groups by the intra-operational intervertebral articular process fusion segment and three subgroups by the injured vertebral segments (T12, L1, or L2 fractures).

In selectively fused subgroup (Group SF), only superior intervertebral articular process and interlaminar fusion were performed.

In bi-segments intervertebral articular process fused subgroup (Group BF), patients underwent bi-segments fusion in both superior and inferior articular processes and interlaminar fusion.

The patients' general information are listed in **Table 1** (no significant difference was observed).

2.2 Surgical methods

Patients were operated by a posterior approach, using a standard surgical technique. Transpedicular instrumentation was performed under C-arm X-ray. We performed short-segment instrumentation that included the vertebrae above and below the fractured vertebrae. According to literature, fixation was recommended to be placed in the fractured vertebrae instead of fractured pedicle or Magerl type A3.3 fractures with extensive vertebral body comminution. Consequently, fracture reduction was obtained by indirect manipulation. After the implantation of transpedicular instrumentation, careful dissection was carried out, and articular anatomy in those non-fused segments was preserved. In the fused spinal segment, the corresponding articular cartilage surface was removed and posterolateral arthrodesis beds were prepared. Autologous bone graft or allograft was added into the superior intervertebral articular process and interlaminar space. Moreover, a drainage tube was inserted and the wound was enclosed in layers.

2.3 Postoperative conductions

After surgery, external support was used (Jewett brace) for 2-3 months. Every patient was kept in a periodical clinical and radiological follow-up. After fracture healing was detected in the radiographs reports, the hardware removal process was initiated at about 6-12 months postoperatively in both groups.

2.4 Evaluations

Radiological measurements were carried out before and after surgery, as well as after the removal of instrumentation, and during late follow-up periods. All measurements were performed by two authors of this study, who took the mean value of the two measurements.

The heights of both anterior (AH) and posterior vertebral body (PH) were measured through lateral thoracolumbar radiography. The vertebral compression ratio (VCR) was calculated ($VCR = [PH - AH] / TT / PH$).

The regional kyphotic angle was measured between the inferior, superior adjacent vertebra. The radiographic measurements of kyphosis were taken preoperatively, i.e., before the removal of instrumentation, 3 months after removal, and at the time of the latest follow-up.

During the follow-up period, we evaluated the intervertebral mobility of the non-fused, fused and adjacent spinal segments using lateral dynamic radiographic in maximum voluntary flexion and extension, which was established by Dvorak et al. The two segments adjacent to the injured vertebrae was targeted (**Figure 1**). The overall clinical outcome was assessed using the Greenough Low-Back Outcome Score[12].

3. Statistical Analysis

The data were presented as the mean \pm standard error of the mean. Continuous data (compression Ratio, kyphosis angle, intervertebral mobility) were analyzed with the independent-samples t-tests. The

Greenough Low-Back score in the two groups were analyzed with the Mann-Whitney U tests based on assumptions of normality. Non-categorical data were analyzed with the χ^2 test. A p-value <0.05 was used to define statistical significance. The IBM SPSS statistical software (Version 19.0) was used to complete the statistical analyses.

4. Results

Sixty-five patients with TLF from T12 to L2 fractures were enrolled in the study period: 33 in the Group SF and 32 in the Group BF. All the patients had an injury at the upper endplate or corresponding IVD in the vertebral column. No significant differences ($p > 0.05$) were present in the demographic data between these two groups (**Table 1**).

All patients were treated by transitory and transpedicular posterior instrumentation with a selective segment or bi-segments intervertebral fusion. However, the patients experienced fracture healing within 12 months after temporary fixation (mean follow-up time: 19.7 months) (**Figure 2, 3**).

The mean preoperative Greenough Low-Back Outcome Scores were 10.0 ± 1.9 points and 10.5 ± 1.9 points in group SF and BF, respectively; whereas, the post-operational scores were 65.0 ± 2.0 and 65.2 ± 1.8 points in group SF and BF, respectively. The clinical outcomes between the two groups were not significantly different (**Table 2**). Nevertheless, one patient in Group BF suffered from a superficial infection after surgery, which was successfully treated with antibiotics. Another patient in the group SF and 3 patients in group BF reported pain at the bone graft donor site. No cerebrospinal fluid leakage, neurological injuries, vascular injuries or any other complications were identified during or after operations. During the follow-up of the patients, no cases of adjacent-segment disease were reported.

Radiological outcomes from 65 patients indicated that following the removal of the implant, the regional kyphotic angle progressed with time regardless of fusion. However, the results were not significantly different between the two groups ($p > 0.05$) (**Table 3**). One patient (50 female, T12 Fracture) had a progressive kyphosis less than 30 degrees without any clinical symptom in Group SF after implant removal. Therefore, we suggested a prolonged external support usage (Jewett brace 3-6 months) and anti-osteoporosis drug.

The residual intervertebral mobility of four segments (superior distal adjacent segment, superior proximal adjacent segment, inferior proximal adjacent segment, and inferior distal adjacent segment) after implant removal of patients in the SF and BF groups are shown in Table 4. No statistical differences were observed for superior proximal and distal adjacent segments between the two groups ($P > 0.05$, *t* test). However, statistical differences were observed for unfused inferior proximal and distal adjacent segments regardless of in T12, L1, or L2 fracture segments between the groups ($P < 0.05$, *t* test) (**Table 4**).

5. Discussion

The thoracolumbar junction is susceptible to injury as it is the fulcrum for increased motion between rigid thoracic spine and mobile lumbar spine. Typically, the classical surgical indications are based on kyphosis, vertebral body height, canal compromises on radiograph and integrity of the posterior ligamentous complex[2]. Moreover, the treatment for TLF varies significantly among various institutions and surgeons. Contemporary concepts propose an evolution of surgical treatment moving from long segment instrumentation toward shorter constructs, aiming at the preservation of the dynamic and protective function of the spine[4]. Nevertheless, the treatment of burst fractures is still controversial, i.e. the management of fractures, whether fusion or non-fusion procedures is debatable[4, 10, 13-15].

Wang *et.al.* first studied the idea of non-fusion treatment for TLF[16], which compared the short-segment reduction and stabilization with and without fusion for patients with thoracolumbar burst fractures. All fractures met generally accepted operative indications, i.e. greater than 50% loss of height, greater than 20 degrees of kyphosis, or canal compromise greater than 50%. Recent research quantified the benefits of a non-fusion approach for surgical treatment of TLF. These studies proposed that bone grafting prolonged the operation time, and increased the amount of bleeding, and could not improve clinical outcomes[6, 13]. In contrast, the patients who received short-segment fixation with fewer fusion segments recovered quickly and had a better clinical outcome with equal correction in the postoperative period[4]. Most surgeons concluded that bone grafting was not necessary for short-segment open instrumentation for Surgically Treated Burst Fractures of the Thoracolumbar and Lumbar Spine[17, 18]. Randomized trials indicated that surgically treated TLF burst fractures with reduction, and posterior fixation were sufficient; and hence, the use of bone grafting for definitive fusion was not necessary[16]. Furthermore, the restitution of intervertebral mobility of such an unfused segment after fracture healing could unload adjacent parts of the spine and reduce the risk of degeneration of these segments[8, 9].

However, surgeons still recommend grafting for TLF, particularly for distraction injuries, fractures with extensive vertebral body comminution, and abnormal intervertebral disc signal [15]. Qian *et al.* compared the two cohorts of patients with thoracolumbar burst fractures treated posteriorly with and without fusion and found out that the later groups had significant loss of correction, recurrence of kyphosis, and worse functional outcome[10]. They reported that stabilization without fusion was not an optimal procedure for TLF with injured endplates and abnormal intervertebral disc signal morphology[11].

In the present study, the enrolled patients had unstable TLF with kyphotic angle above 20 degrees and vertebral body height loss of more than 40%. In our study, the non-fusion procedures were not an optimal option for their treatment. Also, the literature suggested fused schemes only after an abnormal signal of intervertebral disc was prominent [7, 11]. Hence, we proposed the selective fusion or limited fusion schemes for the TLF with short-segment instrumentation, i.e., the vertebrae above and below the fractured vertebrae that preserved not only the motion of the spine postoperatively but also, stabilized the fracture, and restored the spinal alignment. The selection of the fused segment relied on the abnormal signal in the intervertebral disc and the injured endplate. Mostly, the upper endplate was susceptible to injury in TLF. Therefore, we chose the fusion of upper endplate as the content of this study. According to clinical practice, it was found that the group with selective fusion had low surgical complications, blood

loss, and surgical time. Significance progression of regional kyphosis could be observed along with the immediate postoperative kyphotic angle in both groups, however, these were not significantly different between the two groups. Based on previous reports, progressive kyphosis might be inevitable despite fusion. For our study, the residual deformity did not correlate with the symptoms of the patients at their time of follow-up[1, 19]. The result showed that the selective fusion procedures achieved comparable clinical and radiographic outcomes with bi-segment fusion groups, which not only validated the selectively fused schemes but also is appropriate for TLF treatment.

Recently, the researchers were curious to understand if unfused segments regained motion after instrumentation removal [9, 11, 20]. Some reports stated that the potential return to the mobile, non-fused and stabilized vertebrae is highly controversial. Yurac *et al.* studied 21 consecutive patients at 46 months follow-up who were treated with a limited fusion of the injured motion segment, with stabilization that included non-injured, unfused segments. The motion of unfused segments was evaluated after the removal of hardware. Overall, 75% of the segments retained motion[11]. Po-Hsin Chou *et al.* performed a randomized trial on 46 patients treated with posterior transpedicular screw fixation to the levels above and below the injury, with or without fusion. They reported that the non-fusion group had 4.2 degrees of segmental motion compared to 0.9 degrees for the fusion group[13].

In the present study, we compared the intervertebral mobility not only in the proximal adjacent fractured segment but also in the distal adjacent segments following temporary posterior fixation between the two cohorts of patients with single articular process fusion or bi-segments articular process fusion. The intervertebral mobility of superior distal and proximal adjacent segments had no significant difference between the two groups. By selective fusion of superior intervertebral articular process, the inferior distal and proximal adjacent segments in the selective fusion group regained more motion after instrumentation removal. The selectively fused scheme restored the spine and alleviated the adjacent vertebral degeneration[21].

Limitation

This study had several limitations. Firstly, patients with complicated injuries, such as progressive neurologic deficits, and anterior surgery, were excluded. Secondly, an increase of retained motion was observed in patients after hardware removal. However, a long-term comparative study is necessary to assess the functional and radiographic outcomes of such patients.

6. Conclusions

The strategy of selective fusion and short-segment instrumentation is reported to be reliable and useful for the treatment of the vast majority of TLF. The surgeon could fuse only the injured segments, and reliably avoid the bi-segment fusion. Motion in the un-fused inferior proximal and distal adjacent segment in the selective fusion group could be regained after instrumentation removal.

Declarations

Competing interests

Conflict of interest The authors declare that they have no conflict of interest.

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Informed consent

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

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

Ethics approval and consent to participate

The study was approved by the ethical committee of institutional review board. All the patients gave written consent to for research applications of their clinical data. The patient data was anonymized in this study.

Consent for publication

The patients (all adults) all gave their explicit written consent to have all their outcome data, images and demographics included in this article write-up and for publication.

Authors' contributions

XCZ, JL; study design, analyses and interpretation of data, draft of manuscript with tables and figures.

XCZ, JL, GHX; substantial contributions to conception and critical revision for important intellectual content.

XCZ, JL, GHX; substantial contributions to study design and data acquisition.

XCZ, JL, EZJ, XWH, PL, DYN, GHX, DYN; data acquisition. All authors read and approved the final manuscript.

Abbreviations

TLF : thoracolumbar fractures; IVD : intervertebral disc; VCR: vertebral compression ratio; SF: selective fusion; BF: bi-segments fusion; AH: the heights of both anterior; PH: the heights of posterior vertebral body; CT: computed tomography

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Tables

Table 1. Preoperative Data of the Patients

Variable	Group SF (N=33)	Group BF (N=32)
Age at the time of surgery (year)*	42.7±8.5	43.8±7.5
Sex (number)□		
Male	25	20
Female	8	12
Cause of fracture□		
Falling from a height	26	24
Motor vehicle accident	7	8
Segment of Fracture □		
T12	11	11
L1	12	10
L2	10	11
AO classification□		
Type A	25	23
Type B	8	9
Average follow-up time (months)*	19.2±5.2	20.3±5.3

Data expressed as mean standard deviation unless otherwise indicated.
* $P > 0.05$, Independent-sample t -test .
□ $P > 0.05$, Chi-square test.

Table 2. Compression Ratio and Greenough Low-Back Score in two groups preoperatively and postoperatively

Variable	Group SF (N=33)	Group BF (N=32)	p value
Pre-OP Compression Ratio (%)*	43.9±5.3	44.9±6.4	0.503
Post-OP Compression Ratio (%) *	19.3±5.6	17.4±5.3	0.159
Pre-OP Greenough Low-Back Score□	10.0±1.9	10.5±1.9	0.343
Post-OP Greenough Low-Back Score□	65.0±2.0	65.2±1.8	0.616

Data expressed as mean standard deviation unless otherwise indicated.
Pre-OP: post operation
Post-OP: late following-up
* $p > 0.05$, Independent-sample t -test.
□ $p > 0.05$, Mann-Whitney U test

Table 3. The kyphosis angles in two groups preoperatively and in the following-up.

kyphosis angle	Group SF			Group BF		
	T12	L1	L2	T12	L1	L2
Segment						
Pre-OP kyphosis angle *	24.1±3.9	20.8±3.0	21.0±1.3	24.0±3.5	19.3±4.8	21.3±1.6
Post-OP kyphosis angle *	10.8±2.7	9.7±2.7	9.1±2.2	11.6±1.9	10.9±3.7	11.1±2.1
Last time kyphosis angle *	12.2±2.9	10.4±2.7	9.85±2.3	12.9±1.9	11.5±0.38	11.7±2.3
Change of kyphosis angle *	0.6±0.2	0.6±0.4	0.8±0.2	0.45±0.2	0.6±0.2	0.6±0.2

Data expressed as mean standard deviation unless otherwise indicated.

Pre-OP: post operation

Post-OP: 3 months after the removal of instruments

* *p* value > 0.05 (Independent-sample *t*-test).

Table 4. Intervertebral mobility between two groups in different fracture segments

Intervertebral mobility	Group SF (degree)			Group BF (degree)		
	T12 *	L1 ¶	L2 §	T12*	L1¶	L2§
Segment						
Superior distal adjacent segment ¹	0.50±0.31	0.55±0.24	0.67±0.24	0.35±0.23	0.59±0.22	0.48±0.18
Superior proximal adjacent segment ²	0.63±0.33	0.48±0.33	0.53±0.30	0.45±0.19	0.41±0.33	0.58±0.26
Inferior proximal adjacent segment ³	1.85±0.84	2.13±0.65	2.21±0.55	0.52±0.22	0.49±0.32	0.69±0.33
Inferior distal adjacent segment ⁴	2.75±1.38	2.14±0.80	4.33±0.88	0.85±0.42	1.07±0.44	3.54±0.58

Data expressed as mean standard deviation unless otherwise indicated. The *p* value of each Variable between two groups were as follows (Independent-sample *t*-test):

p value (1*) =0.229, *p* value (1¶) =0.690, *p* value (1§) =0.673;

p value (2*) =0.152, *p* value (2¶) =0.655, *p* value (2§) =0.676;

p value (3*) <0.001, *p* value (3¶) <0.001, *p* value (3§) <0.001;

p value (4*) =0.001, *p* value (4¶) =0.001, *p* value (4§) =0.029;

Figures

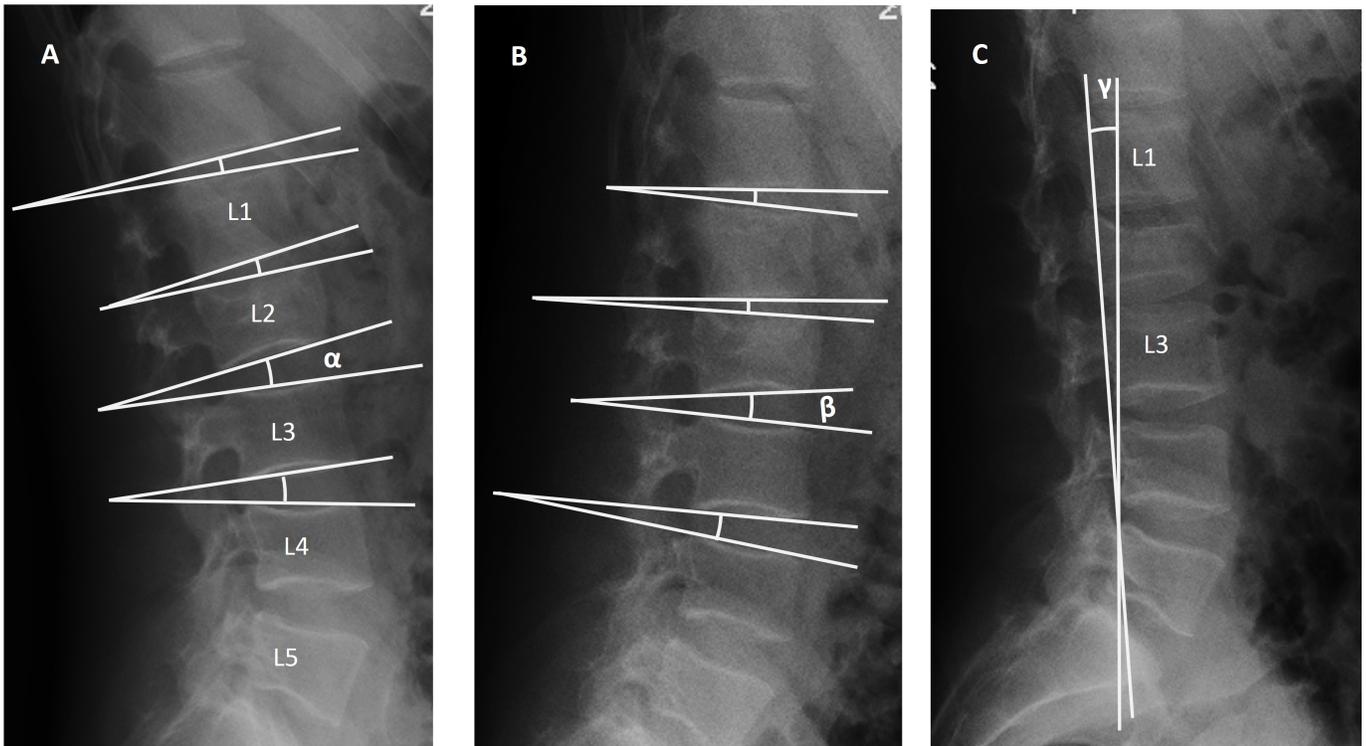


Figure 1

Radiologic measurements of motion in adjacent segments after the removal of instruments and local kyphosis angle. Measurements were made of each numbered motion segments at maximum extension (A) and flexion (B), where α refers to the angle of motion in extension position, and β refers to the angle of motion in flexion, and $(\alpha-\beta)$ refers to the residual segment mobility. C: pre-operative X-ray, γ refers to the measurements of the local kyphosis angle, which was measured above and below the fractured vertebrae (L1 and L3 in this case). All the lines were drawn along the upper endplates, lower endplates, the posterior edge of the vertebrae or adjacent vertebrae.

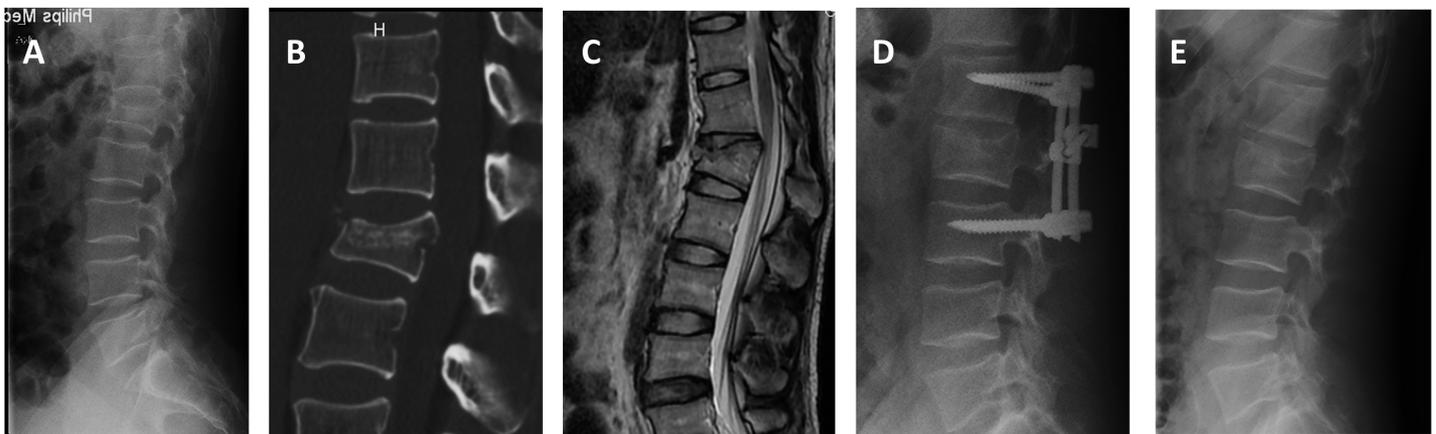


Figure 2

One case of L1 fracture patient. A. The preoperative X-ray showed compression of the L1 with decreased vertebral body height > 40%; B. Preoperative CT scan showed injured upper endplate of the vertebral body. C. The preoperative T2WI magnetic resonance image showed that the upper intervertebral disc was injured with an abnormal IVD signal and the mild compression of the spinal cord. D. Lateral postoperative X-ray showed that the patient underwent transpedicular posterior instrumentation which included only above and below fractured vertebrae with superior intervertebral articular process fusion. The height of the vertebral body was restored. E. Progressive kyphosis or kyphosis recurrence was observed in a lateral radiograph after sixteen months.

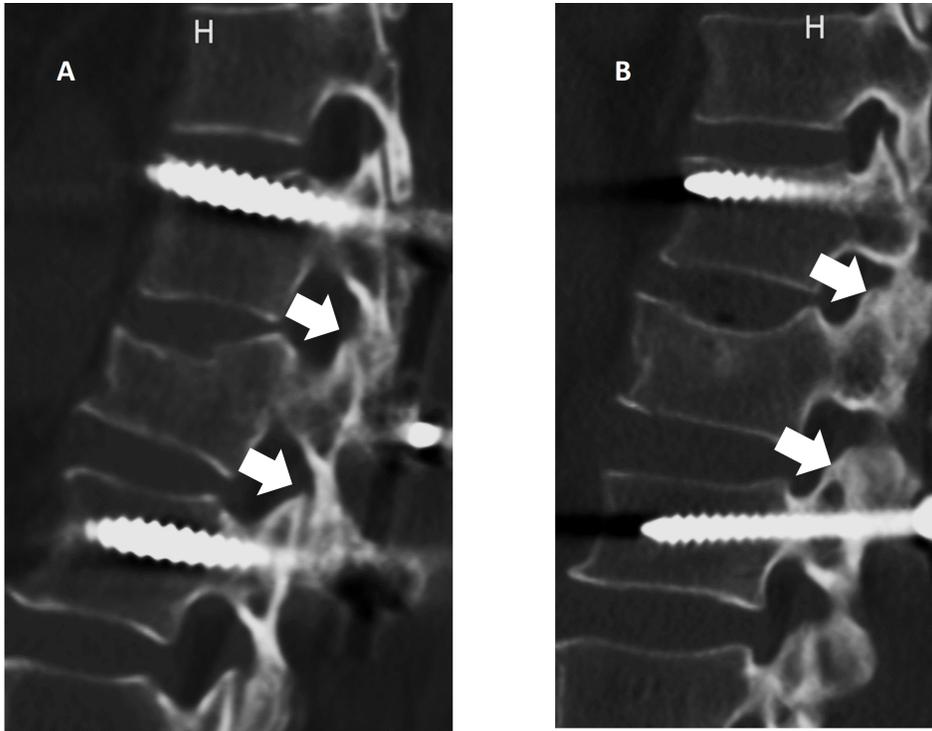


Figure 3

The postoperative CT scan of the selectively fused patients (A) and bi-segments fused patients (B). A: Arrows point to the fusion of superior intervertebral articular process, and the unfused inferior articular process with distinct joint space. B: Arrows point to the fusion of superior and inferior articular process fusion.