

Treatment of A3 thoracolumbar vertebral burst fractures with posterior minimally invasive channels and short tail pedicle screw fixation: technical report and efficacy analysis

fujun wu

Affiliated Hospital of Zunyi Medical College

songli ju

Affiliated Hospital of Zunyi Medical College

Genyi Hou

Affiliated Hospital of Zunyi Medical College

Jun Ao

Affiliated Hospital of Zunyi Medical College

Nijiao Huang

Affiliated Hospital of Zunyi Medical College

Sheng Ye

Affiliated Hospital of Zunyi Medical College

Xin Wang (✉ lchwx@aliyun.com)

<https://orcid.org/0000-0001-5015-3396>

Research article

Keywords: Minimally invasive channel, Thoracolumbar burst fracture, Vertebral fixation

Posted Date: March 4th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-15924/v1>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Background To evaluate the clinical efficacy of common pedicle screw placement combined with pedicle screw fixation for the treatment of thoracolumbar burst fractures using a posterior minimally invasive approach.

Methods Between May 2015 and December 2016, a total of 33 cases of thoracolumbar burst fracture (AO/Magerl type A3) were treated using a posterior minimally invasive procedure with ordinary pedicle screws under the channel in combination with injured vertebra transpedicular fixations. The patient cohort included 20 males and 13 females with an average age of 43.5 yr (range: 26–61 yr). 16 cases were due to traffic accidents, whereas 11 cases were due to falls, and 6 cases of other injuries. All patients showed no nerve injury. Of the injured segments, 5 cases were T 11 , 14 were T 12 , 13 were L 1 , and one was L 2 .No patients presented with spinal nerve injury. The duration of the operations and intraoperative blood loss in each patient were recorded. The pain visual analogue scale (VAS) was used to estimate the degree of back -surgical incision pain. Measurements of the percentage of injured vertebral height loss and the sagittal Cobb angle, which was evaluated for correction of the kyphosis angle and height restoration using plain radiographs, Every patient were recorded preoperatively and at postoperative day 3, 6 month, 1 year, and final follow-up visits. Plain CT scans and reconstructions were used to assess fracture healing.

Results No patients experienced intraoperative complications. The average operating time was 109.2 min (range: 90–130 min), and the average intraoperative blood loss was 82.4 ml (range: 50–150 ml). The VAS scores for the lumbar back incision on the 3rd postoperative day and at the final follow-up were 2.39 ± 0.83 points and 0.70 ± 0.68 points, respectively. Additionally, all incisions healed without any postoperative complications. All patients were followed up over a period of 13 to 24 months postoperatively (average 15.9 months). Compared to preoperative values, every patient in the percentage of vertebral height loss and the sagittal Cobb angle significantly improved over the follow-up period, with significant differences between day 3, 6 month, 1 year, and final follow-up visits ($P < 0.05$). However, the difference was not significant between the groups at all postoperative time points ($P > 0.05$). CT scans showed that the injured vertebrae healed well, with no subsidence, loosening, or fractures of the internal fixation.

Conclusion The minimally invasive posterior approach with common pedicle screw placements and combined pedicle screw fixation is similar to percutaneous minimally invasive screw fixation. The pedicle screw rests on a strong internal fixation to restore and maintain vertebral height. This procedure is safe and effective for the treatment of A3 thoracolumbar burst fractures, resulting in less trauma and bleeding as well as satisfactory deformity correction.

Background

The thoracic vertebrae and lumbar vertebrae are the intersections of physiological curvature. This area has experienced substantial stress and has a heavy load. Moreover, this area is easily fractured. Trauma is a common cause of thoracolumbar burst fractures [1]. Common causes of injury include traffic injuries, falls from height, and other injuries. For patients with thoracolumbar burst fractures without nerve injury, short segmental transpedicular pedicle screw fixation is often used at home and abroad [2]. However, extensive open surgery and intraoperative traction may lead to ischemic necrosis and muscle fibrosis. Additionally, postoperative back pain is a common symptom [3]. Some patients may also have complications such as vertebral height loss and Cobb angle correction failure in the long term [4], which are not conducive to the recovery of muscle function and the maintenance of spinal stability.

With continuous advancements and development of minimally invasive technology, percutaneous hollow pedicle screw reduction and fixation techniques are increasingly applied to the treatment of thoracolumbar fractures. Compared with traditional open surgery, this procedure reduces surgical trauma and postoperative pain, corrects kyphosis and reduces perioperative complications [5-7]. In view of this finding, in this study, we used a posterior percutaneous minimally invasive approach with common pedicle screw placement and fixation for the treatment of A3 thoracolumbar burst fractures. This approach achieved good clinical results. The report is as follows.

Methods

1 Clinical data and methods

The experimental protocol has been approved by the Ethics Committee of the Affiliated Hospital of Zunyi Medical University. The informed consent of the subjects was obtained before the operation. All the imaging data and experimental data were published as scientific research and articles.

1.1 Clinical data

A total of 33 patients with A3 thoracolumbar burst fractures who were admitted to our department from May 2015 to December 2016 were included in the present study. The patients included 20 males and 13 females, aged 26-61 years, with an average of 43.5 years. The causes of injury were as follows: 16 cases were due to traffic accidents, whereas 11 cases were due to falls, and 6 cases of other injuries. All patients showed no nerve injury. The following segments were injured: 5 cases of T₁₁, 14 cases of T₁₂, 13 cases of L₁, and 1 case of L₂. The inclusion criteria were as follows: ☐ single segment vertebral fracture; ☐ fracture classification: type A3 (according to AO-Magerl classification) [8]; ☐ surgery within 10 days after the injury; and ☐ no nerve damage. The following exclusion criteria were used: ☐ neurological dysfunction requiring spinal decompression; ☐ fractures of two or more segments; ☐ fixation of more than 3 segments; and ☐ pathological fractures.

1.2 Surgical methods

Endotracheal intubation was performed, and general anesthesia was administered. In the prone position, the chest and hip were elevated, and the abdomen was suspended to obtain a preliminary reduction in the injured vertebrae. We used C-arm X-ray fluoroscopy to mark the projection of the vertebral body of the injured vertebrae and the upper and lower vertebral bodies. A conventional disinfection drape was used, and we inserted a Kirschner wire by percutaneous puncture at the surface marker. The position and direction of the Kirschner wire were well visualized by C-arm fluoroscopy. We introduced a cortical bone cannula for percutaneous vertebroplasty along the Kirschner wire. Then, we removed the Kirschner wire and inserted a long guide needle for a percutaneous minimally invasive pedicle screw in the expanded cortical sleeve. After adjusting the reverse and angle, we tapped the long guide needle into the middle of the vertebral body and removed the cortical bone cannula. Next, we made a 1.5 cm transverse incision in the skin centered on the long guide needle. The percutaneous minimally invasive pedicle screw working sleeve was inserted along the long guide needle to expand the soft tissue to establish the nailing channel. After the wire was removed, the long guide pin was removed, and a single plane common pedicle screw was built along the channel. Next, we inserted a prebent titanium rod along the soft tissue channel; we first locked the lower vertebral body titanium rod and then properly opened it between the lower vertebral body and injured vertebrae. The collapsed end plate was reset by the curvature of the prebent titanium rod and the pedicle screw of the injured vertebra. Then, the nail rod was locked. Saline was used to wash the incision. Next, the incision was sutured and wrapped. All procedures were performed by a physician who is experienced and skilled in minimally invasive pedicle screw placement techniques. (Fig. 1)

1.3 Postoperative treatment and rehabilitation

Antibiotics were used to prevent wound infection within 24 hours after surgery. At 2 to 3 days after surgery, patients were instructed to wear a thoracic and lumbar spine support brace and start exercises in bed. Did not advocate strenuous activity or exercise. At 3 to 4 weeks after surgery, we recommended resuming normal life and daily work but avoiding physical labor and weight-bearing at the waist. The thoracic and lumbar spine brace was removed 2 months after surgery, and functional back muscle exercise was started to avoid the disuse of the waist and back muscles.

1.4 Observation index

We recorded the operation time and the amount of intraoperative blood loss. A pain visual analogue scale (VAS) was used to assess the degree of postoperative low back pain. An X-ray of the thoracolumbar vertebral body was examined before surgery and at, 3 day, 6 month, 1 year and terminal follow-up visits. The following indicators were measured: \square the percentage of the height of the anterior border of the injured vertebrae = $2 \times$ the height of the leading edge of the injured vertebra / (the height of the upper vertebral body leading edge + the height of the lower vertebral body leading edge) \times 100%, and the height recovery and maintenance of the injured anterior border were evaluated; \square the sagittal Cobb angle = the angle between the vertical line of the upper vertebral endplate extension line and the vertical line of the lower vertebral endplate extension line, and the correction and maintenance of kyphosis were evaluated;

At the final follow-up, the injured vertebra was examined by a simple CT scan and reconstruction. Fracture healing was observed.

1.5 Statistical methods

Analysis was performed using SPSS 18.0 statistical software, and the measurement data are expressed as the mean \pm standard deviation ($\bar{x} \pm s$). Repeated measures analysis of variance was used before and after surgery. $P < 0.05$ was statistically significant.

2 Results

The operation was successfully completed in all patients, with an operation time of 90 ~ 130 min (average: 109.2 min) and an intraoperative blood loss of 50 ~ 150 ml (average: 82.4 ml). The VAS scores of the lumbar dorsal incision at 3 days postoperatively and at the end of follow-up were (2.39 ± 0.83) points and (0.70 ± 0.68) points, respectively. The incisions were healed by the first stage without postoperative complications. All 33 patients were followed up for 13 to 24 months, with an average of 15.9 months. Before surgery and at 3 day, 6 month, 1 year and terminal follow-up visits, the relative height percentages of the injured vertebrae were (56.54 ± 4.87) %, (95.85 ± 1.20) %, (94.27 ± 1.28) %, (93.30 ± 1.13) %, and (92.48 ± 1.27) %, respectively. The height of the injured anterior border was significantly restored after the operation, and the difference in height before and after the operation was significant ($P < 0.05$). By contrast, the difference between the time points after the operation was nonsignificant ($P > 0.05$). The sagittal Cobb angles before surgery and at 3 day, 6 month, 1 year, and terminal follow-up visits were (27.45 ± 4.44) °, (2.33 ± 0.60) °, (3.67 ± 0.65) °, (4.00 ± 0.66) °, and (4.67 ± 0.54) °, respectively. Between the preoperative and postoperative time points, the sagittal Cobb angle was significantly improved ($P < 0.05$). However, there was no significant difference between the postoperative time points ($P > 0.05$) (Table 1). A CT scan and three-dimensional reconstruction of the injured vertebra showed that standard fracture healing was achieved. Additionally, no nerve injury, wound infection, or complications, such as internal fixation cutting, loosening and fracture, were detected (Fig. 2).

Table 1

Comparison of the percentage of the leading-edge height and the sagittal Cobb angle before and after the operation (n = 33, $\bar{x} \pm s$)

Time distribution	Preoperative	3 days after surgery	6 months after surgery	1 year after surgery At follow-up
Peripheral edge height percentage	$56.54 \pm 4.87\%$	$95.85 \pm 1.20\%$	$94.27 \pm 1.28\%$	$93.30 \pm 1.13\%$ $92.48 \pm 1.27\%$
Sagittal Cobb angle	$27.45 \pm 4.44^\circ$	$2.33 \pm 0.60^\circ$	$3.67 \pm 0.65^\circ$	$4.00 \pm 0.66^\circ$ $4.67 \pm 0.54^\circ$

Percentage of traumatic frontal height at each time point after surgery compared with that preoperatively $P < 0.05$; The sagittal Cobb angle at each time point was compared with that preoperatively $P < 0.05$

3 Discussion

The thoracolumbar junction is composed of a relatively stable thoracic vertebra and lumbar vertebra with greater mobility. Due to its special anatomical relationship, spinal injury often occurs in this region [9–10]. In the past 30 years, great advancements have occurred in the treatment of thoracolumbar fractures [11]. Conservative treatment of patients with thoracolumbar burst fractures without nerve injury can also achieve better clinical results than surgery in terms of low back pain and functional recovery [12]. However, for unstable thoracolumbar fractures, surgical treatment should be preferred [13]. The goals of treating unstable thoracolumbar fractures include: restoring spinal stability, preventing or reducing deformities, spinal decompression, and enabling early functional exercise. In all surgical strategies, the posterior short-segment pedicle screw is widely used for the treatment of thoracolumbar fractures. In addition, this procedure is easy to use, lowers the number of pedicle screws used, reduces the amount of bleeding, and shortens the surgical incision, making it more popular in clinical practice [14]. However, short-segment pedicle screw fixation may also cause problems such as long-term stress deficiency leading to internal fixation failure, loss of the correction rate and increased incision pain [15]. Multisegmented fixation of the injured vertebra can be used to maintain greater biomechanical stability of the anterior column and avoid these issues [16]. Compared with transsacral fixation, unstable thoracolumbar burst fractures can increase the stiffness of the implant and reduce the stress of each pedicle screw. Posterior open surgery pedicle screw fixation is simple and easy to use; moreover, the duration of intraoperative X-ray exposure is relatively short. However, in clinical practice, open surgery needs to reveal the attachment points of the exfoliated multifidus muscle on the spinous processes, as well as the laminar and articular processes. Extensive exfoliation may damage the posterior medial branch of the lumbar nerve and increase intraoperative blood loss. Moreover, prolonged intraoperative traction may cause ischemic necrosis, fibrosis, muscle denervation, etc. in the multifidus muscle. In addition, complications such as long-term low back pain cannot be ignored.

In 2001, Foley et al. reported the use of the Sextant system for percutaneous pedicle screw fixation, which greatly reduced muscle tissue damage and improved the safety and effectiveness of the screw. Therefore, the percutaneous pedicle screw internal fixation technique has been widely used in clinical practice. In this context, the expansion sleeve is used to establish a channel through the muscle space. Compared with the traditional posterior open surgery, this technique has caused less trauma and bleeding. With reduced postoperative low back pain and a quick recovery, this procedure has become a minimally invasive treatment for thoracolumbar burst fractures without neurological dysfunction. Another technique, percutaneous pedicle screw internal fixation, involves the use of the tension of the bowstring principle to transmit the anterior middle column stress of the vertebral body. This technique has the inherent "parallelogram" suspension effect of pedicle screw internal fixation, which is also due to the lack of transverse connector fixation. However, this approach has several limitations, including weakening of the anti-spinal rotation strength of the posterior screw and aggravation of postoperative kyphosis; moreover, there is a risk of loosening and fracture of the internal fixation [17]. In addition, the percutaneous pedicle screw is more expensive than the traditional common one-way pedicle screw, and the vertebral

body reduction effect on the burst fracture is not optimal. Thus, clinical use of the percutaneous pedicle screw has relative indications.

Qiang Yuan et al. [18] performed structural mechanical analysis by computer simulation of the effect of a vertical stress screw on fractured vertebrae in thoracolumbar fractures. Yuan and colleagues' findings suggested that the placement of the pedicle screw through the injured vertebra has the following advantages: ☐ it provides good three-dimensional fixation, reduces the hanging effect of the parallelogram internal fixation, increases stability, and reduces kyphosis; ☐ reducing the stretching of the fixed segmental disc is conducive to the recovery of the height of the fractured vertebral body; and ☐ it can effectively share the stress of the pedicle screw and connecting rod. Norton et al. [19] also confirmed that the pedicle screw fixation is more conducive to restoring the height of the anterior column of injured vertebrae, which can better achieve bone reduction in injured vertebrae in the spinal canal, and maintain the lower disc of the injured vertebra. Moreover, the wedge angle can be effectively corrected, and the stability is good. In clinical practice, there is no consensus on the treatment of A3 thoracolumbar burst fractures without nerve root functional impairment, specifically regarding whether vertebral fixation or percutaneous pedicle screw fixation combined with vertebral body grafting should be used. Surgeons usually select a surgical plan based on their own experience and habits. Combined with the biomechanical stability of the short-segment fixation of injured vertebrae, the minimally invasive concept of percutaneous minimally invasive screw fixation, and the characteristics of the A3 thoracolumbar burst fracture, 33 patients in this study were treated with posterior percutaneous minimally invasive surgery. Under the channel, the common pedicle screw and internal fixation of the pedicle screw achieved good clinical results. The surgical experience and operation points are summarized as follows: ☐ because the thoracolumbar migrating site exhibits kyphosis and the paraspinal muscles are relatively thin, patients with injured segments located in the thoracolumbar region (T_{11} - L_2) should be selected to facilitate the insertion of common pedicle screws; ☐ in short-segment fixation and vertebral screw placement in the injured vertebrae, the surgeon should choose a transverse incision; ☐ the vertebral arch screws must be placed in the injured vertebrae. Therefore, the integrity of the injured vertebral pedicle should be evaluated according to imaging examination before surgery. If the bone condition around the nail is relatively complete, sufficient traction strength can be ensured. Complications, such as loose screws and sinking, can occur if severe vertebral fractures involve pedicles; in such situations, this procedure should not be used; ☐ surgeons should make full use of minimally invasive pedicle screw placement tools. Intraoperative C-arm X-ray localization is as invasive as percutaneous minimally invasive pedicle screw placement. In the present study, minimally invasive cannula insertion was used to establish the pedicle screw placement channel. Because the screw was inserted in the common pedicle screw, there was no long guide. Needle guiding is necessary to smoothly insert the screw along the channel, the operating sleeve is fixed, and displacement is prevented before the long guiding needle is removed; ☐ screws should be placed as close as possible to the same line. When the connecting rod is placed without the aid of minimally invasive tools, it is relatively difficult to install through the soft tissue channel. Thus, placement of the pedicle screw on the same side as the straight line is required to facilitate the placement of the connecting rod; ☐ the placement of the titanium rod through the subcutaneous paraspinal muscle space

can significantly reduce damage to the paravertebral muscle tissue [20], and the titanium rod must be prebent to facilitate intraoperative reduction; and when intraoperative expansion is performed, the lower vertebral body nut should be locked first. Then, the lower vertebral body and injured vertebra can be appropriately opened. The direct force of the pedicle screw of the injured vertebral pedicle is used to reset the collapsed end plate. Then, the injured vertebra cap is locked and properly expanded between the injured vertebra and upper vertebrae. The curvature of the prebent titanium rod, the anterior and posterior longitudinal ligament, and paravertebral muscle fibers are tightened to restore the endplate and the injured vertebral body. Good form, which plays a role in continuous support, can ultimately prevent the collapse of the injured vertebrae and simultaneously reduce the risk of a loosened screw and broken nails due to increased torque when transsphenoidal fixation is performed. Because intraoperative nailing is performed with the aid of fluoroscopy, the radiation exposure of doctors and patients is higher than that in open surgery. At the final follow-up of our patient group, the fracture line of the injured vertebra was not detected upon imaging examination, and standard bone healing was achieved. Additionally, there was no obvious loss of the height of the injured vertebral body, and no complications such as loosening or fracture of the internal fixation occurred.

4 Conclusions

In summary, a posterior minimally invasive incision, common pedicle screw fixation, and pedicle screw fixation for thoracolumbar burst fractures demonstrates the advantages of minimally invasive treatment and stabilizes the anterior column through reconstruction. This approach also prevents complications such as late correction loss and internal fixation failure. Thus, this technique can be used as a minimally invasive treatment for A3 thoracolumbar burst fractures. However, this study has the following limitations: the number of patients included was small, the study lacked big data samples, and the follow-up time was relatively short. Additionally, the long-term efficacy of this treatment needs further observation.

Abbreviations

VAS
visual analogue scale

Declarations

Ethics Approval and Consent to Participate

The study is approved by The Ethical Committee of The Affiliated Hospital of Zunyi Medical College, which belongs to the China Association for Ethical Studies. And the Informed Consent (written) was obtained from all patients included in this study.

Consent for Publication

Informed Consent (written) was obtained from all participants included in this study.

Availability of Data and Material

The datasets used during the current study are available from the corresponding author on reasonable request.

Competing Interests

Drs. Fujun Wu, Songli Ju, GenYi Hou, Jun Ao, NiJiao Huang, Sheng Ye and Xin Wang declare no competing interests in this study.

Funding

This study was financially supported by National Natural Science Foundation of China (No.31760266 and 31960209), Scientific Innovation Foundation for Returned Overseas Chinese Scholars of Guizhou Province No.2018-07, 2018 Zunyi "15851 Talent Elite Project", No. National Natural Science Foundation of China 31760266, Doctoral Science Research Startup Funding of Affiliated Hospital of Zunyi Medical University No.2017-01, and Qian Wei Ji Ban Han No.2017-24.

Authors' Contributions

FJW and SLJ composed and revised the manuscript and figures, respectively. XW and JA performed the surgery and FJW also participated as an assistant. GYH and SY collected the clinical materials and completed the table design. NJH is responsible for the postoperative care. All authors read and approved the final manuscript.

Acknowledgments

Thanks for my tutor for his careful modification to this manuscript and thanks for the support from my family.

This trial is registered with ChiCTR 1800020165

References

- [1] Bensch FV,Koivikko MP,Kiuru MJ,Koskinen SK.“**The incidence and distribution of burstfractures**” *Emerg Radiol* 2006;12(3):124–129.
- [2] Kumar A,Aujla, Lee C.“**The management of thoracolumbar burst fractures: A prospective study between conservative management,traditional open spinal surgery and minimally interventional spinal surger**” *Springerplus*,2015,4:204.
- [3] Hung CW,Wu MF,Hong RT,et al.“**Comparison of multifidus muscle atrophy after posterior lumbar interbody fusion with convention-al and cortical bone trajectory**” *Clin Neurol Neurosurg*,2016,145(1):41-

45.

- [4] Lee GW, Yeom JS, Kim H, et al. "A therapeutic efficacy of the trans-pedicular intracorporeal bone graft with short-segmental posterior instrumentation in osteonecrosis of vertebral body: a minimum 5-year follow-up study" *Spine*, 2013,38(4):244-250.
- [5] Blondel B, Fuentes S, Pech-Gourg G, Adetchessi T, Tropiano P, Dufour H. "Percutaneous management of thoracolumbar burst fractures: evolution of techniques and strategy" *Orthop Traumatol Surg Res* 2011;97(5):527–532.
- [6] Yang WE, Ng ZX, Koh KM, et al. "Percutaneous pedicle screw fixation for thoracolumbar burst fracture: a Singapore experience," *Singapore Med J* 2012;53(9):577–581.
- [7] Ni W-F, Huang Y-X, Chi Y-L, et al. "Percutaneous pedicle screw fixation for neurologic intact thoracolumbar burst fractures," *J Spinal Disord Tech* 2010;23(8):530–537.
- [8] Maximilian R, Laurent A, Klaus J, Carlo B, et al. "AO spine injury classification system: a revision proposal for the thoracic and lumbar spine," *Eur Spine J* (2013)22:2184–2201.
- [9] Tiryaki M, Gergin YE, Kendirlioglu BC, et al. "Thoracolumbar fractures: should they be operated according to thoracolumbar injury classification and severity score (TLICS)," *Turkish Spinal Surg* 2016;27:153–8.
- [10] Ozdogan S, Ozturk , Altunrende ME, et al. "Traumatic thoracolumbar fractures: analysis of clinical series," *Turkish Spinal Surg* 2016;27:225–8.
- [11] Wang MY. "Percutaneous thoracolumbar pedicle screw fixation: is it time to revisit spinal fracture treatment?" *World Neurosurg* 2010;74:570–1.
- [12] Wood KB, Buttermann G, Phukan R, et al. "Operative compared with nonoperative treatment of a thoracolumbar burst fracture without neurological deficit: a prospective randomized study with follow-up at sixteen to twenty-two years," *J Bone Joint Surg Am*, 2015,97(1):3-9.
- [13] Kazanci AI, Gurcan O. "Efficacy of impaction of retro-pulsed bony fragments in lumbar burst fractures: comparison with ligamentotaxis," *J Turkish Spinal Surg* 2016;27:71–6.
- [14] Gelb D, Ludwig S, Karp JE, et al. "Successful treatment of thoracolumbar fractures with short-segment pedicle instrumentation," *J Spinal Disord Tech* 2010;23:293–301.
- [15] Siebenga J, Leferink VJ, Segers MJ, et al. "Treatment of traumatic thoracolumbar spine fractures: a multicenter prospective randomized study of operative versus nonsurgical treatment," *Spine (Phila Pa 1976)* 2006;31:2881–90.
- [16] Anekstein Y, Brosh T, Mirovsky Y. "Intermediate screws in short segment pedicular fixation for thoracic and lumbar fractures: a biomechanical study" *J Spinal Disord Tech* 2007;20:72–7.

[17] He D,Wu L,Chi Y,et al.“Facet joint plus interspinous process graft fusion to prevent postoperative late correction loss in thoracolumbar fractures with disc damage:finite element analysis and small clinical trials” *Clin Biomech (Bristol, Avon)*,2011,26(3):229-237.

[18] Yuan Qiang,Tian Wei,Zhang Guilin,et al.“Application of vertical stress screw of fractured vertebrae in thoracolumbar fractures” *Chinese Journal of Orthopaedics*,2006,26(4):217-222.

[19] Norton RP,Milne EL,Kaimrajh DN,et al.“Biomechanical analysis of four-versus six-screw constructs for short-segment pedicle screw and rod instrumentation of unstable thoracolumbar fractures,” *Spine J*,2014,14(8):1734-1739.

[20] Bironneau A,Bouquet C,Millet-Barbe B,et al.“Percutaneous internal fixation combined with kyphoplasty for neurologically intact thoracolumbar fractures:a prospective cohort study of 24 patients with one year of follow-up,” *Orthop Traumatol Surg Res*,2011,97(4):389-395.

Figures

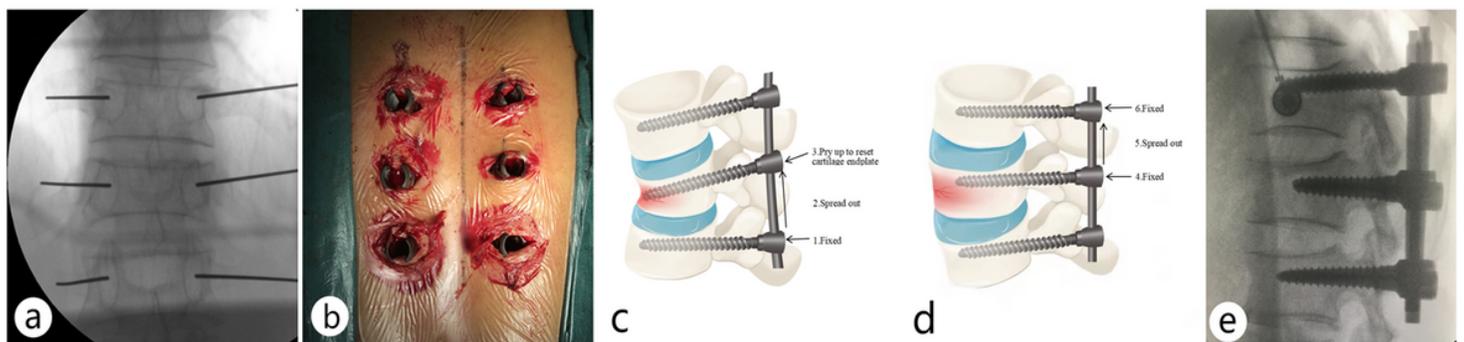


Figure 1

Schematic diagram of the operation a. The projection point of the pedicle of the percutaneous puncture of the Kirschner needle; b. Percutaneous minimally invasive stapling tools were used to insert the common vertebral pedicle screw; c, d. The injured vertebra was propped open, and the vertebral pedicle screw was used for repositioning; e. Intraoperative lateral perspective of vertebral body height recovery

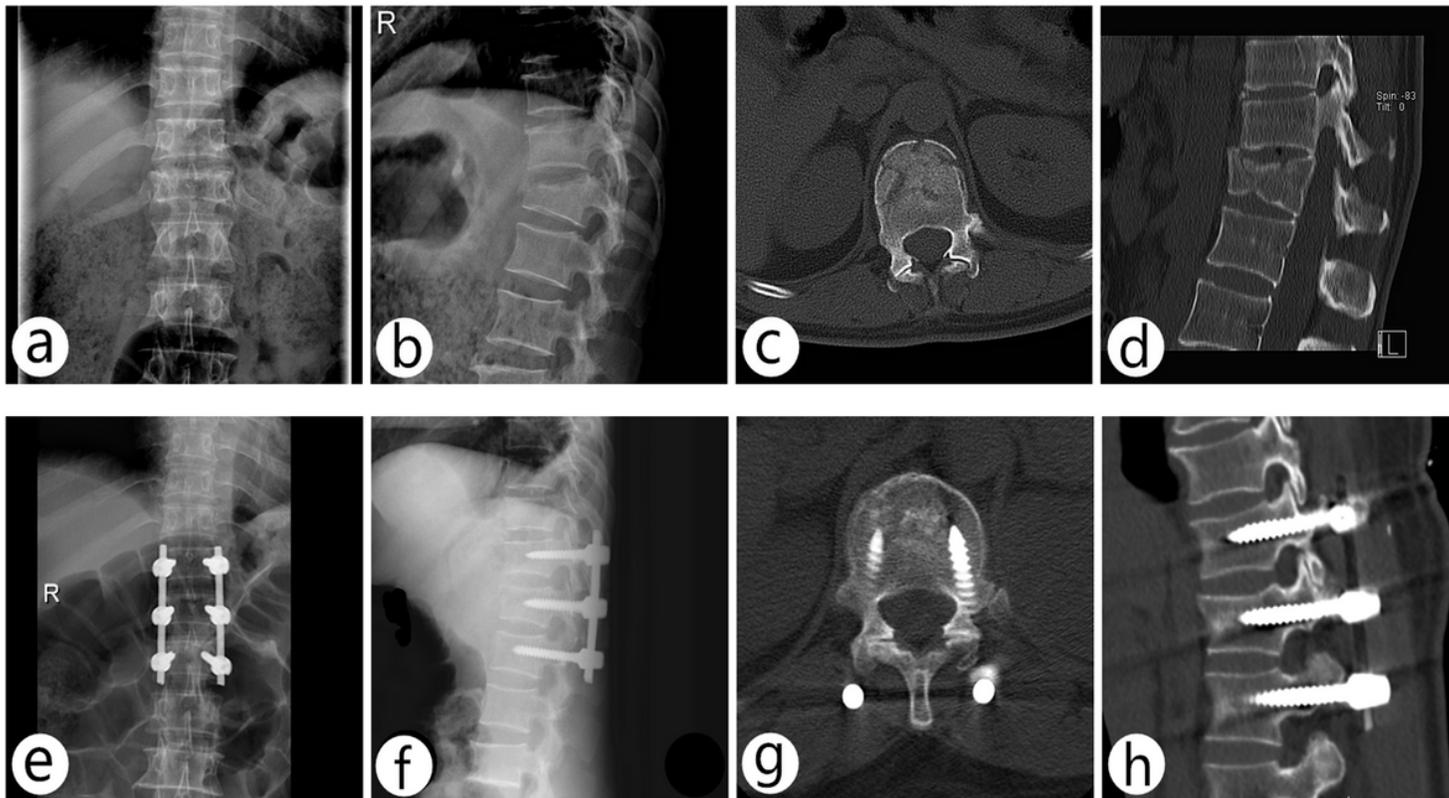


Figure 2

A 42-year-old female patient with a T12 level burst fracture. a,b. spine X-ray films before surgery; c, d. CT scan of the axial position and the dislocated position before surgery; e, f. spinal X-ray films at 3 days after surgery; g, h. axial and sagittal CT of the injured vertebrae showed fracture healing at 1 year after the operation. The height of the injured vertebrae recovered well, and there was no loosening or fracture of the internal fixation.