Treatment of late posttraumatic spinal kyphosis with no osteotomy or only posterior column osteotomy based on prone imaging parameters

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Abstract

Background

The current surgical options for late posttraumatic spinal kyphosis are primarily based on standing x-rays. The degree of deformity is reduced in the prone position. This self-correction of the deformity could be achieved without osteotomy or instruments, making large osteotomies no longer necessary. Osteotomy based on prone imaging data for the treatment of late posttraumatic kyphosis has not been reported. We, therefore, aimed to evaluate the clinical efficacy of simple posterior column osteotomy or non-osteotomy based on prone x-rays.

Methods

From April 2017 to November 2020, we collected preoperative standing, prone, postoperative, and final follow-up imaging data of 18 patients admitted to our hospital for late posttraumatic kyphosis using simple posterior column osteotomy or non-osteotomy. Preoperative prone data of thoracic kyphosis angle (TK), local kyphosis Cobb angle (LKCA), and lumbar lordosis angle (LL), was obtained. Preoperative, immediate postoperative, and final follow-up TK, LKCA, LL, sagittal vertebral axis (SVA), pelvic tilt (PT), and pelvic incidence minus lumbar lordosis angle (PI-LL) data was also obtained on standing x-ray imaging. The operative time, bleeding, and operative complication rate was collected and analyzed. We compared the preoperative, two month postoperative, and final follow-up Oswestry disability index (ODI) and visual analog score (VAS) scores to evaluate the surgical results.

Result

LKCA and TK significantly reduced from the standing to prone position before surgery. The LKCA, TK, and SVA of immediate postoperative and last follow-up data were statistically different compared with those before surgery; the differences in LL, PT, and PI-LL in the postoperative period and at the last follow-up were not statistically significant compared with those before surgery. All patients were operated upon successfully, with an operative time of 152.7 ± 34.2 min, a bleeding volume of 408.3 ± 135.3 ml, no complications of infection or nerve injury, and a decrease in ODI scores and VAS scores at two months and at the last follow-up ($P < 0.05$) after surgery.

Conclusion

Based on prone imaging, simple posterior column osteotomy or non-osteotomy surgery for traumatic kyphosis with good flexibility and no neurological symptoms is safe, with potential reduction in operative time, complications, and bleeding.

Background

Spinal fractures often occur in the thoracolumbar segment and are subject to kyphotic deformity with both conservative and surgical treatment [1, 2], causing severe low back pain, nerve damage, and sagittal imbalance that severely affects patient quality of life [3, 4]. Surgical treatment is the main approach for the treatment of late posttraumatic thoracolumbar kyphosis.

Osteotomy is necessary to achieve spinal correction, and commonly used strategies include spinous process (SP) osteotomy, Ponte osteotomy, pedicle subtraction osteotomy (PSO), and vertical column resection (VCR) [5–21]; these strategies correspond to the Scoliosis Research Society grading system grades I–V, respectively. The incidence of operative time, bleeding, and complications increases with the increase of osteotomy grade. SP and Ponte osteotomy are simple posterior column osteotomies.

The goals of surgery for posttraumatic kyphosis include correction of the deformity, reestablishment of spinal stability, release of nerve compression, and restoration of sagittal balance. Current surgical options are often based on standing x-ray imaging data. In fact, the deformity is self-correcting during postural changes—known as deformity flexibility. Deformities of the surgical segment can be effectively corrected in supine and prone positions [22] up to 37% and account for 50% of the overall correction [23]. This self-correction can be achieved without osteotomy or surgical instrumentation.

In patients with rigid kyphosis, the low mobility of the intervertebral space between the deformed vertebral body and the adjacent vertebral body means that it is impractical to achieve satisfactory deformity correction and sagittal balance by simple posterior column osteotomy [24]. Simple posterior column osteotomies cannot relieve the compression in patients with neurological compression symptoms since the anterior column is the primary source of compression.

In patients with good kyphosis flexibility and no neurological symptoms, self-correction of deformity becomes more important, making it possible to treat late posttraumatic thoracolumbar kyphosis with no osteotomy or only posterior column osteotomy. However, there are no reports in the literature on surgical plans based on prone imaging data.

Methods

We reviewed clinical data of a series of patients and aimed to evaluate the clinical effect of single posterior column osteotomy or no osteotomy to treat posttraumatic kyphosis without neurological symptoms.

Between April 2017 to November 2020, patients with old traumatic spinal fractures, treated surgically in our hospital, were identified. We included patients diagnosed with posttraumatic kyphosis and who underwent spinal correction surgery; with intractable low back pain unresponsive to conservative treatment, a prone kyphosis Cobb angle < 30°, and complete imaging data, including full-length lateral radiographs of the spine in the preoperative standing position, full-length lateral radiographs of the spine in the prone position, CT or MRI, and full-length lateral radiographs of the spine after surgery and at the last follow-up. The exclusion criteria were as follows: patients who could not tolerate surgery; incomplete imaging data; spine tumors or other infectious diseases, such as ankylosing spondylitis; symptoms of nerve compression; and an MRI or CT confirming that nerve compression required decompression.

Surgical procedure

According to the prone position spine full-length lateral film, a non-osteotomy technique was used for a local kyphosis Cobb angle < 20°, and SP osteotomy or Ponte osteotomy was used from 20–30°. After general anesthesia, the patient was placed in the prone position. With the convex vertex as the center, a longitudinal incision was made, and the skin and subcutaneous tissue was cut along the spinous process of the periosteum, revealing the posterior lamina, facet joints, and pedicle screw insertion point. Pedicle screws were placed in 2–3 segments of the injured vertebra.

For the non-osteotomy, after placing the screw, the pre-bent connecting rod was placed and the nut locked. For the posterior column osteotomy technique, SP and Ponte osteotomies were performed according to previous studies [25, 26].

After the osteotomy, the pre-bent rod was installed, the compression rod technique was used to make the osteotomy end axially close, and the posterior column was pressurized to close the residual gap of the osteotomy end. The posterior laminae and facet joints were decorticated and a posterolateral bone graft fusion was performed. Drainage was then placed to close the incision, and anti-infective treatment was prescribed after the operation; the drainage volume was less than 50 ml within 24 hours. A percutaneous kyphoplasty (PKP) was performed in the injured vertebrae of two patients with pseudarthrosis.

Observation indicators

The operation time, blood loss, and surgical complications were recorded. The Oswestry disability index (ODI) and visual analog score (VAS) before the operation, two months after operation, and at the last follow-up, were recorded and analyzed.

The following imaging parameters were measured: LKCA; TK; LL; SS; PT; PI-LL; and SVA were measured and analyzed in the standing position before the operation, immediately after the operation, and at the last follow-up. TK, LL, and LKCA were also recorded and analyzed in the prone position before the operation. LKCA represents the angle between the upper endplate of the upper two vertebrae and the lower endplate of the lower two vertebrae; TK, the angle between the T5 upper endplate and the T12 lower endplate; LL, the angle between the L1 upper endplate and the S1 upper endplate; SS, the angle between the lower horizontal planes of the upper end plate of S1; PT, the angle between the line connecting the midpoint of the sacral endplate and the midpoint of both femoral heads and the line of gravity; PI, the angle between the straight line perpendicular to the midpoint of the sacral endplate and the line connecting the midpoint of the sacral endplate and the midpoint of the bilateral femoral heads; SVA, the vertical distance from the C7 plumbline to the posterior superior margin of the sacral superior endplate (Fig. 1). Kyphotic flexibility was determined by the following formula:

Kyphotic flexibility = (preoperative standing LKCA - prone LCKA)/preoperative standing LCKA;

furthermore, the correction rate was determined by the formula:

Correction rate = (preoperative standing LCKA - postoperative standing LCKA)/preoperative standing LCKA.

Statistical analysis

Continuous data are expressed as mean ± SD. The preoperative, immediate postoperative, and final follow-up imaging parameters were analyzed by repeated measurement analysis of variance (ANOVA). One-way ANOVA analysis was used to compare ODI and VAS scores before the operation, two months after the operation, and at final follow-up. $P < 0.05$ indicated a statistically significant difference.

Results

According to the inclusion and exclusion criteria, a total of 18 patients were included. Demographic characteristics are shown in Table 1 and non-osteotomy, SP, and Ponte osteotomy data are shown in Figs. 2–4. The mean operation time was 152.7 ± 34.2 min and blood loss was 408.3 ± 135.3 ml. No infections or nerve injuries occurred. The ODI scores before the operation, two months after the operation, and at the last follow-up were 54.78 ± 9.63%, 25.16 ± 3.0%, 9.67 ± 23.14%, and the VAS scores were 5.72 ± 1.1, 2.16 ± 0.86, and 1.22 ± 0.81, respectively.

Table 1
Demographic data of the patients

	Mean ± SD	n
Gender		
M		2
F		16
Age	63.67 ± 7.25	
Fracture location		
T11		3
T11, L3		1
T12		7
T12/L1		1
L1		6
Operative strategy		
Non-osteotomy		6
SP		6
Ponte		6
BMI	21.26 ± 3.12	
BDM	1.64 ± 2.4	

SD, standard deviation; M, male; F, female; SP, spinal process; BMI, body mass index; BDM, bone mineral density,

The follow-up time was 24–67 months, with a mean of 45.2 ± 14.95 months. At the last follow-up, there were no complications such as internal fixation loosening and fracture, and no obvious correction loss. The spinal-pelvic parameters of preoperative standing, prone, immediately postoperative, and last follow-up x-rays are shown in Table 2. The spinal flexibility was 42.25 ± 19.42% and the deformity correction rate was 73.73 ± 16.3%. Compared with preoperative standing position, there was no significant difference in LL, PT, and PI-LL immediately after the operation and at last follow-up.

Table 2
Preoperative standing and prone values and immediate postoperative and last follow-up parameters

	LKCA (°)	TK (°)	LL (°)	SS (°)	PT (°)	PI-LL (°)	SVA (cm)
Preoperative standing	42.0 ± 14.2	45.26 ± 14.57	44.03 ± 14.85	27.28 ± 9.94	22.18 ± 9.94	6.9 ± 14.15	5.89 ± 4.23
Preoperative prone	22.95 ± 6.1*	32.27 ± 12.56*	44.23 ± 11.51	-	-	-	-
Postoperative immediate standing	9.87 ± 3.77*#	37.37 ± 10.18*#	42.97 ± 12.43	32.11 ± 8.91	23.3 ± 8.45	7.96 ± 14.4	3.21 ± 2.56*
Last follow-up	10.7 ± 3.53*#	35.02 ± 7.65	39.36 ± 8.15	33.1 ± 10.2	26.45 ± 8.04	11.57 ± 14.23	2.72 ± 1.74

*Compared with preoperative standing X-ray, the difference was statistically significant; #Compared with preoperative prone X-ray, the difference was statistically significant.

TK, thoracic kyphosis; LKCA, local kyphosis Cobb angle; LL, lumbar lordosis angle; SVA, sagittal vertebral axis; PT, pelvic tilt; PI-LL, pelvic incidence minus lumbar lordosis angle; SS, angle between the lower horizontal planes of the upper end plate of S1

Discussion

LKCA and TK significantly reduced from standing to the prone position before surgery. The LKCA, TK, and SVA of immediate postoperative and at last follow-up results were statistically different compared with those before surgery; the differences in LL, PT, and PI-LL in the postoperative period and at the last follow-up were not statistically significant compared with those before surgery. No complications of infections or nerve injuries occurred, and there was a significant decrease in ODI and VAS scores at two months and at the last follow-up after surgery.

The etiology of kyphosis in old traumatic spinal fractures is diverse. Furthermore, the key factors remain unclear, exacerbated by misdiagnosis or delayed diagnosis, treatment failure (regardless of surgical or non-surgical treatment), disc injury, and other diseases affecting bone density [27]. Patients are severely affected and require surgical treatment; and the indications for surgery include pain, nerve damage, and worsening of progressive kyphosis [4, 27].

The selected fusion segment of posttraumatic kyphosis is generally 2–3 vertebrae above and below the fracture site [6, 28]; therefore, we focused on the posterior convex Cobb angle of the surgical segment. In our cases, LKCA was significantly reduced from 45.26° in the standing position to 32.27° in the prone position with a flexibility of 42.25%. This change may be due to the effect of gravity [29, 30]. Fei et al. compared the MRI results of patients with degenerative scoliosis in standing and supine positions and the kyphosis Cobb angle of the surgical segment in the prone position, and found that the kyphosis Cobb angle of the surgical segment in the prone position was significantly reduced [22]. In the prone position, the shoulder and pelvis are cushioned, the trunk collapses forward due to gravity, the anterior disc opens, the posterior column closes, and the kyphosis Cobb decreases. Another reason for this is the average age of 63.67 years in our group of patients. The decrease in muscle strength in elderly patients results in insufficient bony strength to maintain trunk balance in the standing position [31]. The anteversion of the spine above the fracture also led to a large kyphosis Cobb angle, which is eliminated in the prone position. In addition, spinal flexion is also a way for elderly patients to compensate for other diseases, such as spinal stenosis and pain [32]. Pseudarthrosis may also be responsible for the reduction of kyphosis. Two patients in this group had combined pseudarthrosis, and an intraoperative PKP was performed in the injured vertebra to stabilize the anterior column.

LL in the prone position was affected by the hip joint and increased when the hip joint was hyperextended, decreased when the hip joint was hyper flexed, and was less affected by the hip joint when the hip joint was within 30° of flexion [33, 34]. Compared with the standing position, there was no significant change in LL in the prone position in this group, probably due to the pelvic cushion causing hip flexion within 30°.

The main parameters considered in the current surgical plan are the standing kyphosis Cobb angle and neurological function. The normal range of thoracolumbar kyphosis Cobb angle is 2.2 ± 8.0 ° [35], and increases with age [36]. When the patient's LKCA is < 20° in the prone position, using the corrective force of the rod can corrected the alignment to the normal range. In our group, six patients were not osteotomized.

In patients with good flexibility and no neurological compression, the deformity was self-corrected in the prone position. When the kyphosis Cobb angle is 20 to 30° in the prone position, a simple posterior column osteotomy can be used to complete the correction. The non-osteotomy technique and simple posterior column osteotomy, which does not destroy the anterior column, has comparatively better stability of the osteotomy end and less possibility of nerve injury [20].

Therefore, the surgical plan based on the prone sagittal parameters has the potential to reduce the operation time and blood loss. In this group, the operation time was 152.7 min and the mean bleeding was 408.3 ml. SVA, ODI scores, and VAS scores at two months postoperatively and at the final follow-up were significantly improved compared with the preoperative period.

However, non-osteotomy or single posterior column osteotomy has limited correction ability and cannot decompress the compressed nerve. Thus, the technique in the study is not suitable for patients with nerve compression. For patients with rigid or combined anterior nerve compression or kyphosis Cobb angle still over 30° in the prone position, an anterior column osteotomy is required [13, 16, 24, 37], including PSO, VCR osteotomy, etc. Although researchers have refined these osteotomy techniques [11, 12, 14], three-column osteotomy often decreases spinal stability, and neurological complications, operation time, and complication rates increase.

Rigid fixation and bony fusion is the key to prevent correction loss. During PSO and VCR procedures, both the anterior and posterior column could be bone grafted [37, 38], with good long-term outcomes [15, 17]. In our opinion, the simple posterior column fusion used in this study did not destroy the anterior column structure and the posterior column fusion showed a good therapeutic effect in flexile deformity, unlike that in Scheuermann disease, Mucopolysaccharidosis syndrome, etc. [26, 39]. Our patients were followed up for at least two years, and no obvious correction loss was found.

Changes in postoperative imaging parameters in patients with kyphosis are related to compensatory mechanisms. Different from degenerative kyphosis in the elderly, posttraumatic kyphosis is characterized by a decrease in thoracic kyphosis and an increase in lumbar lordosis [40, 41], so theoretically, after the correction of the deformity, TK increases and LL decreases [42], but the compensatory mechanism is not simple. Li et al. found an increase in LL after traumatic kyphosis correction surgery [10], while Olivares et al., who used PSO osteotomy for old traumatic kyphosis, showed that TK and LL were unchanged after surgery [21]. The immediate postoperative TK and LCKA were significantly reduced compared to the preoperative period in our patients, which is similar to previous studies [15, 17]; the lack of change in postoperative LL may be explained by the small SVA and no severe sagittal imbalance in our patients [43]. The mean age of the patients in this group was 63.67, and the results suggest that the compensatory mechanism in the elderly may occur first in the thoracic spine and later in the lumbar lordosis area. There was a tendency for the LL to decrease at the final follow-up, although the difference was not statistically significant ($P > 0.05$).

PT is associated with LL, as well as PT increases and LL decreases [44]. There was no change in the preoperative standing position, prone position, or postoperative LL in our patients; therefore, there was no change in PT, similar to other studies [21, 42]. PI is a fixed value that does not change with position, so PI-LL does not change [21, 42]. SS reflects the degree of pelvic tilt. PI has a geometric relationship with PT and SS, and PI equals PT and SS [25]. PT and SS did not change in this group of patients.

There were some limitations to this study. First, we had a small sample size and no severe sagittal imbalance, which may cause selective bias, and we still need to observe the long-term efficacy. Second, we did not study the factors influencing the flexibility of kyphosis, and require a further large sample, multi-center study. Third, regarding how many degrees were required to choose between an SP or Ponte osteotomy, we did not stipulate any strict criteria, and further studies are required to quantify the effects thereof.

Conclusions

We reviewed 18 patients with old traumatic spinal fracture kyphosis, and the patients showed significant changes in LKCA from standing to prone positions. In patients with good flexibility and no neurological symptoms, the use of single posterior column osteotomy or non-osteotomy techniques can achieve good clinical results with potential reduction in operation time and risk.

Abbreviations

LKCA Local kyphosis Cobb angle

TK Thoracic kyphosis angle

LL Lumbar lordosis angle

SS Sacral slope

PT Pelvic tilt

PI-LL Pelvic incidence minus lumbar lordosis angle

SVA Sagittal vertebral axis

Declarations

Acknowledgments

None

Ethics approval and consent to participate

The study design was approved by of Ethics committee Fuyang people's hospital. All procedures performed in the current study were in accordance with the 1964 Helsinki declaration and its later amendments. Written informed consent was obtained from all individual participants included in the study.

Consent for publication

All patients signed an appropriate release to use their health and sensitive data and to be enrolled in the study.

Availability of data and materials

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

Competing interests

The authors declare no potential conflict of interest.

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Authors’ contributions

Yu HY and Hua ZK – design study. Cui XL, Wang Kangkang, Zhang Wei, and Li BB – data collecting. Cui XL and Yang WM – data analysis. Cui XL, Wang Kangkang, and Yang WM – preparing manuscript. Yu HY and Hua ZK – revising manuscript content. All authors have read and approved the final manuscript.

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Figures

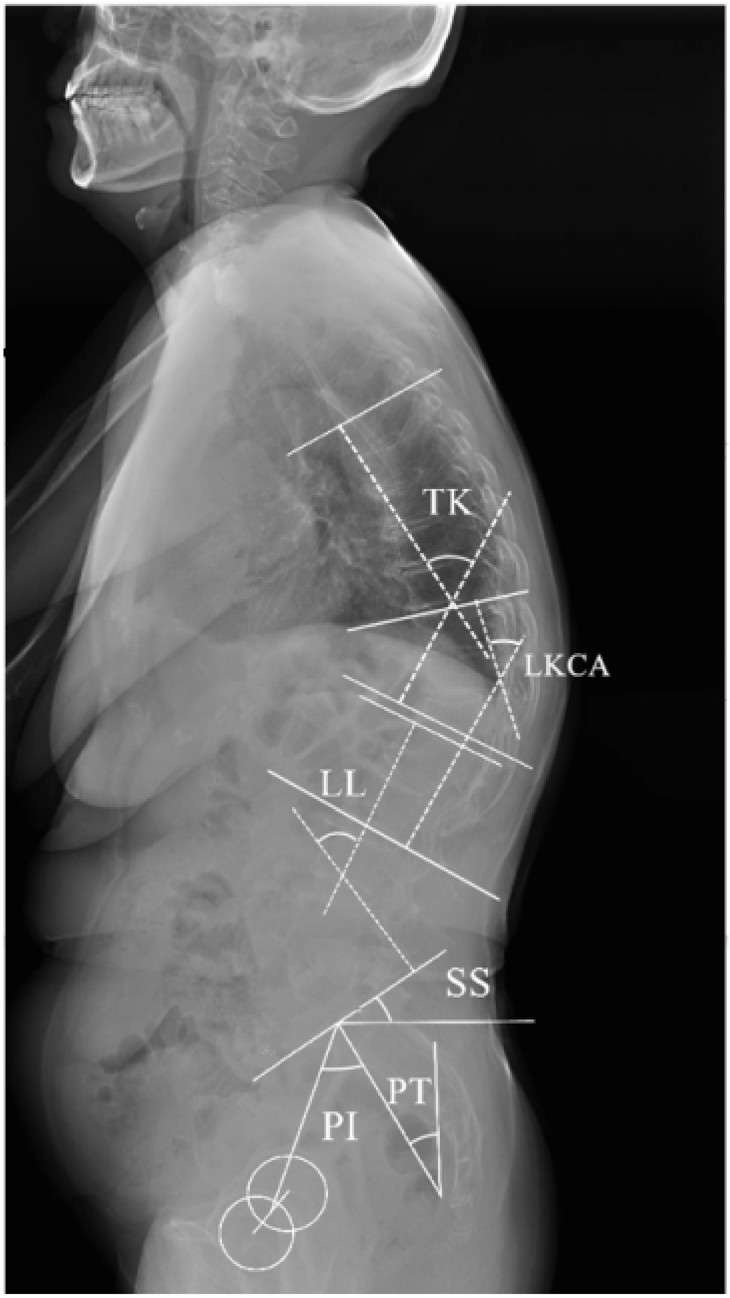

Figure 1

Measurement of spinopelvic parameters

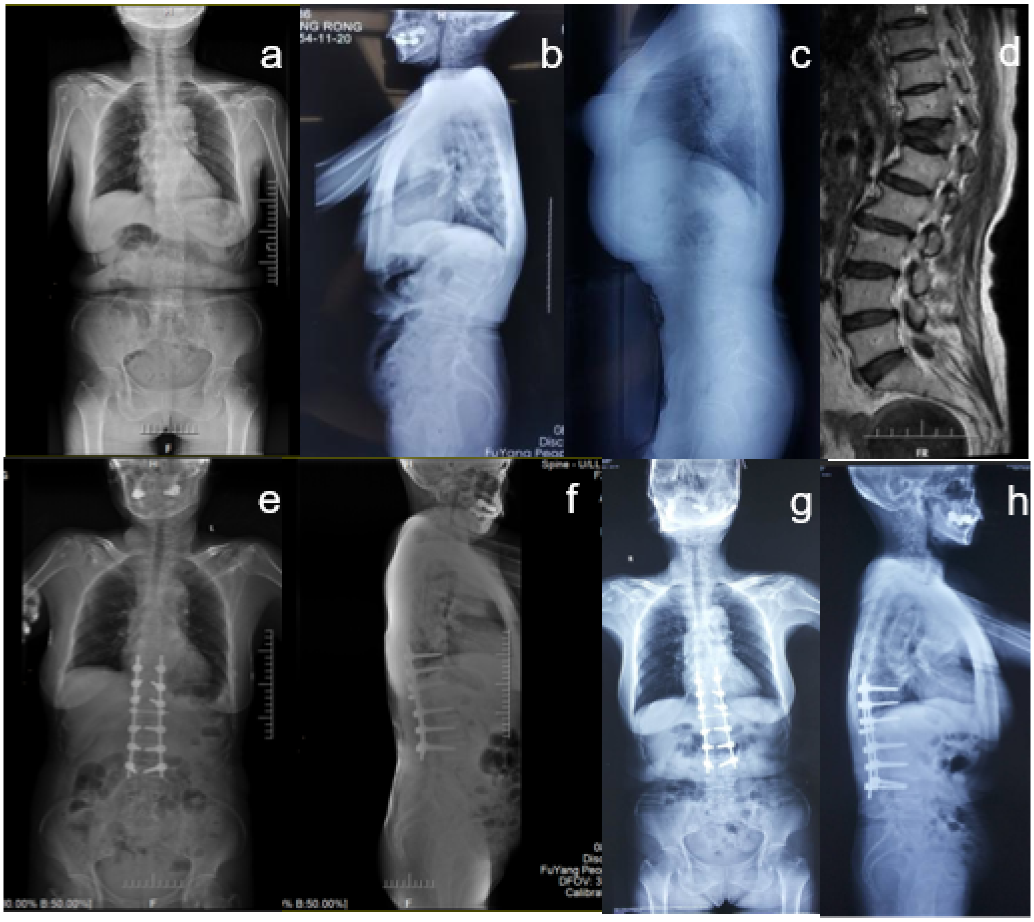

Figure 2

Results from a female, 62 years old, with late posttraumatic kyphosis (T12). (a, b) preoperative full-length spine x-ray in standing position shows an LKCA of 42°; (c) preoperative full-length spine X-ray in prone position shows that the LKCA reduced to 19.6°; (d) preoperative magnetic resonance imaging shows compression changes of T12 vertebral body and no nerve compression; (e, f) postoperative X-Ray showing that the LKCA was corrected to 8.6°. (g, h) X-ray at the last follow-up: the LKCA was 9.2°, and no obvious loss of correction was observed.

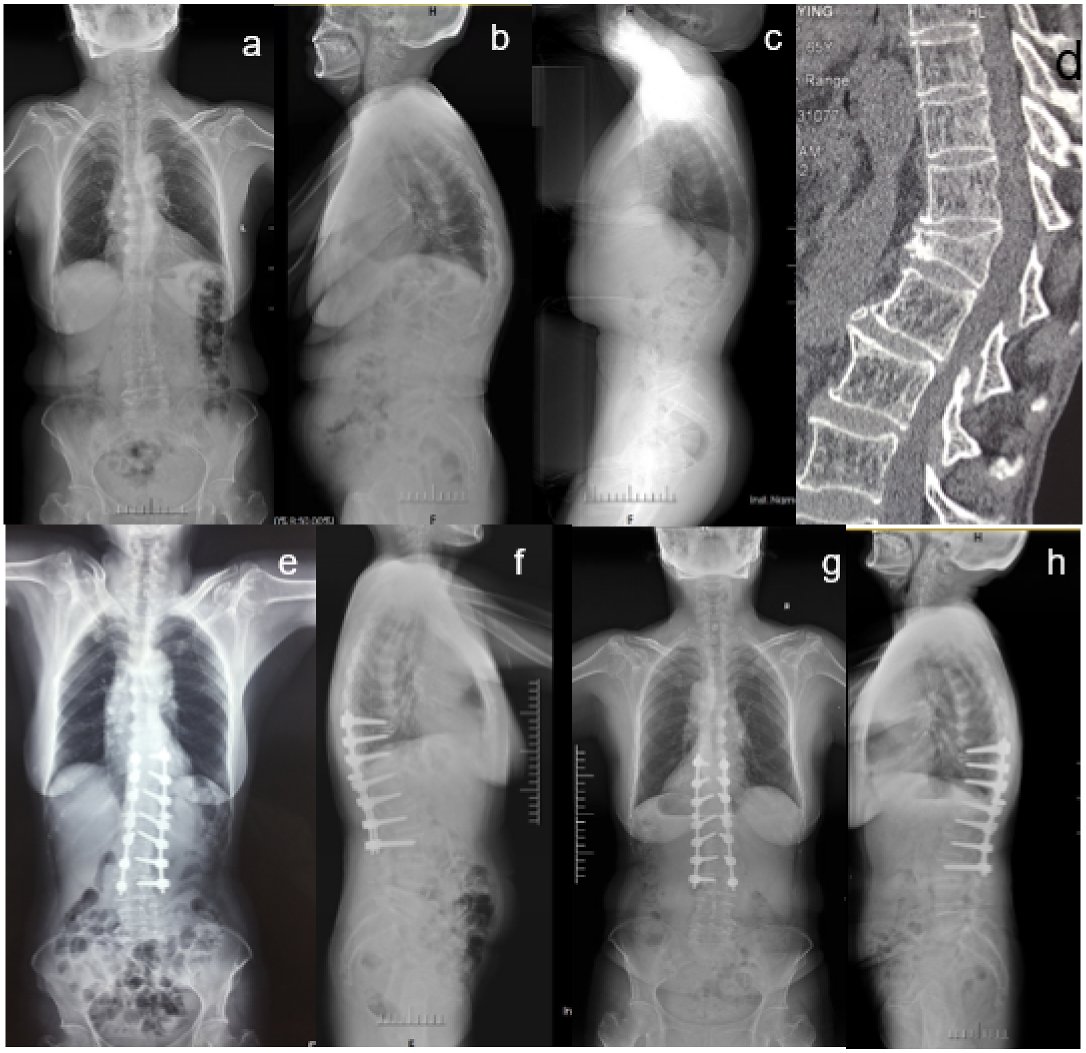

Figure 3

Results from a female, 65 years old, with late posttraumatic kyphosis (T12). (a, b) Preoperative full-length spine X-ray in standing position showing an LKCA of 45.3°; (c) preoperative full-length spine x-ray in the prone position showing the LKCA reduced to 24.2°; (d) preoperative 3D CT showing compression changes of the T12 vertebral body and no nerve compression; (e, f) postoperative x-ray showing that the LKCA was corrected to 9.8°. (g, h) X-ray at the last follow-up: the LKCA was 10.1°. There was no obvious loss of correction.

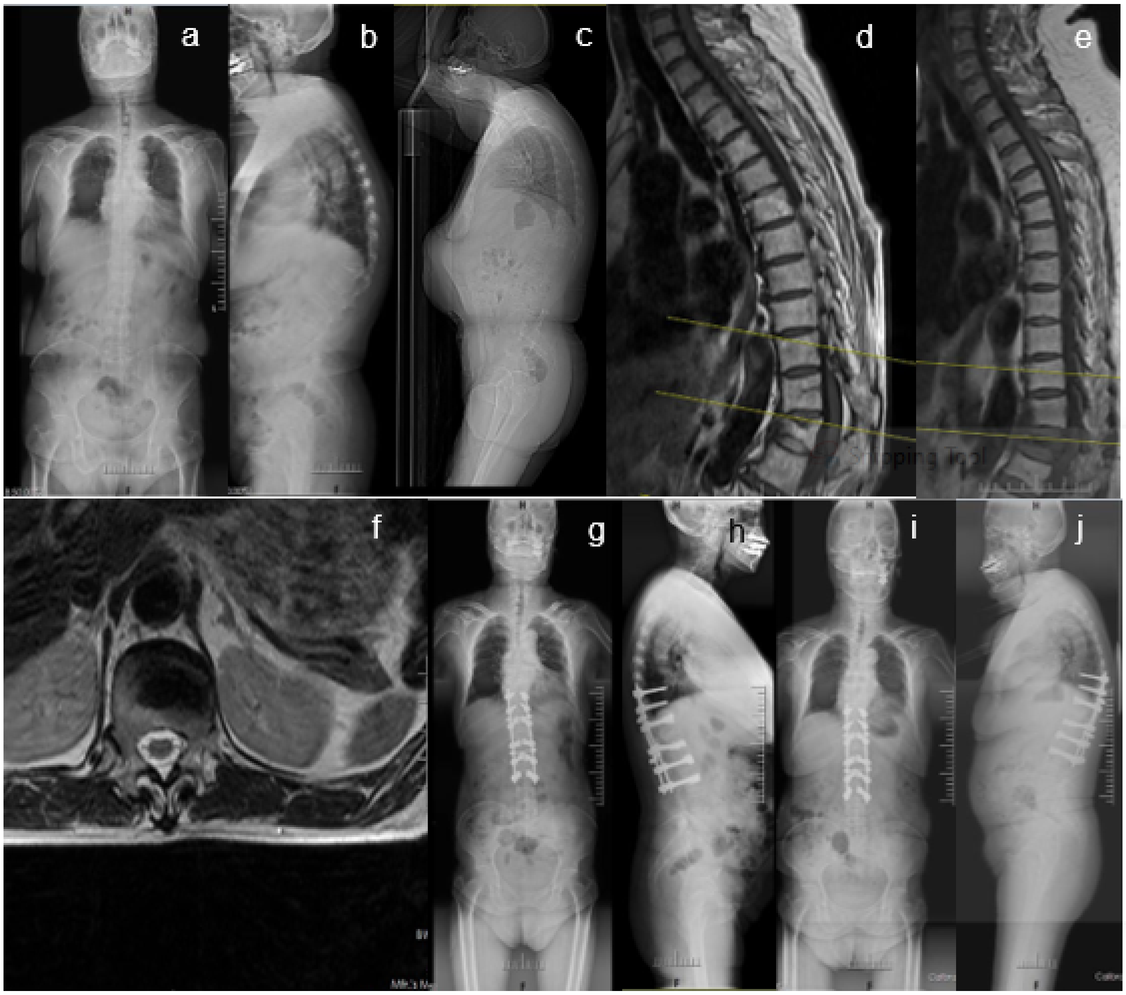

Figure 4

Results from a female, 71 years old, with late posttraumatic kyphosis (T12). (a, b) Preoperative full-length spine X-ray in standing position showing an LKCA of 38.1°; (c) preoperative full-length spine x-ray in the prone position showing that the LKCA reduced to 28.5°; (d, e, f) preoperative magnetic resonance imaging showing compression changes of the T12 vertebral body and no nerve compression; (g, h) postoperative x-ray showing that the LKCA was corrected to 11.2°. (i, j) X-ray at the last follow-up: the LKCA was 11.5°. There was no obvious loss of correction.