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Identifying the Key Anatomic Structures Contributing to Reduction Loss Following Hybrid Stabilization of Osteoporotic Thoracolumbar Spine Fractures

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Abstract Introduction. Hybrid stabilization has been established as a viable treatment strategy for unstable osteoporotic thoracolumbar fractures. However, reduction loss remains a concern, and the specific anatomical structure responsible for this loss is not well-defined. Methods. This retrospective study was conducted at Bukhara Regional Multidisciplinary Medical Center and involved patients aged 61 and older who underwent hybrid stabilization following acute and unstable osteoporotic vertebral body fractures in the thoracolumbar spine. Posterior stabilization was performed using short-segmental and minimally invasive techniques with cement-augmentation of all pedicle screws. The minimum follow-up period was 2 years, and outcome parameters included reduction loss, relative loss of height of adjacent intervertebral discs, fractured vertebral body, and a reference disc (the intervertebral disc superior to the stabilization) between postoperative and latest lateral radiographs. Implant positioning and loosening were also analyzed. Results. The study included 29 patients, mainly female (72%), with a mean age of 73.3 ± 6.0 years. Fractures consisted of 26 incomplete burst fractures and 3 complete burst fractures, primarily located at the thoracolumbar junction (86%) and midlumbar spine. The mean follow-up time was 36 months (range: 24–58 months). The mean reduction loss was 7.7° (range: 1–25), and significant relative loss of heights was observed in both adjacent intervertebral discs, the reference disc, and the central vertebral body. The superior adjacent disc height had the highest loss and was significantly greater than the reference disc. The relative loss of central vertebral body height and reduction loss showed significant correlation. No implant loosening was observed in any patient. Conclusions. Moderate reduction loss was observed 3 years after hybrid stabilization of unstable osteoporotic vertebral fractures of the thoracolumbar spine. Significant loss of heights was observed in both adjacent intervertebral discs and the central vertebral body, with the highest loss occurring in the superior adjacent disc. The superior adjacent intervertebral disc and the central part of the fractured vertebral body were identified as potential contributors to reduction loss.

Keywords Osteoporotic thoracolumbar vertebral fractures, Hybrid stabilization, Fractured vertebral body, Unstable osteoporotic vertebral fractures, Thoracolumbar spine

1. Introduction

Hybrid stabilization is a widely accepted treatment option for unstable osteoporotic thoracolumbar vertebral fractures, leading to positive clinical outcomes for the majority of patients [1,2]. Hybrid stabilization of the spine typically involves the use of vertebral augmentation techniques such as vertebroplasty (a procedure in which a special material, such as cement, is injected into the vertebra) as well as the implantation of metallic rods, screws, and/or plates into the spine. While trauma-associated intervertebral disc lesions following osteoporotic vertebral fractures are unlikely, a significant loss of intact intervertebral disc heights cannot be ruled out despite age-related sclerotic changes and posterior stabilization [1]. One of the issues associated with hybrid stabilization of the spine is the reduction of vertebral bodies, which is the loss of vertebral height. This can occur due to many factors, including degenerative changes in the intervertebral discs and the lack of additional support for stabilization. To reduce the risk of vertebral body reduction, surgeons may take various measures such as using more rigid implants, more precise surgical planning, and more careful patient selection for surgery.

There are many studies that investigate the effectiveness of hybrid stabilization of the spine and the risks associated with vertebral body reduction. These studies help surgeons better understand how to minimize the risk of vertebral body reduction and improve surgical outcomes for patients. A previous study by Spiegl et al. [2] reported a mean reduction

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loss of over 7° after hybrid stabilization of osteoporotic vertebral fractures, but it remains unclear which anatomic structures are responsible for this loss. Is the reduction loss localized at the fractured vertebral body or at the adjacent intervertebral discs?

The objective of our study was to examine the location of reduction loss after hybrid stabilization of unstable burst fractures of the thoracolumbar spine in patients aged 60 years or older. We hypothesized that the majority of the reduction loss would be located at the fractured vertebral body without significant participation of the adjacent vertebral discs.

2. Materials and Methods

This retrospective study was conducted at Bukhara Regional Multidisciplinary Medical Center between December 2016 and September 2021, and aimed to further investigate the impact of hybrid stabilization on unstable osteoporotic vertebral fractures of the thoracolumbar spine. Our study cohort consisted of patients aged 61 and older who underwent the procedure using short-segmental and minimally invasive techniques with cement-augmentation of all pedicle screws. To ensure accurate analysis of disc and vertebral body heights, only patients with orthograde beam path of both postoperative and latest lateral radiographs were included in the study, which differed from our previous investigation. Additionally, posttraumatic MRI was employed to evaluate potential intervertebral disc lesions. The study was approved by the regional ethics committee and all inclusion and exclusion criteria are listed in Table 1. Through our analysis, we aimed to better understand the specific anatomical structures responsible for reduction loss following hybrid stabilization, as well as evaluate the efficacy of the procedure in achieving stable outcomes for these patients.

Table 1. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Age: > 60 years	Non-orthograde beam path at the fracuted level of the lateral postoperative or final radiographs
Unstable fracture or failed conservative treatment	Inability or unwillingness to join the study
Thoracolumbar junction and mid lumbar spine (Th 11 – L4)	Neurologic impairment
Acute fracture situation	Pathologic vertebral body fractures (tumor/infection)
Posttraumatic total spine MRI	High energy trauma

Th-Thoracic spine; L-Lumbar spine; MRI-Magnetic resonance imaging

All patients underwent a comprehensive clinical examination, including conventional radiographs and magnetic resonance imaging (MRI) with STIR sequences of the entire spine. Patients who had MRI contraindications were excluded from the study.

Fracture classification was performed using the AO spine classification [3], the OF-classification [4], and an OF score of at least 6 [5]. The indication for surgery was based on the guidelines provided by the spine section of the German society for orthopaedics and trauma (DGOU) [5].

The surgical technique utilized in this study involved minimally invasive hybrid stabilization with posterior cement-augmented bisegmental instrumentation (Matrix, Fa. DepuySynthes; Viper, Fa. DepuySynthes, Longitude, Fa. Medtronic) utilizing polyaxial screws, without posterior fusion, and bilateral transpedicular kyphoplasty (Vertecem, Fa. DepuySynthes) of the fractured vertebral body. Additionally, all pedicle screws were cement-augmented.

Outcome parameters

All patients were evaluated at a minimum of 2 years following their initial surgery. Patients were initially contacted by phone and invited to participate. Those who agreed underwent a clinical examination at the study center, which included an anterior-posterior x-ray centered on the affected vertebral body and lateral 36 in. views while standing. The height of the vertebral body and adjacent intervertebral discs, both at the time of postoperative radiographs and at the final follow-up, were compared. To assess the average loss of disc height due to the natural aging process, the height of the disc superior to the instrumentation was used as a reference disc. Patients with inadequate postoperative and/or final lateral radiographs, such as non-orthograde beam path, were excluded from the study.

Disc height was defined following the method of Spiegl et al. [6]. The disc height was calculated as the average of three measurements taken at three positions: the anterior cortex, the posterior cortex, and the center between both cortices (Fig. 1). Given the asymmetric deformity progression of the vertebral body, the height of the vertebral body was assessed at the anterior and posterior cortices as well as at the center (Fig. 1). To avoid errors in magnification due to the radiographic technique, the implanted rods were used as a reference tool between the postoperative and latest lateral radiographs (Fig. 2).

The primary outcomes of interest were the relative changes in the height of the fractured vertebral body and the intervertebral discs adjacent to the fracture site, as well as the disc height superior to the instrumentation, which served as a reference disc. Additionally, implant positioning was analyzed. Correlations between the relative changes in vertebral body and disc heights, bisegmental reduction loss, and patient parameters were evaluated.

All statistical analysis was performed using SPSS software 17.0 (SPSS, Inc., Chicago, USA). Descriptive statistics were used to analyze the data. Fisher's exact test and paired t-test were used to evaluate the associations between the relative changes in vertebral body heights, intervertebral disc heights, and bisegmental reduction loss. Pearson correlation coefficient was used to calculate correlations between parameters. A significance level of 0.05 was used for all analyses.

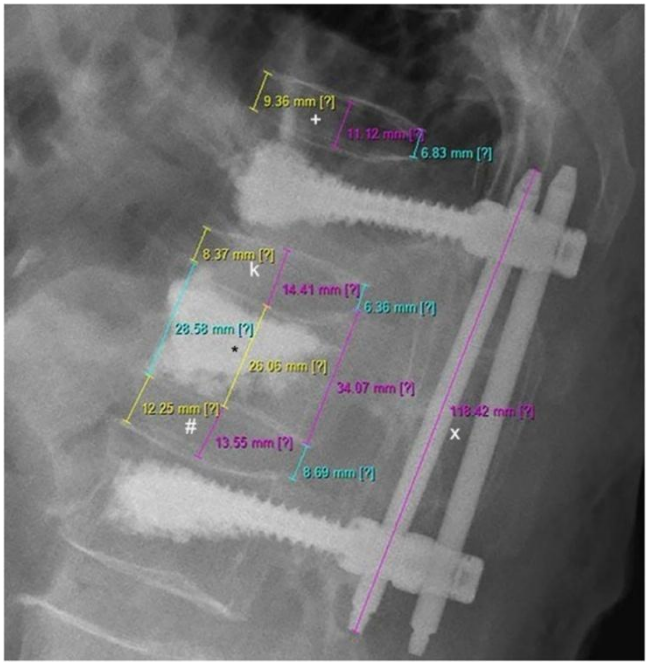

Figure 1. All measurements are depicted. Structures of interests are the fractured vertebral body (*), the superior adjacent intervertebral disc (k), the inferior interverterbral disc (#), the reference disc (+) and the length of the posterior rod (x) in order to minimize magnification errors. The heights of the discs and the vertebral body were measured at the anterior cortex, the posterior cortex and in the center (mid size) between the anterior and posterior cortex. The height of the intervertebral discs were calculated in accordance to Spiegl et al 60] as one third of the sum of the anterior, central and posterior height

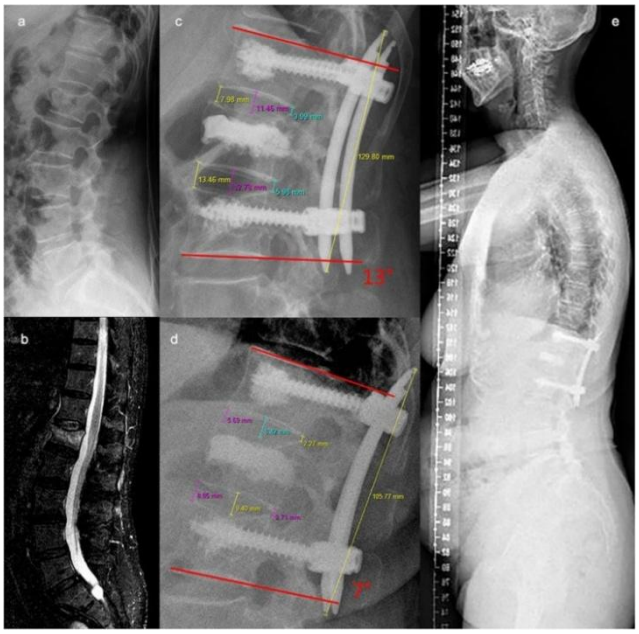

Figure 2. 75- year old patient who fell in her apartment while strumbling. An acute fracture of the 2nd lumbar vertebral body with posterior cortex affection of about 25% type OF 3 was diagnosed. Hybrid stabilization was performed after failed non-operative treatment for 7 days with anatomic fracture reduction and a bisegmental lordotic Kobb angle of 13° (c). The latest follow-up were perfomred after 41 months. The patient was very satisfied, suffered from mild pain (VAS: 2) and no limitations (ODI: 0%). A reduction loss of 6 ° is visible (d) with a relative loss of superior disc height of 14% and a compensated sagittal balance (e)

3. Results and Discussion

A total of 29 patients who met the inclusion criteria were included in the study. The mean age of the patients was 73.3 years (range: 61 to 98 years), with the majority being female (72%). Most fractures occurred at L1 (n=11) and Th12 (n=8), with fewer fractures at L2 (n=5), L3 (n=3), Th11 (n=1), and L4 (n=1). Most of the fractures were incomplete burst fractures, with 20 OF 3 fractures having significant involvement of the posterior cortex and 6 OF 2 fractures having minor involvement of the posterior cortex and an OF score of at least 6. Three patients had complete burst fractures (A4; OF 4). All patients with OF 2 fractures had persistent pain and acquired significant loss of reduction after mobilization. The mean follow-up time was 36 months (range: 24-58 months). Post-traumatic MRIs did not reveal any obvious trauma-related intervertebral disc lesions. During the follow-up period, a total of three patients suffered from adjacent fractures (10.3%).

The average loss of reduction was 7.7° (range: 1° – 25°). The relative loss of vertebral body and intervertebral disc heights are presented in Table 2. The heights of both adjacent intervertebral discs (superior disc: $p < 0.001$; inferior disc: $p = 0.001$), the reference disc ($p = 0.003$), and the central part of the fractured vertebral body ($p = 0.006$) were significantly reduced at the latest follow-up compared to the postoperative radiographs. The relative loss of height of the superior adjacent disc was significantly higher compared to the reference disc ($p = 0.001$). However, only the relative loss of central vertebral body height and loss of reduction had a significant correlation ($coef = -0.471$; $p = 0.048$). The changes of the anterior and posterior vertebral body heights were not significant. Overall, there was significant variability in all parameters.

Table 2. Changes between the lateral postoperative and latest radiographs

Parameter	Mean	Std	Range
Reduction loss [°]	7.7	5.8	1–25
Rel. loss of disc height: superior [%]	19.0	9.0	4–39
Rel. loss of disc height: inferior [%]	11.9	11.2	-14 – 35
Rel. loss of vertebral body height: central [%]	7,2	9.6	−16 – 36
Rel. loss of vertebral body height: anterior [%]	2.9	8.3	−17 – 21
Rel. loss of vertebral body height: posterior [%]	3.4	10.0	−18 – 36
Rel. loss of disc height: reference disc [%]	6.6	10.9	−22 - 19

The implant position was analyzed, and no visible implant failure, screw cut-out, or screw-loosening was observed. However, there were no significant correlations found between the loss of disc height and reduction loss, fracture location, fracture classification, age, gender, and time of follow-up.

The study found that the main cause of reduction loss after hybrid stabilization of unstable thoracolumbar fractures was

the superior adjacent intervertebral disc and the central part of the fractured vertebral body. The loss of reduction was significantly correlated with the loss of height at the central part of the fractured vertebral body, but there were no significant correlations with other parameters such as fracture location, classification, age, gender, or time of follow-up. The highest relative loss of height was seen in the superior disc adjacent to the fracture, which was significantly higher compared to the reference disc. There were no implant-associated causes for reduction losses.

The posttraumatic MRI did not show any obvious severe trauma-associated disc lesions, but the short tau inversion recovery (STIR) sequences used may not have been sufficient for a detailed analysis of intervertebral disc lesions. Most of the patients had low- to moderate-energy traumata, which made posttraumatic disc lesions unlikely [7,8]. However, over 80% of the fractures were incomplete burst fractures of the superior vertebral body with potential fracture-associated disc involvement. The loss of height of both intervertebral discs might have been caused by obstructed motion due to posterior stabilization or cement-associated reduced blood flow to the superior or inferior endplate, leading to a lack of sufficient nutritional supply and resulting in an acceleration of the degenerative cascade [9]. Another hypothesis was a partial shift of intervertebral disc material into the depression of the centrally fractured vertebral body, which might be reduced by optimal cement technique and positioning. The authors attempted to position the cement at the optimal location, but no postoperative computed tomography was performed to evaluate the exact cement positioning [10,11,12].

Hybrid stabilization has been reported as an effective treatment for unstable thoracolumbar vertebral body fractures in several studies [13,14,15,16]. However, the loss of reduction in geriatric patients can be quite high, ranging from 4.6 to 23 degrees [17,18,19]. It is important to note that some studies did not use cement-augmentation to reinforce pedicle screw stability. In our patient population, we did not detect any implant loosening or screw cut-out. However, it should be noted that no computer tomography was performed during the final follow-up to rule out screw loosening that may have been missed in conventional radiographs due to reduced local visualization capacity based on the bone cement.

In a normal post-traumatic osteoporotic scenario, the reduction loss can be assumed to be higher. For example, Minamide et al. evaluated 51 patients with comparable osteoporotic vertebral body fractures and found that the local kyphosis was significantly higher in the group that was initially treated non-operatively with kyphoplasty compared to the group that had initial kyphoplasty [20].

Recent studies have reported varying outcomes of isolated kyphoplasty with an intervertebral expander. Arabmotlagh et al. [21] reported a complete loss of reduction one year after the procedure, while Spiegl et al. [6] found a significant correlation between the amount of reduction loss and patient limitations defined by ODI scores. In this context, Li et al. [22] reported a positive correlation between lumbar lordosis and fatty infiltration of the low back muscles, which may lead to worse clinical outcomes. Thus, persistent re-creation of the anatomic alignment could have a positive impact on long-term clinical outcomes [23]. Additional implementation of fracture screws or posterior fusion could be possible solutions to reduce the amount of reduction loss, but an open or more extended minimally invasive approach would be necessary, which could result in longer surgeries and higher blood loss.

The indication for surgery has to be discussed critically in all patients [24]. Some of the patients might have comparable clinical outcomes without surgery or with augmentation procedures of the fractured vertebral body alone. Generally, we have seen the indication for an operative stabilization very strictly and in accordance with the recommendation of the spine section of the German Society of Orthopaedics and Trauma (DGOU) [5]. Surgery was indicated in patients with unstable vertebral fracture and relevant destruction of the anterior column defined by OF scores of three and higher or failed conservative therapy [25]. Additionally, all patients were informed about a non-operative therapy summing up all advantages and disadvantages.

There are several limitations to this study. Firstly, the retrospective study design should be critically evaluated. Additionally, the patient sample size is relatively small. To gain more insight into the impact of posttraumatic disc lesions on reduction loss, an MRI at the latest follow-up would be beneficial, especially if T1 and T2 sequences were included. However, minor screw loosening cannot be entirely ruled out, particularly when using a cement-augmented pedicle screw implantation technique. CT examinations would be useful to detect screw loosening and assess the osseous consolidation of the fracture. However, the exposure to radiation may not be justifiable in patients with good clinical outcomes. A reference sphere was not used, and instead, the posterior stabilization rods were measured to ensure the identical size relationship. However, variations in the beam path and coronal malalignment could lead to diminished comparability, and non-orthograde beam path could reduce measurement accuracy. Furthermore, the time of day of the examinations was not identical, which could explain the smaller disc height due to late-day examinations that may affect the results. Lastly, osteoporotic screening was not routinely performed during the admission, and only a few patients received antiosteoporotic therapy. This may have influenced the regional alignment. Regular radiographic follow-ups, such as yearly follow-ups, would also be helpful in understanding the time course of reduction loss and disc height loss.

4. Conclusions

The study found that there was a moderate amount of reduction loss three years after performing hybrid stabilization for unstable osteoporotic vertebral fractures in the thoracolumbar spine. The analysis showed a significant

loss in both disc heights adjacent to the fractured vertebral body and the central vertebral body height, with the superior disc experiencing the greatest loss compared to the reference disc. This suggests that the superior disc and central part of the fractured vertebral body may be responsible for the majority of the reduction loss observed.

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