COMPARATIVE RADIOLOGICAL ANALYSIS OF HYBRID AND CIRCULAR STABILIZATION METHODS FOR THE TREATMENT OF OSTEOPOROTIC VERTEBRAL BURST FRACTURES

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Objective. To perform a comparative radiological analysis of the methods of hybrid stabilization (posterior fixation in combination with cement vertebroplasty and osteoplasty with deproteinized allobone) and circular stabilization (posterior fixation in combination with anterior fusion) used in the treatment of uncomplicated burst fractures of the vertebral bodies associated with osteoporosis.
Material and Methods. The study is retrospective. Two groups of patients were formed, and inclusion and exclusion criteria were determined. The magnitude of kyphosis correction (according to Cobb), the magnitude of residual postoperative kyphotic deformity, as well as its recurrence in the long-term postoperative period, and the sagittal balance (Barrey index) were assessed. The follow-up period was 12 months. Subjective assessments of the patient's condition were not considered.
Results. The magnitude of initial kyphotic deformity (>20°), incomplete achievement of kyphosis correction after surgery (>5°), the value of densitometry T-score, and sagittal imbalance before and after surgical intervention are, with a statistically significant difference, the main predictors of local kyphosis recurrence, incomplete correction of deformity and decompensated sagittal imbalance.
Conclusions. When comparing the methods of hybrid and circular stabilization, there was no statistical difference in radiological outcomes.
Key Words: burst fracture, osteoporosis, hybrid stabilization, circular stabilization, vertebroplasty, osteoplasty, anterior fusion, kyphosis, sagittal balance.
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A heightened interest in the surgical treatment of patients with vertebral body fractures associated with osteoporosis has been noted in the literature in recent years. Burst fractures account for about 40 % of cases in this cohort of patients [1]. Due to inadequate selection of treatment strategy, the outcomes of such injuries in more than 60 % of cases are post-traumatic, painful kyphotic deformities [2]. Because of the low effectiveness of puncture methods (cement vertebroplasty and balloon kyphoplasty) in the treatment of burst fractures, the concept of the need for stabilization of all support columns of the injured vertebra remains [3–5]. The procedures for using posterior fixation in conjunction with cement vertebroplasty [6] or allobone [7], wherein comparison has already been described in the literature [8], are presented. This stabilization technique is called hybrid. Nonetheless, circular stabilization, which is an anterior spinal fusion and transpedicular fixation, is still popular and, in some cases, indispensable [9, 10]. However, the use of such stabilization is limited in patients with osteoporosis. The lack of clear indications for the use of a particular treatment option, the identified causes of adverse outcomes as well as reasonable and reliable studies have prompted us to state the objective of this paper. The objective is to perform a comparative X-ray-based analysis of the methods of hybrid stabilization (transpedicular fixation in combination with cement vertebroplasty or osteoplasty of the injured vertebra) and circular stabilization (transpedicular fixation in combination with anterior spinal fusion) used in the treatment of burst fractures of the vertebral bodies associated with osteoporosis.

Material and Methods

The tasks of the retrospective study included the identification of predictors of incomplete correction of kyphotic deformity, recurrence of local kyphosis and sagittal imbalance in patients.

Inclusion criteria: uncomplicated fractures of vertebral bodies associated with osteoporosis of the thoracolumbar spine (T10–L2), complete and incomplete burst fractures (types A3, A4 according to AO Spine classification), T-score according to densitometry from -2.5 and below, absence of osteotropic therapy before surgery, postoperative follow-up period of at least 12 months. Additionally local osteoporosis of vertebral bodies was estimated in all patients by calculating the units of the Hounsfield scale.

Exclusion criteria: complicated spinal injuries and secondary osteoporosis.

The following parameters were assessed: the magnitude of kyphosis correction (according to the Cobb method) and the magnitude of residual postoperative kyphotic deformity. The correction was regarded as incomplete if its magnitude was more than 5°. Recurrences of deformity were assessed over 12 months. The deformity was considered recurrent if it increased by more than 5° during the entire postoperative follow-up (the error in the accuracy of radiological measurements of intersegmental correlations was 5°). The sagittal profile was assessed prior to and after the procedure, and 12 months after, the Barrey Index – C7/SFD ratio (-0.9+/-1) was also considered. The sagittal balance was divided as follows: balanced (C7/SFD is close to 0); compensated imbalance (0.5 < C7/SFD < 1); and decompensated imbalance (C7/SFD > 1) [11]. The subjective assessment of the patient's condition, as well as the complications occurred during the postoperative period were not considered in this study.

In 2014–2022, 2,351 patients underwent surgical treatment at the Department of Spinal Pathology of the Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan. Out of them 197 suffered from osteoporosis; 171 patients had incomplete and complete burst fractures. The injury in the thoracolumbar spine was in 149 of them. Our study involved 134 patients, who were divided into two groups. The first group included 58 patients who underwent posterior stabilization combined with cement vertebroplasty or osteoplasty of the injured vertebral body. Surgical treatment in this group was performed in 2018–2022. The second group included 76 patients who underwent posterior stabilization combined with anterior fusion in 2014–2017. The mean time from the moment of injury to surgery was 15 ± 7 days. The morphology of burst fractures in the study groups is presented in Fig. 1.

Statistical method. Descriptive statistics of continuous indicators were estimated as a median; for binary indicators, the number of cases and the percentage [95 % confidence interval of the percentage] were calculated using the Wilson's formula. The normality of the data distribution was checked using the Shapiro – Wilk test; the Mann – Whitney U test was used to compare the indicators between the groups; and the bias of the distributions was calculated with the construction of a 95 % confidence interval. Predictors of insufficient correction and loss of correction of kyphosis were determined by constructing logistic regression models. Pairwise numerical associations were identified by the construction of univariate models; multiple numerical associations (predictors) were determined by the construction of multivariate models. Statistical hypotheses were tested at a critical significance level of $p = 0.05$, i.e., the difference was considered statistically significant if $p < 0.05$.

Results

There was no statistical difference between the groups in the initial patient data. The age in the first group of patients was 66.17 ± 8.66 years, in the second: 59.37 ± 9.29 years; the value of the T-score in the first group was -3.2 ± 0.59, in the second: -2.96 ± 0.61; the magnitude of the initial kyphotic deformity in the first group was 14.91° ± 7.39°, in the second: 21.54° ± 5.58°. The morphological change of the injury was as follows: in the first group type A3 was 43.1 %, type A4 was 56.4 %; in the second group type A3 was 32.9 %, type A4 was 67.1 %. There was no difference in the sagittal profile (balanced, compensated or decompensated) between the groups prior to surgery ($p = 0.568$). There was no statistically significant difference in the magnitudes of kyphotic deformity and its correction after surgery and at the specified time of postoperative follow-up between the groups (Table 1). There was also no statistically significant difference in the course of the sagittal balance between the groups: $p = 0.081$ after surgery; $p = 0.617$ after 12 months.

When building logistic regression models, it was found that the technique of procedure does not affect either the completeness of correction or the frequency of recurrence of deformity in all follow-up periods ($p = 0.068$). The predictors of incomplete correction of deformity are decompensated imbalance before surgery, T-score value and initial kyphosis of more than 20° (Table 2). It is worth noting that the latter indicator has a significant function in the hybrid stabilization group (2.96 [1.07; 9.02], $p = 0.043$). The sensitivity of these predictors is 88.2 %. The loss of correction 12 months after surgery is significantly affected by decompensated imbalance and kyphosis of more than 10° (Table 3). The predictors of sagittal imbalance 12 months after surgery are T-score (6.76 [1.91; 28.82], $p = 0.005$) and decompensated imbalance not resolved during surgery (3.9 [1.49; 10.56], $p = 0.006$).

Clinical cases in both groups are given below (Fig. 2, 3).

Discussion

According to Josten et al. [12], injuries to intervertebral discs in burst fractures in the elderly are quite rare. This is due to two main reasons: the process of fibrotization (hyaline degeneration of the nucleus pulposus and dehydration) of the discs themselves and the low-energy injury resulting from osteoporosis. Because of this fact, it is believed that fixing the injured vertebral body with cement may be sufficient for the stability of the anterior column, and consequently, performing anterior spinal fusion with discectomy and partial corpectomy in such patients may constitute overtreatment [13]. Spiegl et al. [14] note loss of correction by 7.7° at mean after performing hybrid stabilization and, as a consequence, an increase in pain syndrome during 12 months after surgery. The authors do not specify the reasons for these outcomes. Schnake et al. [15] designed classification of osteoporotic fractures in which the morphology of injury to the vertebral body is crucial in the choice of surgical technique, and when defining indications for surgery, the value of the T-score, the severity of the pain syndrome and the concomitant medical condition were used. It is worth pointing out that the bone density is not considered by the authors as

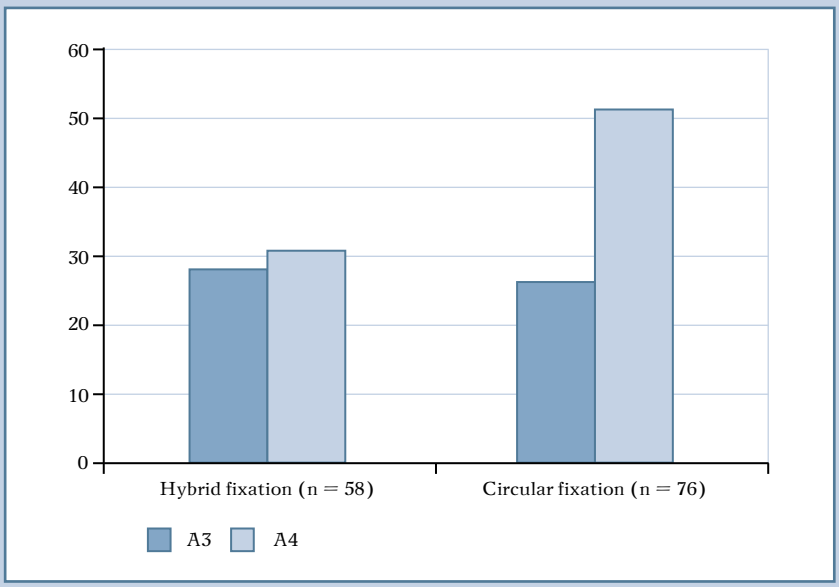

Fig. 1
Morphology of burst fractures in study groups

the leading criterion for choosing the surgical technique that probably led to a spread in the final treatment outcomes. Meanwhile, in these studies, the question of the state of the sagittal balance of patients before and after surgery, its change in the long-term postoperative period, as well as the its importance is not considered.

In our study, when comparing two surgical techniques, there was no statistically significant difference in radiological outcomes. Predictors of incomplete correction are bone mineral density (T-score) and the magnitude of the initial kyphosis of more than 20°. It should be note that the latter indicator significantly affects the risks of incomplete correction in the hybrid stabilization group that indicates the limited corrective capabilities of this technique. It is likely enough that preference for anterior spinal fusion should be given in the presence of a kyphotic deformity of more than 20°, because the fact that a complete deformity correction is necessary does not lose its relevancy in such patients. This is proved by other studies [16, 17]. Nevertheless, one should consider that there are high risks of unfavorable outcomes of anterior spinal fusion, in particular graft subsidence that may have a direct dependence on a reduced bone mineral density measured by the T-score [18]. The practical use of Hounsfield scale remains unclear. Though there are studies indicating the correlation of this parameter with the instability of instrumentation in degenerative diseases of the spine [19, 20], there are not enough papers devoted to the influence of this criterion in spinal injury in the junctional thoracolumbar spine. Additional cement augmentation of the vertebral bodies contiguous with the graft is proposed to prevent subsidence [21, 22]. Nevertheless, this technique remains controversial and requires additional research. Some authors use the techniques of corrective vertebrotomy and posterior spinal fusion with autogenous bone to eliminate the performance of anterior fusion [23].

Posttraumatic kyphotic deformities have a local nature. However, they cause compensatory changes in the thoracic and lumbar spine and may be accompanied by the sagittal imbalance. Meanwhile, it is common for patients with

Table 1
Dynamics of kyphosis in the study groups before surgery and at control follow-up examinations

Group	Before surgery	After surgery	4 months after	6 months after	12 months after	Difference (effect size) PSEUDOMED [95 % CI]	Wilcoxon signed-rank test p value
the 1st (n = 58)	13 [6; 16] 10.89 ± 7.46	0 [0; 3] 0.44 ± 5.59	0 [0; 5] 1.65 ± 6.14	1 [0; 6] 2.11 ± 6.21	2 [0; 6] 2.65 ± 6.66	0–1: 11.0 [10.5; 11.0] 1–2: -0.5 [-0.5; 0.0] 2–3: -0.5 [-0.5; -0.5] 3–4: 0.0 [-0.5; 0.0] 0–4: 8.5 [8.5; 8.5]	>0.05
the 2nd (n = 76)	20 [15; 26] 21.71 ± 8.60	0 [0; 2] 0.36 ± 3.23	0 [0; 2] 0.65 ± 3.15	0 [0; 2] 1.17 ± 3.67	1 [0; 2] 1.53 ± 4.23	0–1: 20.5 [20.5; 21.0] 1–2: 0.0 [0.0; 0.0] 2–3: 0.0 [0.0; 0.0] 3–4: 0.0 [0.0; 0.0] 0–4: 19.5 [19.5; 20.0]	>0.05

Table 2
Logistic regression models for incomplete correction of kyphosis in all patients

Covariates	Univariate models		Multivariate models	
	OR [95 % CI]	p	OR [95 % CI]	p
Decompensated imbalance before surgery	1.02 [1.01; 1.04]	0.010	1.02 [1.00; 1.05]	0.032
Initial kyphosis of >20°	0.34 [0.11; 0.94]	0.043	0.17 [0.04; 0.69]	0.019
T-score	2.19 [1.09; 4.63]	0.020	3.90 [1.36; 12.04]	0.013

OR — odds ratio.

Table 3
Logistic regression models for recurrence of kyphosis after 12 months in all patients

Covariates	Univariate models		Multivariate models	
	OR [95 % CI]	p	OR [95 % CI]	p
Decompensated imbalance before surgery	1.04 [1.02; 1.06]	<0.001	1.04 [1.01; 1.06]	0.002
Kyphosis after surgery of >10°	2.17 [0.66; 8.54]	0.02	3.08 [0.85;13.48]	0.04

OR — odds ratio.

spinal injuries associated with osteoporosis to have compensated and uncompensated changes in the sagittal balance before the injury. We assess the sagittal balance to evaluate the true magnitude of kyphotic deformity, as well as the spinopelvic correlation according to the guidelines [24]. The Barrey Index was used to simplify the assessment of the sagittal profile. It was noted that a number of patients suffering from decompensated imbalance before surgery in the long-term postoperative period not only remained in a decompensation condition but also lost local correction. This fact confirms the need for correction of the postural profile. Such outcomes correlate with reduced bone mineral density that is reflected both in our study and in the papers of other authors [25, 26]. Nevertheless, due to the small size of patient sample, additional studies are required to verify the confidence level as well as to analyze the effect of the spinopelvic parameters on the aggravation of the imbalance.

Conclusion

Circular and hybrid stabilization techniques result in the same radiological outcomes in the treatment of burst fractures of vertebral bodies associated with osteoporosis. The predictors of incomplete correction and loss of correction in the postoperative period are the following: decompensated imbalance, the quality of bone tissue and the magnitude of the initial kyphosis. During the preoperative planning of the choice of the surgical technique, it is required to consider not only the morphology of the injury and the magnitude of deformity, but also the assessment of the quality of the bone tissue and the sagittal profile of the patient.

The study had no sponsors.
The authors declare that they have no conflict of interest.
The study was approved by the local ethics committee of the institution.
All authors contributed significantly to the research and preparation of the article and read and approved the final version before publication.

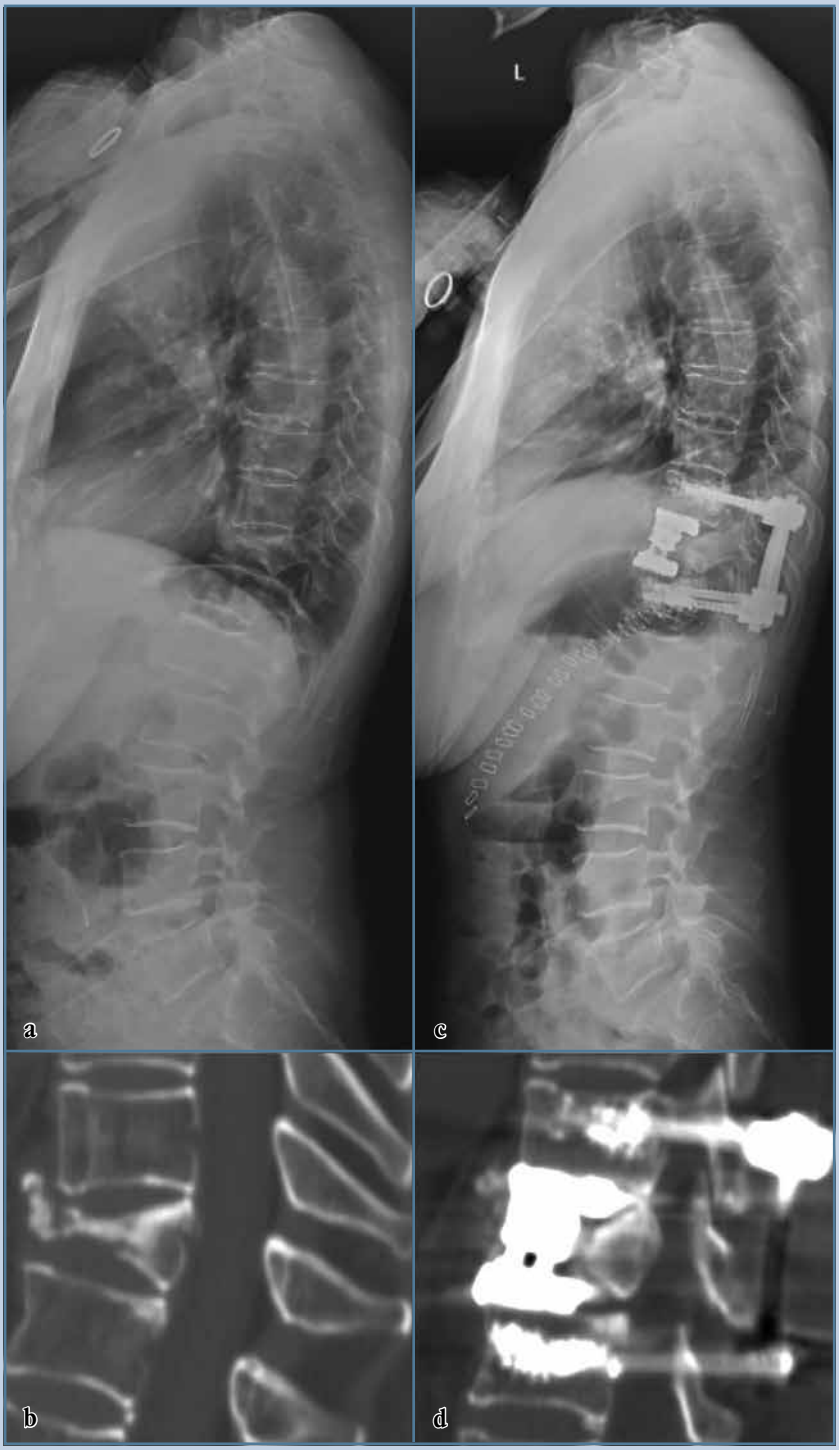

Fig. 2
Data from a 74-year-old female patient: **a, b** – burst fracture of the T11 vertebral body, posttraumatic kyphosis at the T10–T11 level is 27°, vertebral osteoporosis (T-score is -4.1), HU 106–111 SD; **c, d** – condition after anterior bisegmental spinal fusion at the T10–T12 level with a telescopic instrumentation, posterior stabilization with additional augmentation of screws

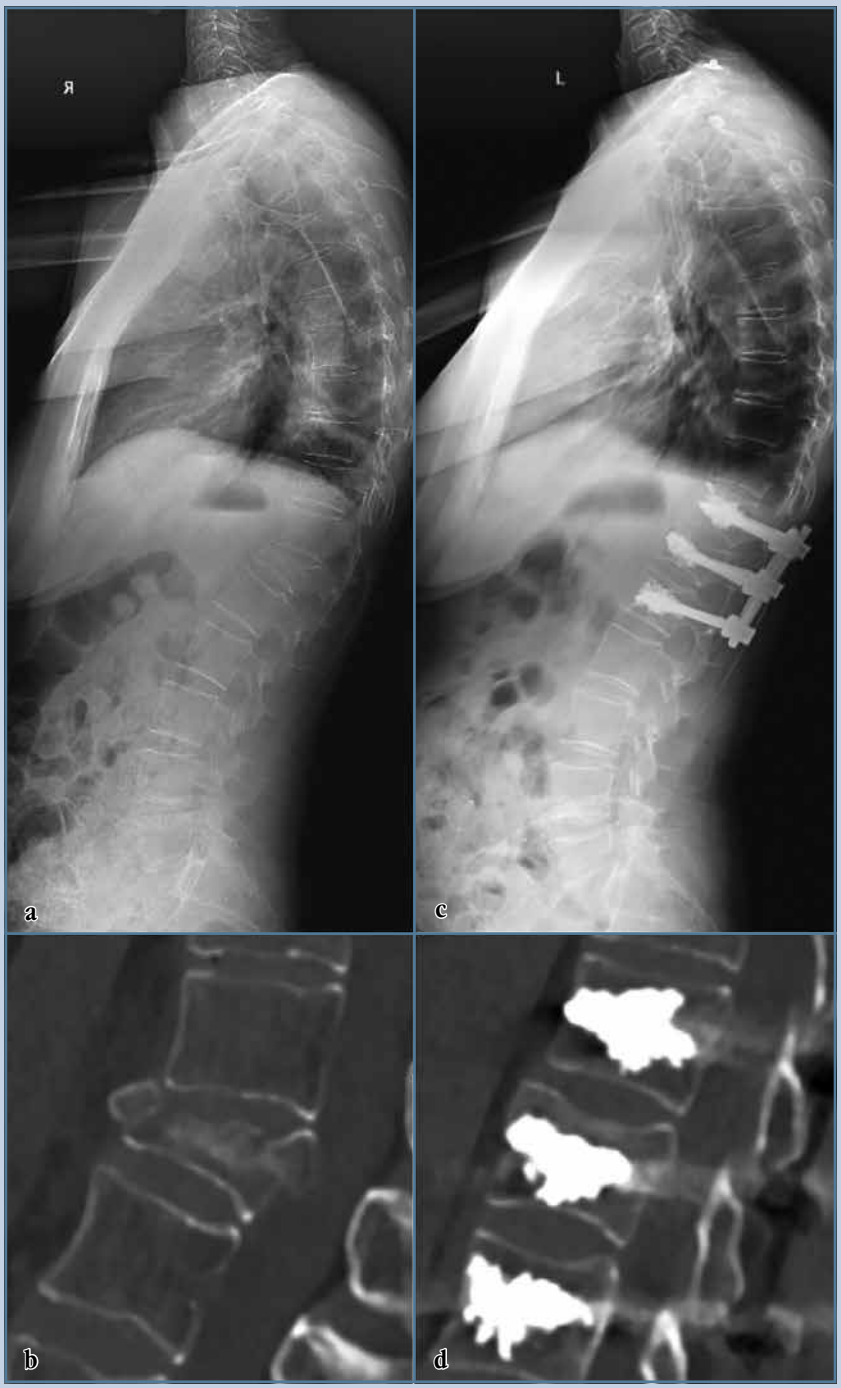

Fig. 3
Data from a 57-year-old female patient: **a, b** – burst fracture of the T12 vertebral body, posttraumatic kyphosis at the T11–T12 level is 18°, vertebral osteoporosis (T-score is -4.7), HU 46–72 SD; **c, d** – condition after posterior fixation in combination with cement augmentation of the injured vertebral body and screws

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