**Original article**
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# Comparative analysis of surgical treatment results for osteoporotic burst fractures of thoracolumbar vertebral bodies

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**Abstract**

**Introduction** Surgical methods for osteoporotic burst vertebral body fracture repair have their advantages and shortcomings. The use of circumferential stabilization and corrective vertebrotomies in elderly patients is highly invasive and carries great surgical risk. On the other hand, minimally invasive methods lead to recurrence of the deformity. Thus, in the treatment of patients with such pathology, it is necessary to choose a surgical method that allows achieving optimal results.

**Purpose** of the work was to compare the results of surgical treatment for osteoporotic burst fractures in thoracolumbar vertebral bodies using the developed method and methods of circular and hybrid stabilization based on clinical and radiological criteria.

**Materials and methods** The study was retrospective. Three groups of patients were formed according to the type of surgical intervention. Inclusion criteria were patients with primary osteoporosis who did not receive osteotropic therapy before surgery, with osteoporotic fractures (type OF3 and OF4) of the vertebral bodies of the thoracolumbar location (Th10–L2). The follow-up period was 12 months. The following criteria were assessed: the amount of kyphosis correction (according to the Cobb method), the amount of residual postoperative kyphotic deformity, as well as its recurrence in the long-term postoperative period; sagittal balance of the torso (Barrey index), subjective evaluation of the patient's condition (VAS). Quality of life assessment was not performed.

**Results** There were no statistically significant differences in the dynamics of sagittal balance during the follow-up period between the groups ($p > 0.99$). There was no difference between groups in clinical outcomes (VAS) at follow-up ($p > 0.05$). A statistically significant difference in the magnitude of kyphotic deformity and its correction in the specified postoperative periods was revealed between the hybrid fixation groups and the corrective vertebrotomy group. No difference was found with the circular stabilization group.

**Discussion** Due to the high risks of poor outcomes of anterior spinal fusion, in particular, implant subsidence, to avoid anterior spinal fusion, we used a method of focal kyphosis correction and posterior spinal fusion with autologous bone. The method proposed by the authors for the correction of focal kyphotic deformity in the treatment of patients with osteoporotic burst fractures of the vertebral bodies combines satisfactory correction of focal kyphosis with minimal surgical invasiveness, which reduces the risks of complications and poor outcomes. The proposed method may also be combined with hybrid fixation.

**Conclusion** The developed method for focal kyphotic deformity correction in the treatment of osteoporotic burst fractures of vertebral bodies provides satisfactory correction of focal kyphosis, reduces the risks of complications and poor outcomes in comparison with circular and hybrid stabilization.

**Keywords**: burst fracture, osteoporosis, hybrid stabilization, circular stabilization, vertebrotomy, kyphosis, sagittal balance

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## INTRODUCTION

In the contemporary world, the incidence of osteoporotic vertebral compression fractures has increased, and along with this, the number of patients seeking treatment for acute and chronic pain and progressive spinal deformities has grown [1]. In more than 60 % of cases, the outcome of these injuries is severe painful kyphotic deformities resulting from the pseudarthrosis of the damaged vertebral body [2, 3]. Therefore, spinal surgeons face the task of selecting rational methods of surgical intervention to avoid further compression of the damaged vertebra, achieve correction of focal kyphosis, create conditions for stabilization and consolidation of the fracture, and also prevent neurological disorders. The methods of circular stabilization using anterior spinal fusion in elderly patients with concomitant co-morbidities are highly invasive and carry a greater surgical risk [4, 5, 6, 7]. Minimally invasive methods of posterior stabilization in combination with vertebroplasty of the damaged vertebral body, as an alternative to circular fixation [8, 9], may lead to poor outcomes, such as loss of correction and relapse of pain syndrome [10], which was confirmed in our previous study [11]. In specific and complex cases associated with severe kyphosis (more than 30°) and/or sagittal imbalance, vertebral osteotomies are recommended [12, 13]. Those methods have a high ability to correct the deformity, but are technically complex and have a high risk of complications, which is especially important for patients in the older age group.

**The purpose of the work** was to compare the results of surgical treatment for osteoporotic burst fractures in thoracolumbar vertebral bodies using the developed method and methods of circular and hybrid stabilization based on clinical and radiological criteria.

## MATERIALS AND METHODS

The study included 52 patients. All were admitted to the clinic as emergency cases. Based on clinical and radiographic findings, and MSCT data, vertebral body fractures due to osteoporosis were detected in the thoracolumbar spine. Among the patients there were 40 women (77.7 %) and 12 men (22.3 %). The average age was 64.36 ± 6.74 years. The main causes of osteoporotic fractures were low-energy trauma (falls from body height onto the back or buttocks) in 68.4 % of cases and physical activity (bending work, lifting weights) in 31.6 %.

By simple randomization, all patients were divided into three groups. Group 1 ($n$ = 17) underwent posterior stabilization in combination with cement plasty or osteoplasty of the injured vertebral body (hybrid fixation). Group 2 ($n$ = 18) underwent posterior stabilization combined with anterior spinal fusion (circular stabilization). Groups 1 and 2 were control groups. Patients in group 3 ($n$ = 17, study group) underwent extended posterior fixation in combination with corrective vertebrotomy (authors' method).

A comparative analysis was carried out using a number of radiological and clinical criteria.

Correction of focal kyphotic deformity (RF patent for invention No. 2810182) was performed as follows. At the preoperative stage (Fig. 1 a), the angle of kyphotic deformity was measured according to Cobb. Next, the amount of resection of the articular pairs of vertebrae at the level of injury was determined.

To do this, at the damaged level on both sides, a resection angle was drawn, which corresponds to the angle of kyphotic deformity (Fig. 1 b):

— on one side of the articular pairs of vertebrae, the apex of the angle was determined, which is the caudo-dorsal point of the body of the overlying vertebra from the damaged one;

— the next point was located on the lateral part of the lower articular process of the overlying vertebra from the damaged one;

— the end point of the angle was determined by the lateral surface of the lower edge of the superior articular process of the damaged vertebra.

Next, the points were projected onto the opposite side of the articular pairs of vertebrae (the points marked on the articular processes form the base of the resection angle). The height of the base of the angle of the wedge-shaped defect was measured in order to subsequently perform resection equal to the height of the base.

During the operation, transpedicular screws were first installed in accordance with anatomical landmarks under X-ray control, at least into two segments above and below the apex of the focal deformity. Then, according to preoperative planning, an osteotomy was performed to the full transverse size of the articular processes on both sides, while the lower articular processes of the overlying vertebra and the upper articular processes of the damaged vertebra were removed in the plane to the apex of the resection angle in the anterior and upward direction, thereby forming a wedge-shaped defect (Fig. 1 c). Resection of the articular pairs on the other side was performed in a similar manner. Next, by postural extension, the lower articular process of the overlying vertebra was joined with the upper articular process of the damaged vertebra, thereby achieving correction of the kyphotic deformity, and the angle became equal to 0° according to Cobb (Fig. 1 d, e). Finally, the rods of the transpedicular structure were installed and fixed in the screw heads and the final implantation of the structure was carried out; if necessary, additional contraction was performed to improve the contact of the bone surfaces of adjacent vertebrae in the resection area. The position of the spinal roots was revised. The bone graft obtained during resection was placed along the posterior surface, overlapping the resection line.

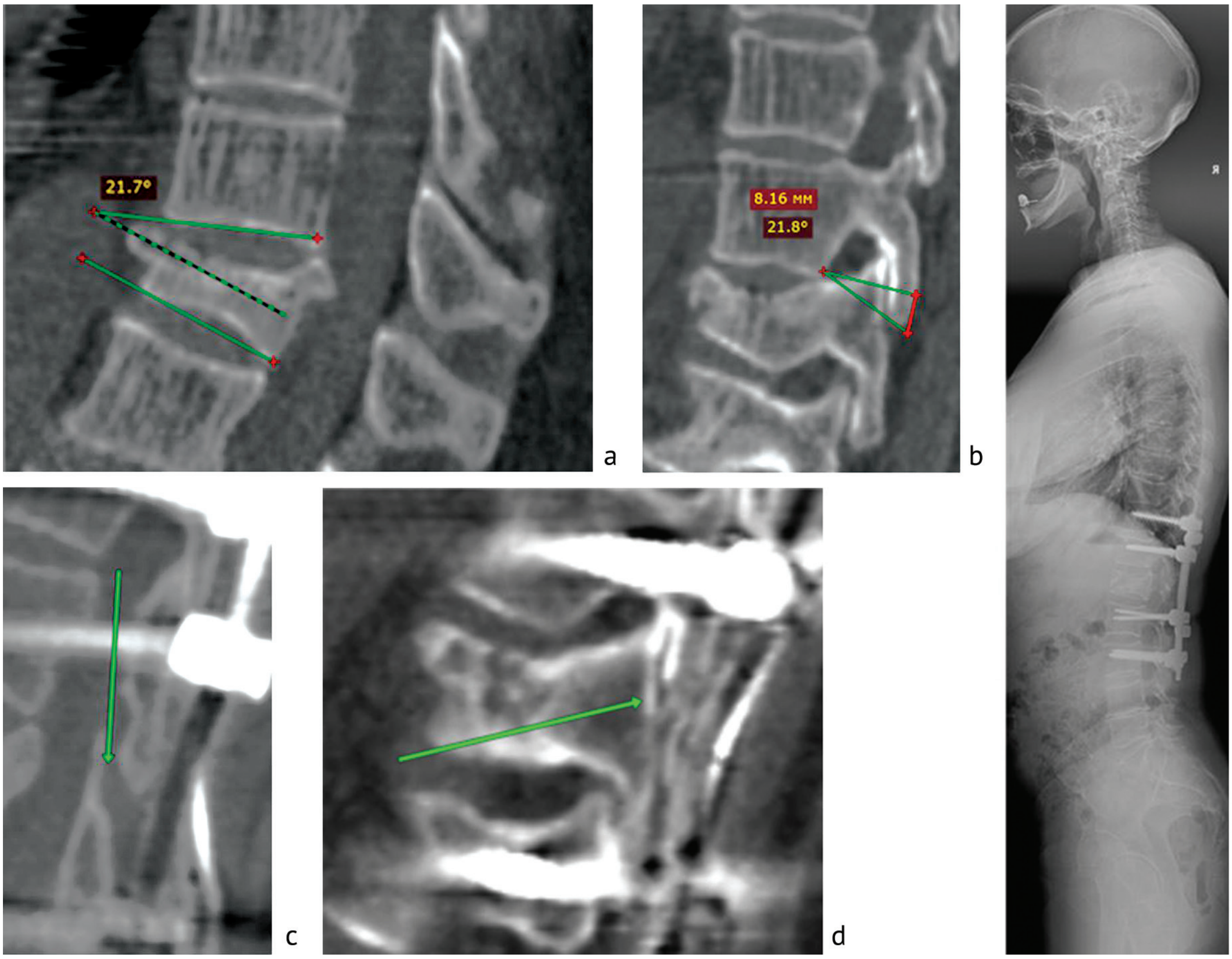



**Fig. 1** Stages of the method for correcting focal kyphotic deformity: *a* measuring the angle of kyphotic deformity; *b* calculation of the resection angle; *c* resection zone; *d, e* closure of the defect, correction of kyphotic deformity

Inclusion criteria were primarily diagnosed uncomplicated vertebral body fractures due to osteoporosis in the thoracolumbar spine (Th10–L2); complete and incomplete pathological burst fractures (type OF3 and OF4 according to DGOU) [14]; T-criterion according to densitometry data from −2.5 and lower; lack of osteotropic therapy before surgery; postoperative follow-up of at least 12 months; the initial kyphotic deformity from 20° and more.

Exclusion criteria were complicated spinal injuries (with neurological deficit); presence of secondary osteoporosis.

The following criteria were assessed: the amount of kyphosis correction (according to the Cobb method), the amount of residual postoperative kyphotic deformity. The correction was considered incomplete if its value was > 5°. Recurrence of deformity was assessed after 12 months. The deformity was considered recurrent if it increased by more than 5° throughout the entire postoperative follow-up (the error in the accuracy of radiological measurements of intersegmental relationships is 5°). The sagittal profile was assessed before, immediately after surgery and 12 months after surgery, the Barrey index C7/SFD parameter (−0.9 ± 1) was considered. Sagittal balance was divided as follows: balanced (C7/SFD close to 0); compensated imbalance (0.5 < C7/SFD < 1); decompensated imbalance (C7/SFD > 1) [15]. Subjective assessment of the patient's condition was assessed using the VAS pain score. Quality of life assessment was not evaluated. The average time from injury to surgery was 15 ± 7 days. The duration of operations and blood loss were assessed according to medical documentation. Osteotropic therapy was recommended to all patients after surgery, but its effectiveness in the postoperative period was not assessed in this study.

*Statistical methods* Continuous data on age, hospital days, rotation center shifts, and VAS and Harris scores were tested for normal distribution using the Kolmogorov method. Due to the small number of normal data, comparisons were made using nonparametric methods.

To describe continuous indicators, medians [first quartile; third quartile] (MED [Q1; Q3]), and as auxiliary — mean ± standard deviation (MEAN ± SD) and minimum – maximum values were used. For categorical and binary indicators, the number of patients (frequency) for each category was determined; for the frequencies of binary indicators of magnitude and kyphosis correction, the error of the 95 % confidence interval (95 % CI) was calculated. Comparisons of continuous measures between groups were performed using the Mann – Whitney U test. To assess the average difference between distributions (effect size), the median of pairwise differences between groups (pMED) was calculated with the construction of 95 % CI and the standardized mean difference (SMD). Categorical measures were compared using two-tailed Fisher's exact test. Statistical hypotheses were tested at a critical significance level of p = 0.05, i.e. the difference was considered significant if $p < 0.05$. Statistical calculations were carried out in R version 4.1.3 2022-03-10 (Vienna, Austria).

## RESULTS

The initial kyphotic deformity in the first group was 22.06 ± 1.92° (20–27°), 27.17 ± 5.36° (20–35°) in the second group and in the third it measured 25.94 ± 5, 24° (20–35°). The average T-criterion value according to densitometry in all groups was 3.18 ± 0.59. There were no differences in the sagittal profile (balanced / compensated / decompensated) before surgery between the groups: in groups 1 and 3 $p = 0.16$, in groups 2 and 3 $p = 0.302$. Within the groups, there was a difference in the dynamics of kyphosis; in group 1 (loss of correction) $p = 0.011$ (Table 1, Fig. 2). A statistically significant difference in the magnitude of kyphotic deformity and its correction in the specified periods of the postoperative observation was revealed between groups 1 and 3 (Table 1); comparing groups 2 and 3, no difference was found (Table 1, Fig. 3). There was no statistically significant difference in the dynamics of sagittal balance at the control point of observation between groups 1 and 3, 2 and 3 ($p > 0.99$) (Fig. 4). There was no difference between groups in clinical outcomes (VAS) at the follow-up ($p > 0.05$) (Fig. 5).

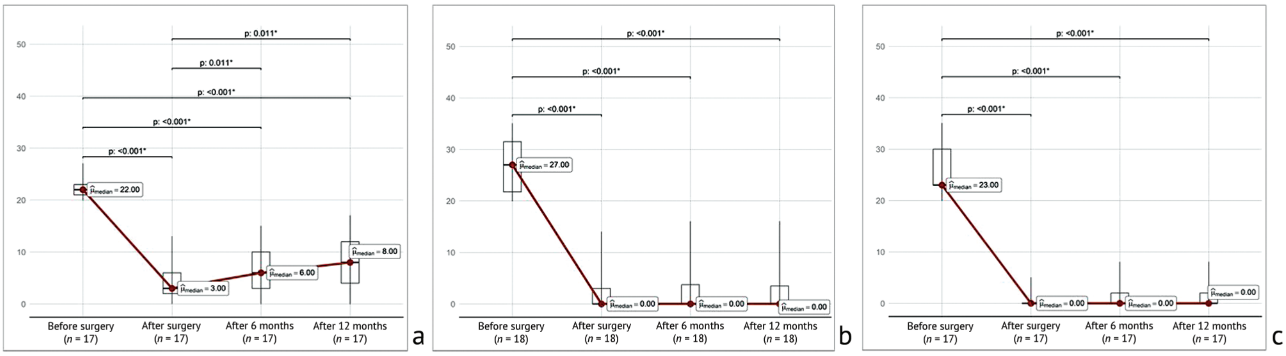


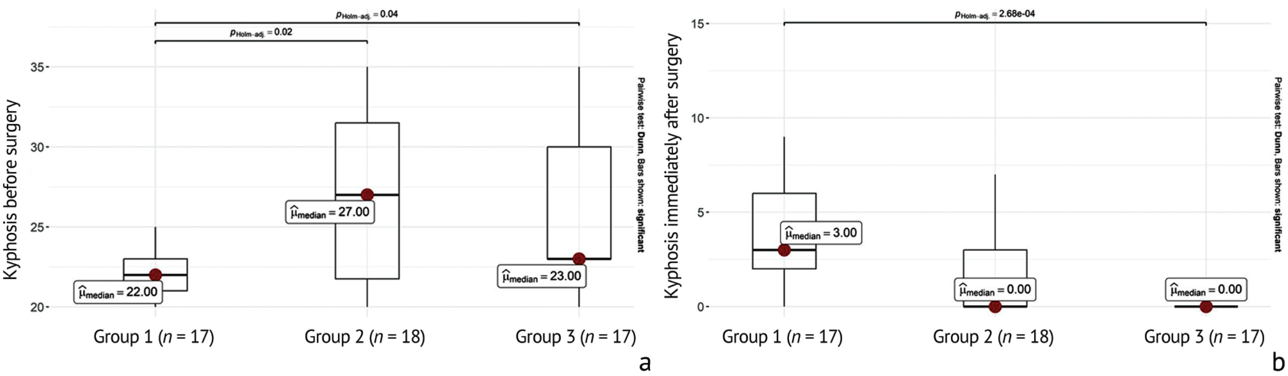

**Fig. 2** Dynamics of kyphosis values within groups: *a* — group 1; *b* — group 2; *c* — group 3

Table 1

Comparison of correction values and dynamics of focal kyphosis between groups

| Parameter | Group 1<br>(*n* = 17) | Group 2<br>(*n* = 18) | Group 3<br>(*n* = 17) | Comparison | |
|---|---|---|---|---|---|
| | | | | Difference | *p*–level |
| Kyphosis before surgery,<br>MED [Q1; Q3]<br>MEAN ± SD<br>(MIN – MAX) | 22 [21; 23]<br>22.06 ± 1.92<br>(20 – 27) | 27 [21.75; 31.5]<br>27.17 ± 5.36<br>(20 – 35) | 23 [23; 30]<br>25.94 ± 5.24<br>(20 – 35) | пМЕД [95 % ДИ]: 2 [1; 8]<br>СО [95 % ДИ]: –0.98 [–1.7; –0.27]*<br>пМЕД [95 % ДИ]: –1 [–6; 3]<br>СО [95 % ДИ]: 0.23 [–0.43; 0.9]** | 0.012*.<br>0.584** |
| Kyphosis after surgery,<br>MED [Q1; Q3]<br>MEAN ± SD<br>(MIN – MAX) | 3 [2; 6]<br>4.24 ± 3.51<br>(0 – 13) | 0 [0; 3]<br>2.5 ± 4.02<br>(0 – 14) | 0 [0; 0]<br>0.47 ± 1.37<br>(0 – 5) | пМЕД [95 % ДИ]: –3 [–6; –2]<br>СО [95 % ДИ]: 1.41 [0.66; 2.17]*<br>пМЕД [95 % ДИ]: 0 [–2; 0]<br>СО [95 % ДИ]: 0.67 [–0.01; 1.35]** | < 0.001*.<br>0.040** |
| Kyphosis at 6 months post-surgery,<br>MED [Q1; Q3]<br>MEAN ± SD<br>(MIN – MAX) | 6 [3; 10]<br>7.06 ± 4.64<br>(0 – 15) | 0 [0; 3.75]<br>3.11 ± 4.97<br>(0 – 16) | 0 [0; 2]<br>1.24 ± 2.28<br>(0 – 8) | пМЕД [95 % ДИ]: –6 [–9; –3]<br>СО [95 % ДИ]: 1.59 [0.82; 2.37]*<br>пМЕД [95 % ДИ]: 0 [–2; 0]<br>СО [95 % ДИ]: 0.48 [–0.19; 1.15]** | < 0.001*.<br>0.304** |
| Kyphosis at 12 months post-surgery,<br>MED [Q1; Q3]<br>MEAN ± SD<br>(MIN – MAX) | 8 [4; 12]<br>7.71 ± 5.27<br>(0 – 17) | 0 [0; 3.5]<br>3.11 ± 5.06<br>(0 – 16) | 0 [0; 2]<br>1.29 ± 2.37<br>(0 – 8) | пМЕД [95 % ДИ]: –6 [–9; –3]<br>СО [95 % ДИ]: 1.57 [0.8; 2.35]*<br>пМЕД [95 % ДИ]: 0 [–2; 0]<br>СО [95 % ДИ]: 0.46 [–0.22; 1.13]** | < 0.001*.<br>0.331** |

*Note*: * — comparison of groups 1 and 3 (hybrid fixation and corrective vertebrotomy); ** — comparison of groups 2 and 3 (circular fixation and corrective vertebrotomy)



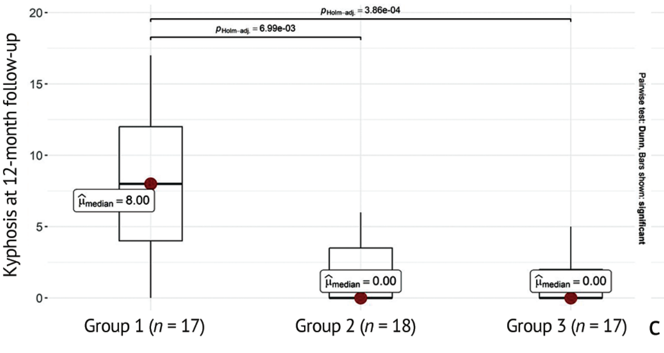




**Fig. 3** Comparison of kyphosis values before surgery (*a*), immediately after surgery (*b*) and at 12-month follow-up (c) in all groups

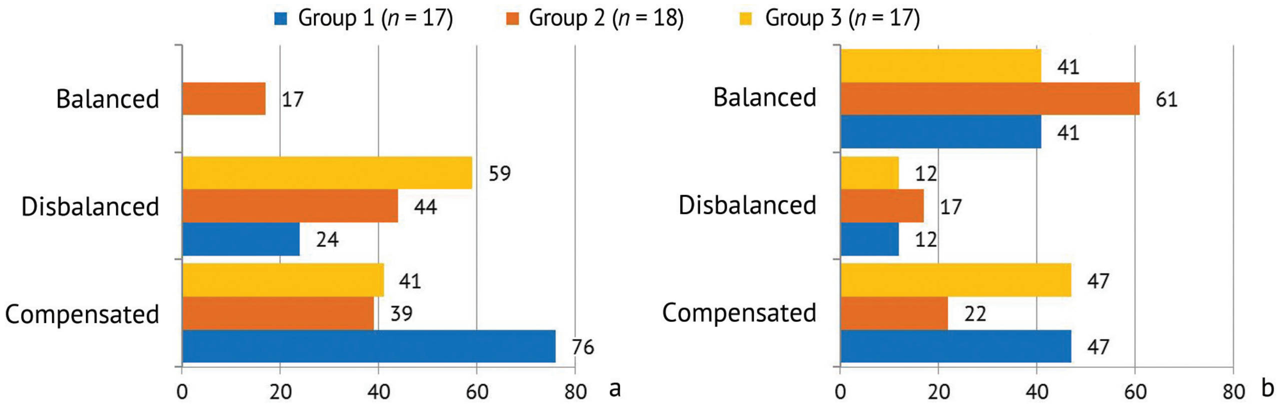



**Fig. 4** Dynamics of the sagittal profile before surgery (*a*) and after surgery (*b*) in all groups

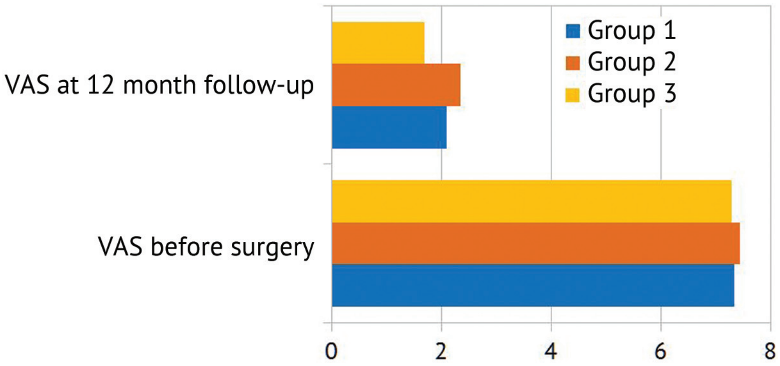



**Fig 5** Comparison of VAS score between the groups

There were no complications in groups 1 and 3. In group 2, the early postoperative period in 2 patients (11.1 %) was complicated by brachioplexopathy, and hospital-acquired pneumonia was detected in 1 patient (5.5 %). The average blood loss in group 1 was 233.6 ml, in group 2 — 531.3 ml, in group 3 — 329.2 ml. The average time of surgical intervention in group 1 was 96.6 minutes, in group 2 — 262.3 minutes; in group 3 — 153.5 min.

## DISCUSSION

The classification of spinal osteotomies proposed by Schwab et al. [16], as well as the features and principles of surgical methods of their use for vertebral injuries due to osteoporosis remain the same. There is a Smith-Peterson vertebrotomy method [17, 18], which involves resection of at least three spinous processes, separation of the ligamentum flavum, and cutting of the articular surfaces of both pairs of articular processes in the frontal plane. The method involves using the dorsal parts of the vertebral body (middle column) as a rotation point while correcting the deformity through a blocked intervertebral disc. The result is lengthening of the anterior and shortening of the posterior columns of the spine. In this case, the anterior longitudinal ligament ruptures and the vertebral bodies diverge with the formation of some space between them. The manipulation is accompanied by a high risk of damage to large vessels. Another shortcoming of this method is incomplete bone defect closure, which does not ensure consolidation and fusion of the fracture and, as a result, the spine remains unstable. This method is characterized by a low degree of deformity correction (about 10°) and high trauma, which leads to a long postoperative period and a high risk of infection [19]. Along with this, there is a Ponte method of corrective vertebrotomy [20, 21], which is performed in the thoracic spine (levels 11–13): the spinous and articular processes are completely removed, a wide resection of the semi-arches is performed, the ligamentum flavum is completely removed, and the roots of the arches are resected. The shortcoming of this method is the limitation on its use (only the thoracic spine). High morbidity during its implementation and resection of a large volume of bone structures accompanied by significant blood loss increase the duration of postoperative care and the risk of infection. The spine remains in an unstable position due to resection of the articular processes that is performed in the anteroposterior direction until complete excision.

A number of studies assessed the clinical and radiological results, complications and outcomes of subtraction osteotomy (PSO), including the authors' modifications [22, 23, 24]. In each of them, satisfactory restoration of focal kyphosis and sagittal balance was noted. However, the authors place special emphasis on patients with neurological deficits secondary to trauma, for which decompression of neural structures is important. Therefore, due to the high morbidity, this surgical technique in patients with uncomplicated pathology is not needed [25, 26, 27].

Some researchers also tried to correct the sagittal imbalance using VCR for severe kyphosis. The results of a two-center retrospective study including 17 patients showed significant improvement in segmental kyphosis and regression of pain [28]. In a five-year study of 109 patients, Pehlivanoglu et al. [29] suggested that VCR combined with telescopic cage implantation is a safe and effective procedure that significantly improves clinical outcomes through decompression and reconstruction of the resected vertebra. The telescopic cage provides stabilization of the ventral column, minimizing the load on the posterior structure [30]. In their retrospective study, Sehmisch et al. [31] used the VCR technique on the thoracic spine in patients with osteoporotic fractures and post-traumatic kyphosis of more than 45°. The follow-up period was 36 months. All patients showed correction of kyphotic deformity by 20 ± 10° and a decrease in pain from 8.6 ± 2.0 VAS points to 5.0 ± 1.4. The average kyphosis was 25 ± 14° (5–53°). Bone fusion was achieved within 6 months. Preoperative Oswestry Disability Index (ODI) analysis showed severe disorders in two patients (41–60 %), five patients had very severe functional disorders (61–80 %) and three patients had complete functional failure (81–100 %). After surgery, six patients reported severe impairment (41–60 %), three reported very severe impairment, and one patient reported complete functional failure.

The work of Xu et al. [32] presented a retrospective study involving 238 patients with chronic osteoporotic fractures, 48 of whom had severe kyphotic deformity. Postoperative follow-up in all groups was carried out up to 38 months. According to VAS assessment, the pain syndrome in all patients decreased to 2 points (2.12 ± 0.74), the disability index dropped from 70 (70.18 ± 2.24) to 40 (40.09 ± 2.24). Depending on the level of kyphosis and neurological deficit, Ponte, SPO, PSO, VCR operations were performed. Using all methods, the authors achieved satisfactory results, which correspond to the results of the work of other researchers [33, 34, 35, 36]. However, VCR requires a higher level of surgical skills and longer training for surgeons [37]. Tomita et al. [38] reported that shortening of the posterior column can be divided into three intervals: shortening of the spine to 1/3 of the segment is safe, characterized by the absence of deformity of the dural sac or spinal cord; shortening of the spine from 1/3 to 2/3 of the segment is relatively safe, characterized by corrugation of the dural sac without spinal cord deformity; a dangerous variant involves shortening a spinal segment by more than 2/3 of a segment, which causes deformity of the dural sac and spinal cord with neurological impairment. Despite the high degree of deformity correction, three-column vertebrotomies are accompanied by a long surgical session, much blood loss and big volume of bone tissue resection, as well as the risk of iatrogenic neurological [39] and mechanical complications [40, 41].

The advantages of our method compared to existing versions of spinal osteotomies are that the method has no restrictions on its use and can be performed on any part of the spine. The method is low-traumatic, since a small volume of bone structures is resected with minimal blood loss, which reduces the duration of the early postoperative period and reduces the risk of infection, the spine remains in a stable position. The method ensures planned correction of focal kyphosis in the sagittal plane, minimal volume of bone tissue resection, tight contact of resected areas of adjacent vertebrae in the position of the achieved correction and posterior bone fusion.

Our method of correction of focal kyphotic deformity presented in the study was compared with circular stabilization and there was no statistically significant difference in the amount of deformity correction between the groups. There was a significant difference with the hybrid stabilization group both in the correction of deformity and in the magnitude of kyphosis after surgical treatment and during the specified periods of postoperative follow-up. The results were also assessed within groups. It is noteworthy that the average loss of correction in the hybrid fixation group was 7.7°, which coincides with the results of the authors of this method [42]. In the study group, loss of correction was detected in three patients (13.6 %). In the first case, the initial deformity was 35°, and the residual one was 11°, which indicates the limited corrective capabilities of our method. However, it is worth noting that kyphosis of this magnitude in acute burst fractures is rare and develops mainly into rigid deformities in osteonecrosis of the vertebrae. Two patients had decompensated imbalance both before and after surgery, what again confirms the need for correction of the sagittal profile [43–47].

## CONCLUSION

Our method for correcting focal kyphotic spinal deformity in osteoporotic burst fractures of the vertebral bodies, in comparison with circular and hybrid stabilization, demonstrates satisfactory correction of focal kyphosis, with minimal surgical invasiveness, which reduces the risks of complications and poor outcomes. The technique can also be combined with hybrid fixation, but it requires future studies.

***Conflict of interest*** *The authors declare no conflict of interest.*

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***Ethical statement*** *Based on the results of the conclusion of the Local Ethics Committee (extract from the minutes of the meeting 001/24 of January 15, 2024), this study can be published in the open press and does not contain classified information.*

***Informed consent*** *Not required.*

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