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A novel assessment system for osteoporotic vertebral compression fractures

Weiqi Han[1,2,3], Zhibo Deng[1,3], Zhao Lin[1,3], Jun Luo[1] & Jie Xu[1]✉

The objective of this study was to introduce and validate a novel developed scoring system tailored specifically for osteoporotic vertebral compression fractures (OVCFs), aiming to provide guidance for treatment selection. A retrospective analysis spanning from March 2016 to March 2021 was conducted on 208 patients diagnosed with osteoporotic vertebral compression fractures (OVCFs) who received conservative treatment. Patients were categorized into low-score (47 cases), medium-score (98 cases), and high-score (63 cases) groups based on the Novel Assessment System for OVCFs (NASOVCF) scores. Comparative analyses of radiographic and clinical data were performed, and logistic regression analysis was used to determine the risk factors for bone non-union and progressive kyphosis. The high-score group exhibited significantly inferior outcomes, characterized by higher Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) scores ($P < 0.05$), increased vertebral height loss, and kyphosis angle differences compared to the low and medium-score groups ($P < 0.05$). Notably, a bone union rate of 38.1% (24/63) was observed in the high-score group, significantly lower than that of the low-score group (97.9%, 46/47). Furthermore, the progressive kyphosis rate was 47.6% (30/63) in the high-score group, significantly higher than the 17.3% (17/98) observed in the medium-score group and the 2.2% (1/46) observed in the low-score group. In multivariate analysis, higher NASOVCF score emerged as an independent risk factor for bone non-union (OR = 1.713, 95% CI 1.458–2.013, $P < 0.001$). Similarly, higher NASOVCF score (OR = 1.373, 95% CI 1.203–1.568, $P < 0.001$), along with female gender and higher pre-treatment ODI score, were identified as independent risk factors for progressive kyphosis. The area under the curve (AUC) for bone non-union and progressive kyphosis were 0.895 and 0.835, respectively, indicating robust discriminative performances. Higher NASOVCF score was identified as a significant risk factor for non-union and progressive kyphosis following conservative treatment in OVCFs. NASOVCF score emerged as a crucial predictor for adverse outcomes in patients at high risk who underwent conservative management. Surgical interventions such as vertebral augmentation may represent a potentially superior option for individuals with high NASOVCF scores.

Keywords Osteoporotic vertebral compression fracture, Thoracic vertebra, Lumbar vertebra

Abbreviations

OVCFs	Osteoporotic vertebral compression fractures
TLICS	Thoracolumbar Injury Classification and Severity Score
NASOVCF	New assessment system for osteoporotic vertebral compression fractures
MRI	Magnetic resonance imaging
BMD	Bone mineral density
MRI	Magnetic resonance image
T1WI	T1-weighted image
T2WI	T2-weighted image
VAS	Visual analog scale
ODI	Oswestry disability index
KA	Kyphosis angle
VHL	Vertebral height loss

[1]Shengli Clinical Medical College of Fujian Medical University, Fuzhou, People's Republic of China. [2]Department of Orthopaedics, Shaoxing People's Hospital, Shaoxing, Zhejiang, People's Republic of China. [3]Weiqi Han, Zhibo Deng, and Zhao Lin contributed equally to this work. ✉email: jiexud@126.com

Background

Osteoporotic vertebral compression fractures (OVCFs) are a common fracture among individuals with osteoporosis, particularly postmenopausal women[1]. According to data from the International Osteoporosis Foundation, approximately 9.2 million new fracture events occur globally each year, with about 50% of them attributed to osteoporosis, including OVCFs[2]. Studies have shown that the incidence of OVCFs is higher among individuals aged 65 and above. Research indicates that the incidence rate of OVCFs in elderly women can reach 20–25%[1]. These fractures can lead to symptoms such as back pain, loss of height, and spinal kyphosis, which can significantly affect patients' quality of life and increase the risk of further fractures. Therefore, effective, and proactive treatment of OVCFs is crucial.

Conservative treatment, due to its advantages such as low risk, non-invasiveness, low cost, and reversibility, is a commonly used treatment method for OVCFs[3,4]. However, conservative treatment may require a longer rehabilitation process, especially for severe fractures, which may take more time to pain relief and functional recovery. Therefore, some scholars advocate for active surgical treatment[5]. Surgical treatment offers the advantage of rapidly restoring vertebral stability, directly repairing the fracture, restoring vertebral height, and facilitating posture recovery[6,7]. However, surgical treatment such as percutaneous vertebroplasty was also associated with corresponding surgical complications, including bone cement leakage and secondary fractures[8–10]. It has been reported that the incidence of bone cement leakage in percutaneous vertebroplasty ranges from 10–40%[8,9]. Therefore, the treatment of OVCFs still remains controversial.

The formulation of treatment plans necessitates a comprehensive and effective assessment system for evaluating OVCFs. The Thoracolumbar Injury Classification and Severity Score (TLICS) classification, extensively utilized in assessing the severity of thoracolumbar fractures and determining treatment plans, evaluates thoracolumbar fractures based on three key aspects: type of injury, integrity of the posterior ligamentous complex, and additional nerve injury[11]. It is important to note, however, that this system is primarily applicable to traumatic fractures rather than osteoporotic fractures. Osteoporotic fractures primarily manifest due to weakened bones resulting from osteoporosis and typically do not involve significant traumatic factors. Alternative classification systems, such as the Genant classification or Magerl classification, are employed to assess the severity of fractures[12]. However, these classification systems primarily focus on fracture morphology and lack comprehensive evaluation for OVCFs. Currently, there is still a lack of an effective evaluation system specifically designed for OVCFs to guide treatment selection.

In this study, a novel assessment system for osteoporotic vertebral compression fractures (NASOVCF) is proposed, encompassing the evaluation of four aspects, including fracture type, fracture morphology, MRI signal changes, and bone mineral density (BMD). The objective of this study was to validate the NASOVCF score for predicting bone non-union and progressive kyphosis after conservative treatment of OVCFs, with the aim of providing guidance for treatment selection.

Methods

Study design

From March 2016 to March 2021, a retrospective study was undertaken at a single spinal center, encompassing the inclusion of 208 patients with a single osteoporotic thoracolumbar compression fracture who underwent conservative treatment. Based on NASOVCF scoring system, the patients were classified into low, medium, and high score groups. A comparison of clinical and radiographic outcomes was conducted among the three groups. Logistic regression analysis was used to determine the risk factors for bone non-union and progressive kyphosis, and to validate whether the NASOVCF scoring system could predict the prognosis of OVCFs treated conservatively, demonstrating its clinical utility. Approval was obtained from the Ethics Committee of Shaoxing People's Hospital (NO2024-040-Y-01), and informed consent was acquired from all patients.

Participants

The inclusion criteria for this study included patients aged 60 years or older with single-segment thoracolumbar compression fractures caused by low-energy trauma, who received conservative treatment, had a preoperative BMD value ≤ -1.0 SD, and had a follow-up period of more than 6 months. The exclusion criteria included patients with secondary osteoporosis due to endocrine disorders, spinal infections, or corticosteroid use, as well as patients with pathological fractures caused by primary or metastatic tumors and those with severe cardiopulmonary dysfunction and an expected lifespan of less than 1 year.

Baseline data

Baseline data included age, gender, fracture segment, height, weight, body mass index (BMI), and fracture type, which were directly obtained from the electronic medical record system. BMD was measured using dual-energy X-ray, with the result being the average BMD value from L1 to L4, excluding the fractured segment.

NASOVCF scoring system

Univariate analysis identified several significant risk factors for bone nonunion, including burst fractures (OR = 5.677, 95% CI: 2.781–11.586, $P < 0.001$), vertebral height loss (VHL) of ≥ 15% (OR = 9.162, 95% CI: 4.181–20.080, $P < 0.001$). kyphosis angle (KA) ≥ 15° (OR = 7.382, 95% CI: 2.567–21.226, $P < 0.001$), diffuse low signal on T2WI (OR = 6.427, 95% CI: 2.919–14.151, $P < 0.001$) and Lower BMD. Based on the logarithmic transformation of OR values, a scoring system was developed, assigning 2 points each for burst fracture, VHL ≥ 15%, KA ≥ 15°, diffuse low signal on T2WI (T2-weighted image), and BMD (-3.5 < T ≤ -2.5), while BMD (T ≤ -3.5) was assigned 4 points (Table 1).

Characteristics	Total (*N*)	Univariate analysis		Ln (OR)	Score
		Odds ratio (95% CI)	*P* value		
Fracture type	208				
Compression fracture	161	Reference			
Brust fracture	47	5.677 (2.781–11.586)	< 0.001	1.74	2
VHL at pretreatment	208				
< 15%	171	Reference			
≥ 15%	37	9.162 (4.181–20.080)	< 0.001	2.21	2
KA at pretreatment	208				
< 15°	191	Reference			
≥ 15°	17	7.382 (2.567–21.226)	< 0.001	2.00	2
MRI signal on T2WI	208				
Non-diffuse low signal	103	Reference			
Diffuse low signal	105	6.427 (2.919–14.151)	< 0.001	1.86	2
BMD	208				
−2.5 < T ≤ -1.0	91	Reference			
−3.5 < T ≤ -2.5	83	5.826 (2.083–16.294)	< 0.001	1.76	2
T ≤ -3.5	34	35.964 (11.354–113.909)	< 0.001	3.58	4
Age	208	0.999 (0.953–1.048)	0.975		
Gender	208				
Female	157	Reference			
Male	51	0.436 (0.182–1.042)	0.062		
Injured vertebrae	208				
T11	30	1.150 (0.375–3.526)	0.807		
T12	38	1.349 (0.482–3.780)	0.569		
L1	97	1.174 (0.491–2.806)	0.718		
L2	43	Reference			

Table 1. Odds ratios and assigned scores for risk factors of bone non-union. *BMD* bone mineral density, *MRI* magnetic resonance image, *T2WI* T2-weighted image, *VHL* vertebral height loss, *KA* kyphosis angle.

Categories	Score
Fracture type	
Compression fracture	0
Brust fracture	2
Morphology of fracture	
Vertebral height loss	
< 15%	0
≥ 15%	2
Local kyphosis angle	
< 15°	0
≥ 15°	2
MRI signal on T2WI	
Non-diffuse low signal on T2WI	0
Diffuse low signal on T2WI	2
BMD	
−2.5 < T≤−1.0	0
−3.5 < T≤−2.5	2
T≤−3.5	4

Table 2. The novel assessment system of osteoporotic vertebral compression fracture. *BMD* bone mineral density, *MRI* magnetic resonance image, *T2WI* T2-weighted image.

The NASOVCF scoring system included four aspects: fracture type, fracture morphology, MRI signal change, and BMD (Table 2). A total of 208 patients were assessed using this scoring system, with scores ranging from 0 to 10. Univariate regression analysis was used to explore the relationship between bone non-union and the NASOVCF score. The optimal cut-off value for risk categorization was determined to be 0.893, based on the

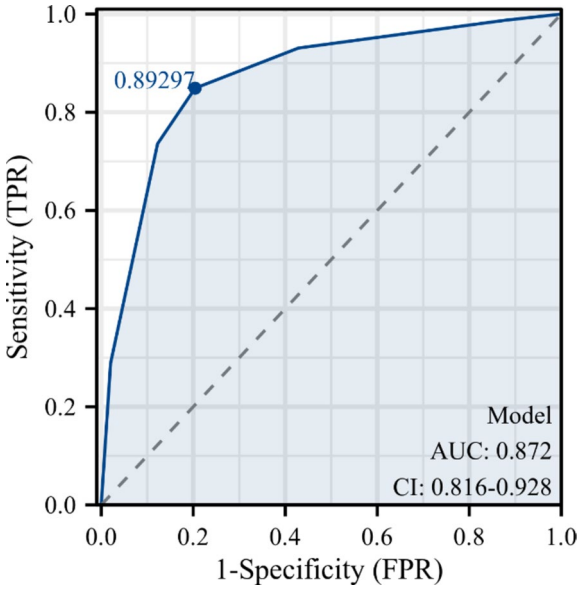

Fig. 1. ROC curve for NASOVCF score. Receiver operating characteristic (ROC) curve demonstrating the accuracy of the NASOVCF score in predicting bone non-union. The area under the curve (AUC) was 0.872 (95% CI: 0.816–0.928), with an optimal cut-off value of 0.893.

Youden Index from the ROC curve analysis (Fig. 1). Based on this cut-off value, patients were divided into three groups: the low-score group (score < 2), the high-score group (score > 4, i.e., three times the cut-off value), and the medium-score group (2 ≤ score ≤ 4).

MRI

All patients underwent thoracolumbar MRI examinations before treatment, utilizing a 1.5 T MRI apparatus (Siemens, Germany) equipped with a spine coil. The routine sequences employed for patients with trauma included T1-weighted spin echo (SE) sagittal, T2-weighted SE axial, and T2-weighted SE sagittal sequences. Recent OVCFs were diagnosed in all patients, with a low signal observed on T1-weighted imaging. As per previous literature, signal changes on T2-weighted imaging were categorized into four groups: confined high signal, diffuse high signal, confined low signal, and diffuse low signal[13]. Diffuse low signal was defined as an area of low signal change covering more than 1/2 of the vertebral body area on the mid-sagittal T2-weighted sequence.

Conservative treatment

The patients maintained no weight-bearing or functional muscle training in bed for six weeks. After six weeks, they were able to move freely with a soft brace. Patients received analgesic therapy for one–two weeks (celecoxib 200 mg, orally, twice daily). The patients also received anti-osteoporosis treatment, which included calcitriol 0.25 μg, orally, daily, calcium carbonate 600 mg, orally, daily, and zoledronic acid 5 mg, intravenous, annually.

Clinical outcomes

Clinical outcomes were evaluated through the application of the Visual Analog Scale (VAS)[14], and the Oswestry Disability Index (ODI)[15]. The VAS was employed to assess pain, where zero signified the absence of pain, and ten denoted the presence of unbearable pain. Pain assessment occurred at pretreatment, one month, three months, and six months after treatment. The ODI served as a tool for the self-assessment of disability at pretreatment, one month, three months, and six months after treatment.

Radiographic outcomes

Radiographic outcomes, encompassing measurements of kyphosis angle (KA), vertebral height loss (VHL), and bone union rate, were conducted in this study. The assessments were performed by two radiologists utilizing electronic measuring tools provided by a picture archiving and communication system (PACS V3.0, Zhejiang Rad Information Technology Company, Hang Zhou, China), with the results subsequently averaged.

At both pretreatment and six months post-treatment, the KA was determined as the angle between the inferior endplate of the vertebra above and the superior endplate of the vertebra below on lateral radiography (Fig. 2). The KA difference signifies the variation between the KA measured six months after treatment and the initial KA at pretreatment. Referring to previous literature, a KA difference greater than 10 degrees is defined as progressive kyphosis[16].

The measurement of VHL was conducted on lateral radiographs at pretreatment and six months post-treatment, with the methodology illustrated in Fig. 2 (Fig. 2). The VHL difference represents the contrast between the VHL measured six months after treatment and the initial VHL at pretreatment.

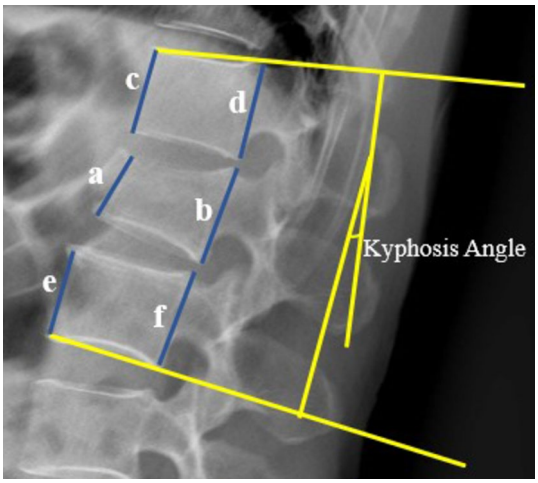

Fig. 2. Measurement method for vertebral height loss and kyphosis angle. (1) The kyphosis angle was measured as the angle between the inferior endplate of the vertebra above and the superior endplate of the vertebra below on lateral radiography. (2) a: anterior height of the fractured vertebrae; b: posterior height of the fractured vertebrae; c: anterior height of the cranial vertebrae; d: posterior height of the cranial vertebrae; e: anterior height of the caudal vertebrae; d: posterior height of the caudal vertebrae. Vertebral height loss $= \left[\frac{\frac{(c+d+e+f)}{4} - \frac{(a+b)}{2}}{\frac{(c+d+e+f)}{4}} \right] \times 100\%$.

Characteristics	Low-score group	Medium-score group	High-score group	*P* value
n	47	98	63	
Age (Y), median (IQR)	70 (64.5, 77.5)	70.5 (65, 76)	71 (67, 77)	0.601
Gender, n (%)				
Female	31 (14.9%)	75 (36.1%)	51 (24.5%)	0.184
Male	16 (7.7%)	23 (11.1%)	12 (5.8%)	
Injured vertebrae, n (%)				
T11	5 (2.4%)	16 (7.7%)	9 (4.3%)	0.979
T12	9 (4.3%)	17 (8.2%)	12 (5.8%)	
L1	24 (11.5%)	44 (21.2%)	29 (13.9%)	
L2	9 (4.3%)	21 (10.1%)	13 (6.2%)	
Height (m), median (IQR)	1.56 (1.52, 1.68)	1.56 (1.52, 1.62)	1.55 (1.5, 1.6)	0.185
Weight (Kg), median (IQR)	60 (56, 67.5)	60 (55, 65)	60 (56, 65)	0.478
BMI (Kg/m^2), mean ± SD	24.51 ± 2.61	24.30 ± 2.49	24.89 ± 2.31	0.325

Table 3. Baseline data of the three groups.

The bone union rates in the three groups were evaluated 6 months after treatment. Non-union of fractured vertebrae was defined as the occurrence of an intravertebral vacuum cleft on MRI or change in anterior height of the fractured vertebrae between the standing and supine positions on lateral radiography[17].

Statistical analysis

Statistical analysis was conducted using SPSS (version 19.0; SPSS Inc., Chicago, IL, USA) for Windows. Age, height, weight, VHL, and KA were compared among the three groups using the Kruskal-Wallis test. BMI was assessed across the three groups using the ANOVA test. Before performing these analyses, normality was tested using the Shapiro-Wilk test, and homogeneity of variance was evaluated using Levene's test. Gender, injured vertebrae, progressive kyphosis rate and bone union rate were compared across the three groups using the Pearson chi-squared test with the Bonferroni correction. The Two-way mixed ANOVA test, followed by Pairwise t-tests, was used for comparing VAS scores and ODI scores. Additionally, logistic regression analysis was applied to model the relationship between bone non-union and independent variables, as well as progressive kyphosis and independent variables. A predefined significance level of 0.05 was used.

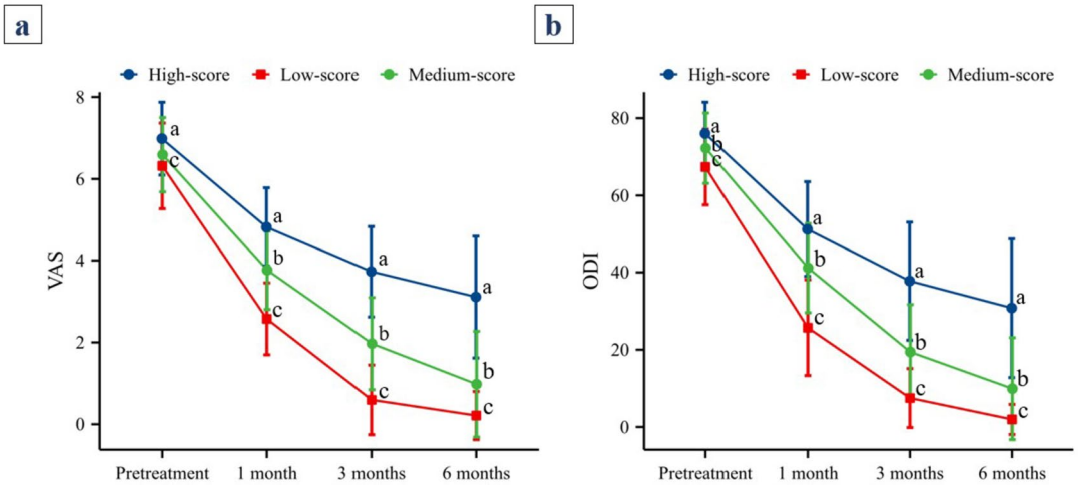

Fig. 3. VAS and ODI scores of the three groups. (**a**) VAS scores and (**b**) ODI scores of the three groups at different time points (pretreatment, 1 month, 3 months, 6 months). a: $P<0.001$, high-score group compared with medium-score group; b: $P<0.001$, medium-score group compared with low-score group; c: $P<0.001$, low-score group compared with high-score group. *VAS* visual analog scale, *ODI* Oswestry disability index.

Characteristics	Low-score group	Medium-score group	High-score group
VHL			
Pretreatment, median (IQR)	2.5 (0.8, 7)	5.4 (2.5, 8.4) [c]	15.1 (11.85, 23) [a, b]
6 months, median (IQR)	4.8 (1.6, 9.25)	9.35 (6.7, 15.1) [c]	28.6 (20.7, 36.1) [a, b]
Difference, median (IQR)	0.9 (0.5, 1.4)	3.5 (2.3, 6.25) [c]	13.1 (5.35, 18.65) [a, b]
KA			
Pretreatment, median (IQR)	2.4 (1.5, 5.45)	3.65 (2.7, 5.5) [c]	12.5 (9.35, 14.85) [a, b]
6 months, median (IQR)	4.1 (2, 6.85)	7.45 (5.2, 11.125) [c]	22.1 (18.55, 27) [a, b]
Difference, median (IQR)	0.9 (0.5, 1.5)	2.95 (1.5, 5.3) [c]	9.5 (5.05, 15.55) [a, b]

Table 4. Vertebral height loss and kyphosis angle of the three groups. *VHL* vertebral height loss, *KA* kyphosis angle. a, $P<0.05$, high-score group compared with low-score group; b, $P<0.05$, high-score group compared with medium-score group; c, $P<0.05$, medium-score group compared with low-score group.

Results

Baseline data

A total of 208 patients were included in this study, with 47 cases in the low-score group, 98 cases in the medium-score group, and 63 cases in the high-score group. There were no statistically significant differences among the three groups in terms of age, gender, injured vertebrae, height, weight and BMI ($P>0.05$) (Table 3).

Clinical outcomes

The pre-treatment VAS score in the high-score group was significantly higher than that in both the low-score and medium-score groups ($P<0.001$). No statistically significant difference in VAS scores was observed between the medium-score and low-score groups. At 1 month, 3 months, and 6 months post-treatment, the high-score group consistently had higher VAS scores at each time point compared to both the medium-score group ($P<0.001$) and the low-score group ($P<0.001$). Additionally, the medium-score group had significantly higher VAS scores compared to the low-score group at all follow-up points ($P<0.001$).

Similarly, prior to treatment, the low-score group exhibited significantly lower ODI scores than both the medium-score ($P<0.001$) and high-score ($P<0.001$) groups. At 1 month, 3 months, and 6 months post-treatment, the high-score group consistently showed significantly higher ODI scores at each time point compared to both the medium-score group ($P<0.001$) and the low-score group ($P<0.001$). Furthermore, the medium-score group had significantly higher ODI scores than the low-score group at all follow-up times ($P<0.001$) (Fig. 3).

Radiographic outcomes

Higher VHL values were observed in the high-score group at both pre-treatment and 6 months after treatment, with statistically significant differences compared to both the medium-score group ($P<0.001$) and the low-score group ($P<0.001$). The VHL difference in the high-score group was 13.1 (5.35, 18.65), which was significantly greater than in the medium-score group (3.5 (2.3, 6.25); $P<0.001$) and the low-score group (0.9 (0.5, 1.4);

$P < 0.001$). The medium-score group also showed significantly higher VHL values at pre-treatment, at 6 months, and in the VHL difference compared to the low-score group ($P < 0.001$) (Table 4).

The KA difference in the high-score group was 9.5 (5.05, 15.55), significantly greater than in the medium-score group (2.95 (1.5, 5.3); $P < 0.001$) and the low-score group (0.9 (0.5, 1.5); $P < 0.001$). The high-score group had significantly higher KA at both pre-treatment and 6 months after treatment compared to the medium-score group ($P < 0.001$) and the low-score group ($P < 0.001$). Additionally, the medium-score group exhibited significantly greater KA at pre-treatment, at 6 months, and the KA difference compared to the low-score group ($P < 0.001$) (Table 4).

Bone-union rate and progressive kyphosis rate

At the 6-month follow-up, bone union was achieved in 24 patients in the high-score group, corresponding to a union rate of 38.1% (24/63), which was significantly lower than the 97.9% (46/47) observed in the low-score group ($P < 0.001$). In the medium-score group, the bone union rate was 90.8% (89/98), showing no statistically significant difference compared to the low-score group ($P = 0.222$) (Fig. 4a).

Progressive kyphosis was observed in only 1 case in the low-score group, with an incidence of 2.2% (1/46), significantly lower than the rates in the medium-score group (17.3%, 17/98) and the high-score group (47.6%, 30/63) ($P < 0.001$). Additionally, the high-score group had a significantly higher incidence of progressive kyphosis compared to the medium-score group ($P < 0.001$) (Figs. 4b, 5 and 6).

Risk factors for bone non-union after conservative treatment in OVCFs

In the univariate analysis, several independent risk factors of non-union were identified, including higher NASOVCF score, higher pre-treatment VAS score, and higher pre-treatment ODI score. Subsequently, in the multivariate analysis, higher NASOVCF score emerged as an independent risk factor (OR = 1.713, 95% CI 1.458–2.013, $P < 0.001$) (Table 5). The computation of the area under the curve (AUC) yielded a value of 0.895 (95%CI: 0.841–0.949), indicating a robust discriminative performance (Fig. 7a).

Risk factors for progressive kyphosis after conservative treatment in OVCFs

Similarly, in the univariate analysis, several independent risk factors of progressive kyphosis were identified, including higher NASOVCF score, female gender, higher pre-treatment VAS score, and higher pre-treatment ODI score. Subsequently, in the multivariate analysis, higher NASOVCF score (OR = 1.373, 95% CI 1.203–1.568, $P < 0.001$), female gender (OR = 4.326, 95% CI 1.324–14.138, $P = 0.015$), and higher pre-treatment ODI score (OR = 1.096, 95% CI 1.023–1.174, $P = 0.009$) were determined as independent risk factors (Table 6). The area under the curve (AUC) was 0.835 (95%CI: 0.768–0.903), signifying a robust discriminative performance (Fig. 7b).

Discussion

The most significant discovery of this study is the development of a novel scoring system for OVCFs. This system facilitates a comprehensive assessment of OVCFs, encompassing considerations of fracture type, fracture morphology, MRI signal change, and BMD. The evaluation based on this system may provide effective recommendations for the selection of treatment plans. In this study, a retrospective analysis encompassed 208 patients with OVCFs treated conservatively. Utilizing the proposed scoring system, patients were divided into low, medium, and high-score groups. The findings indicated that the high-score group exhibited inferior outcomes concerning pain relief, functional improvement, prevention of vertebral height loss and kyphotic deformity, as well as a lower bone-union rate and higher progressive kyphosis rate compared to the medium and low-score groups. Furthermore, in the multivariate regression analysis, higher NASOVCF scores were identified

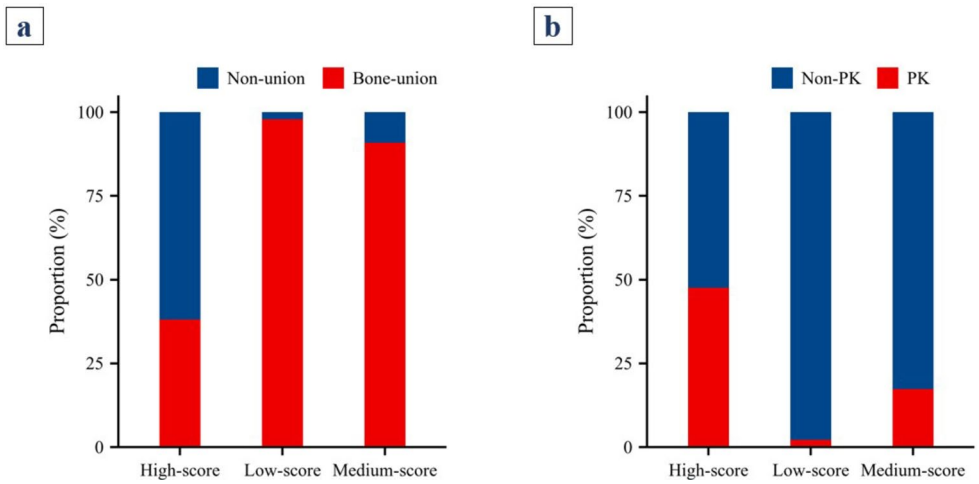

Fig. 4. Bone-union rate and progressive kyphosis rate of three groups. *PK* progressive kyphosis, *Non-PK* non-progressive kyphosis.

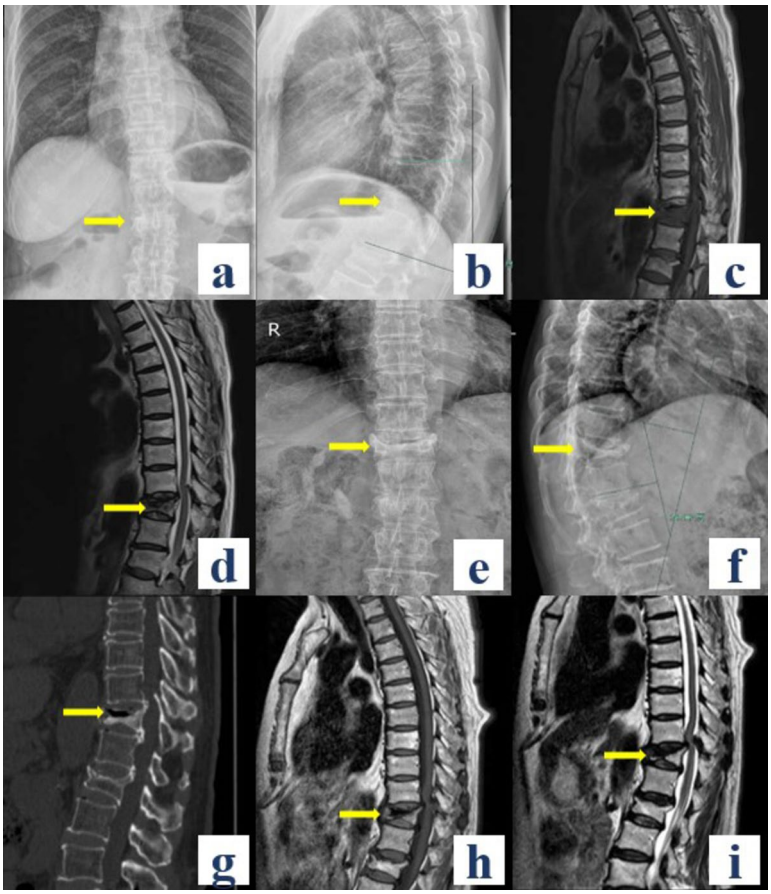

Fig. 5. One case in the high-score group. A compression fracture of T11 occurred in a 71-year-old female due to a fall. The preoperative BMD was − 3.6 SD, and the NASOVCF score was 10. (**a**,**b**) At pretreatment, the vertebral height loss measured 17.8%, and the kyphosis angle was 19.6° on the X-ray. (**c**) Preoperative MRI revealed a compression fracture of T11 with low signal changes on the T1-weighted image. (**d**) Diffuse low signal change was observed on the T2-weighted image. (**e**,**f**) At 6 months after treatment, the vertebral height loss and kyphosis angle measured 38.1% and 26.0°, respectively, on the X-ray. (**g**–**i**) At 6 months after treatment, bone non-union of the injured vertebra was confirmed with the occurrence of an intravertebral vacuum cleft on CT or MRI. *NASOVCF* novel assessment system of osteoporotic vertebral compression fractures, *MRI* magnetic resonance imaging.

as significant risk factors for non-union and progressive kyphosis following conservative treatment in OVCFs. NASOVCF score emerged as a crucial predictor for adverse outcomes in patients at high risk who underwent conservative management. Surgical interventions such as vertebral augmentation may represent a potentially superior option for individuals with high NASOVCF scores.

Fracture type and morphology play crucial roles in this scoring system. Within its framework, a compression fracture is designated a score of 0, while a burst fracture is allocated a score two point higher. Compression fractures predominantly affect the anterior column of the vertebra, whereas burst fractures involve both the anterior and middle columns, rendering the latter more unstable. Fractures involving the middle and posterior columns present a heightened propensity for non-union and progressive kyphosis compared to those confined to the endplate and anterior column[18,19]. Moreover, increased preoperative VHL and KA correspond to elevated scores, serving as indicators of compromised fracture stability. VHL surpassing 50% correlates with an increased occurrence of intravertebral cleft and fluid sign, indicative of bone non-union on imaging[20]. Additionally, a notable correlation exists between the initial KA and vertebral height with the final KA[21]. Therefore, VHL and KA were added as important components of this scoring system.

The role of MRI signal changes in predicting OVCF prognosis is significant. Tsujio et al. demonstrated that diffuse low signal on T2WI is associated with a heightened risk of non-union in OVCFs and correlates with a notable increase in vertebral height loss compared to diffuse high signal on T2WI. In this scoring system, the classification of MRI signal changes on T2WI is grounded in previous literature, and corresponding scores are assigned accordingly[13]. A larger area of low signal on T2WI is anticipated to signify more trabecular bone injury, whereas high signal on T2WI suggests relatively milder bone marrow edema. Additionally, BMD significantly influences OVCF bone union. Zhang et al. highlighted that low BMD is a high-risk factor for conservative treatment failure in OVCFs[22]. Hence, the incorporation of the BMD indicator into this scoring system is warranted.

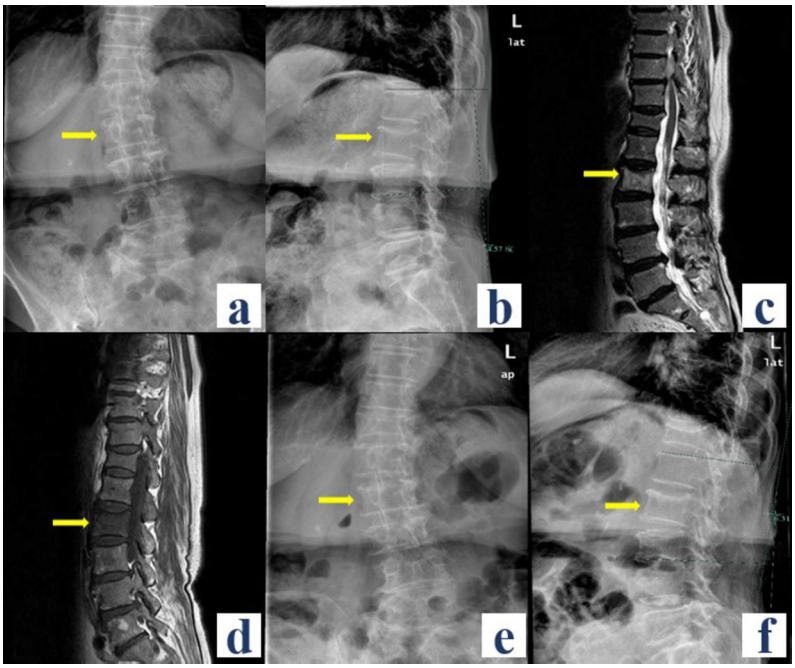

Fig. 6. One case in the low-score group. Conservative treatment was administered to a 79-year-old female who experienced a compression fracture of L2 following a fall. Her BMD was − 1.5 SD and NASOVCF score was 0 at pretreatment. (**a**,**b**) The vertebral height loss was 0.5% and kyphosis angle was 4.6° on the X-ray; (**c**,**d**) Her preoperative MRI indicated a compression fracture of L2 with low signal change on T1 weighted image, and diffuse high signal change was observed on the T2 weighted image. (**e**,**f**) At 6 months after treatment, bone union of injured vertebra was showed on the X-ray. The vertebral height loss was 5.3%, and the kyphosis angle was 6.3°. *NASOVCF* novel assessment system of osteoporotic vertebral compression fractures, *MRI* magnetic resonance imaging.

	Univariate analysis		Multivariate analysis	
Characteristics	**Odds ratio (95% CI)**	***P* value**	**Odds ratio (95% CI)**	***P* value**
NASOVCF score	1.754 (1.504–2.046)	< 0.001	1.713 (1.458–2.013)	< 0.001
Age	0.999 (0.953–1.048)	0.975		
Gender				
Female	Reference		Reference	
Male	0.436 (0.182–1.042)	0.062	0.531 (0.177–1.593)	0.259
Injured vertebrae				
T11	1.150 (0.375–3.526)	0.807		
T12	1.349 (0.482–3.780)	0.569		
L1	1.174 (0.491–2.806)	0.718		
L2	Reference			
BMI	0.992 (0.871–1.130)	0.900		
VAS at pretreatment	1.817 (1.234–2.677)	0.003	0.984 (0.502–1.931)	0.963
ODI at pretreatment	1.093 (1.047–1.141)	< 0.001	1.070 (0.993–1.154)	0.076

Table 5. Univariate and multivariate analysis of risk factors for bone non-union. *VAS* visual analog scale, *ODI* Oswestry disability index, *NASOVCF* novel assessment system for osteoporotic vertebral compression fractures.

Conservative treatment of OVCFs typically leads to noticeable pain reduction and functional improvement after a 1-month follow-up. The VAS score commonly shows a pain improvement of around 40–50%, while the ODI score reflects a functional improvement of approximately 30–50%[14]. In this study, all three groups showed significant improvements in VAS and ODI scores following treatment. Although the VAS and ODI scores of the low-score group were significantly lower than those of the high-score group before treatment, the possible reason is that the NASOVCF score in the low-score group was relatively low, indicating a less severe fracture. Therefore, the pain and functional status of patients in the low-score group were better than those in the high-

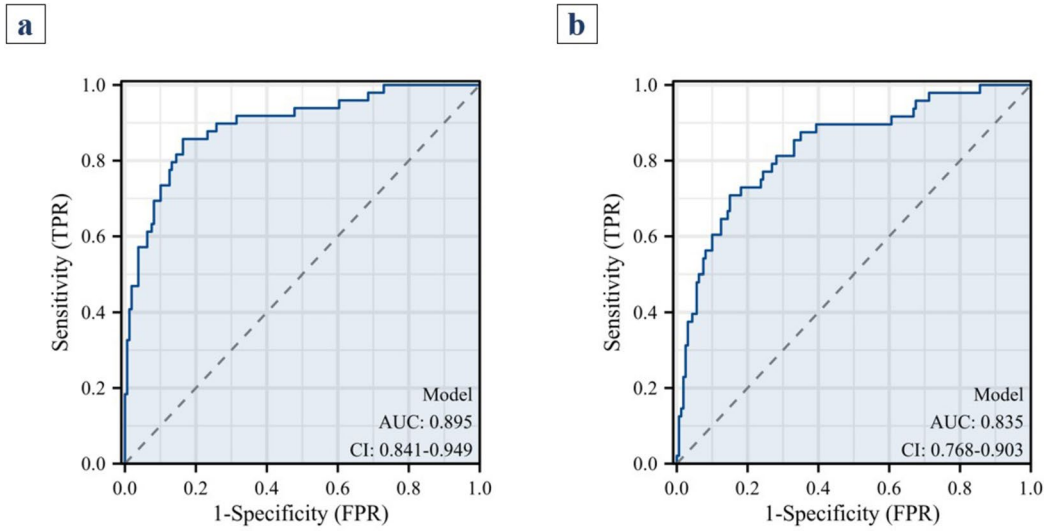

Fig. 7. Receiver-operating curves. (**a**) Receiver-operating curve demonstrating the accuracy of the model for prediction of bone non-union. The area under the curve (AUC) was computed to be 0.895 (95%CI: 0.841–0.949). (**b**) Receiver-operating curve demonstrating the accuracy of the model for prediction of progressive kyphosis. The area under the curve (AUC) was 0.835 (95%CI: 0.768–0.903).

Characteristics	Univariate analysis		Multivariate analysis	
	Odds ratio (95% CI)	*P* value	Odds ratio (95% CI)	*P* value
NASOVCF score	1.429 (1.266–1.614)	< 0.001	1.373 (1.203–1.568)	< 0.001
Age	1.045 (0.996–1.096)	0.070	1.043 (0.984–1.106)	0.155
Gender				
Male	Reference		Reference	
Female	4.575 (1.556–13.454)	0.006	4.326 (1.324–14.138)	0.015
Injured vertebrae				
T11	0.608 (0.210–1.765)	0.360		
T12	0.944 (0.392–2.273)	0.898		
L1	Reference			
L2	0.922 (0.396–2.145)	0.850		
BMI	1.039 (0.911–1.185)	0.565		
VAS at pretreatment	1.504 (1.041–2.172)	0.030	0.728 (0.391–1.354)	0.315
ODI at pretreatment	1.091 (1.045–1.138)	< 0.001	1.096 (1.023–1.174)	0.009

Table 6. Univariate and multivariate analysis of risk factors for progressive kyphosis. *VAS* visual analog scale, *ODI* Oswestry disability index, *NASOVCF* novel assessment system for osteoporotic vertebral compression fractures.

score group before treatment. This result indirectly suggests that the NASOVCF score may be related to the severity of the fracture.

In the literature, conservative treatment of OVCFs has been associated with a potential decrease in vertebral height by 10–20% and an increase in the local kyphosis angle by approximately 10 degrees[23]. In our study, the mean difference in vertebral height loss for the low-score group was 0.9 (0.5, 1.4), and the difference in kyphosis angle was 0.9 (0.5, 1.5), which was significantly lower compared to findings from previous studies. Furthermore, significantly higher vertebral height loss and kyphosis angle differences were observed in the high-score group compared to the low-score and medium-score groups, suggesting inferior outcomes in terms of mitigating further vertebral height loss and progression of kyphotic deformity for patients in the high-score group compared to the other two groups.

Studies have indicated that the incidence of non-union in conservative treatment of OVCFs typically falls within the range of 10–20%[1,5]. In this study, the non-union rate in the low-score group was 2.1%, while in the high-score group, it reached 61.9%. A significant statistical difference was observed between the two groups, with the non-union rate in the high-score group also surpassing the levels reported in previous literature. Various factors such as patient age, gender, severity of osteoporosis, fracture type, and severity can influence the occurrence of non-union in conservative treatment of OVCFs[22]. This study found that NASOVCF score was

identified as a high-risk factor for non-union, underscoring the effectiveness of this scoring system in evaluating OVCFs.

This study has several limitations. First, the sample size was relatively modest, and larger, randomized controlled trials are needed to further validate our results. Additionally, the follow-up period of six months, based on prior literature[18,19], may be considered short. Longer follow-up studies are required to assess the long-term efficacy of the NASOVCF scoring system. Furthermore, the inclusion criterion for a BMD of ≤ -1.0 SD may limit the generalizability of our findings, as the World Health Organization's 1994 criteria for osteoporosis diagnosis require a T-score ≤ -2.5 SD, while the 2017 Chinese Guidelines[24] allow for a diagnosis based on fragility fractures or T-scores between − 2.5 and − 1.0. The study also focused on fractures between T11 and L2, which are the most common locations for OVCFs. However, fractures in the mid-to-upper thoracic spine (T4–T10) are also common, and their exclusion may limit the applicability of the NASOVCF scoring system across different spinal regions. Another limitation is the potential variability in adherence to the bed rest protocol, which may affect clinical outcomes. Non-compliance could introduce uncertainty in the healing process, and future studies should monitor patient adherence more rigorously to assess its impact on fracture recovery. Finally, future research should compare the NASOVCF system with existing fracture scoring systems to further validate its clinical utility and demonstrate its advantages. We also plan to assess inter-rater reliability using statistical methods such as Cohen's kappa or intraclass correlation coefficient in future studies. We fully agree that large-scale, multi-center prospective trials are needed to refine and validate the NASOVCF system.

Conclusion

Higher NASOVCF score was identified as a significant risk factor for non-union and progressive kyphosis following conservative treatment in OVCFs. NASOVCF score emerged as a crucial predictor for adverse outcomes in patients at high risk who underwent conservative management. Surgical interventions such as vertebral augmentation may represent a potentially superior option for individuals with high NASOVCF scores.

Data availability

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

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Author contributions
WQ H and JX conceived the design of the original study. ZB D and WQ H conducted statistical analysis and drafted the manuscript. ZBD, ZL and JL were involved with interpretation of data and critical revision of the manuscript. All authors read and approved the final manuscript.

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Declarations

Competing interests
The authors declare no competing interests.

Ethics approval and consent to participate
The authors confirmed that the study was performed in accordance with the Declaration of Helsinki. The study was approved by the Ethics Committee (full name: Ethics Committee of the Shaoxing People's Hospital, reference number NO2024-040-Y-01), and informed consent was obtained from all patients.

Additional information
Correspondence and requests for materials should be addressed to J.X.