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Effects of modified vertebral bone quality score and paravertebral muscle mass on multiple osteoporotic vertebral compression fractures: a retrospective multicenter cohort study

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Abstract

Background Multiple osteoporotic vertebral compression fractures (OVCF) are common in clinical practice and often have serious consequences. This study aimed to investigate the factors influencing the occurrence of multiple OVCFs.

Methods A total of 652 patients with thoracolumbar OVCF from January 2019 to January 2024 were enrolled and divided into single and multiple OVCF groups. The total cross-sectional area (CSA) and functional cross-sectional area (FCSA) of the L4 multifidus (M), erector spinae (ES), paravertebral muscle (PVM), psoas major, and quadratus lumborum muscles were measured using demographic, underlying disease, and laboratory variables. Fat infiltration rate (FIR) and modified vertebral bone quality (MVBQ) scores were calculated, and correlation and multivariate logistic regression analyses were performed.

Results The two groups differed significantly in body mass index and bone mineral density (BMD) (L1-L4). The CSA and FCSA of M, ES, and PVM were smaller in the multiple OVCF group, while FIR and MVBQ scores were higher. Lower BMD (L1-L4), lower ES-FCSA, higher ES-FIR, and higher MVBQ scores were independent risk factors for multiple OVCF. The AUC of the MVBQ was 0.754, with a good predictive value. When MVBQ > 3.975, the risk of multiple OVCFs was 3.767 times that of a single OVCF.

Conclusion Independent risk factors for multiple OVCFs were identified. The combination of MVBQ with BMD (L1-L4) and PVM quality holds the potential for accurately identifying high-risk patients with multiple OVCF in the early stage.

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Keywords Osteoporotic vertebral compression fracture, Multiple, Modified vertebral bone quality score, Paravertebral muscle

Background

Osteoporotic vertebral compression fractures (OVCF) are common and serious complications of osteoporosis [1, 2]. The incidence of OVCF in china has exhibited a significant upward trend [3], and as the population ages, this problem has become increasingly prominent, resulting in a heavy economic [4] and health burden [5–8] for patients and their families.

Currently, dual-energy X-ray absorptiometry (DEXA) is a common method for the clinical diagnosis of osteoporosis; however, it has certain limitations, including spinal degeneration, obesity, and other factors, resulting in inaccurate measurement results and an inability to accurately reflect bone quality [9]. Although DEXA assessment has become widely accepted, screening rates are still lacking in most patient populations [10]. Consequently, it is important to identify a more effective and convenient evaluation method. The vertebral bone quality (VBQ) score, which is based on MRI, has recently attracted more interest [11]. Studies have demonstrated that VBQ scores can indirectly reflect bone quality by measuring the degree of vertebral fat infiltration and can independently predict fragility fractures in high-risk patients [12]. This approach accounts for all the fat in the spinal cord and the blood vessels and nerves behind the vertebrae, leading to a higher count. Accordingly, we used the modified VBQ (MVBQ) measurement method [13]. The paravertebral muscle (PVM) mass is also closely related to OVCF, and changes in parameters, including fat infiltration and cross-sectional area (CSA), are linked to lower back pain, unstable spine, increased fracture risk, adjacent segment disease, and unfavorable outcomes following spinal surgery [14–18].

Multiple OVCF is very common in clinical practice [19] and is more likely to cause residual back pain [20–22], with poorer PVM quality and prognosis [23, 24]. Severe clinical outcomes frequently include intractable back pain and comorbidities associated with braking [25, 26]. Understanding the factors affecting multiple OVCFs is significant for formulating accurate treatment strategies [27, 28] and reducing the risk of fractures. Previous studies have revealed that age, gender, bone mineral density (BMD), corticosteroid, PVM mass, and VBQ are risk factors for OVCF development [12, 29–33]. However, the effects of these factors on multiple OVCFs remain unclear. The role and relationship between the MVBQ score and PVM mass in multiple OVCFs must also be explored further.

The purpose of this study was to examine how BMD, MVBQ, and PVM mass impact multiple OVCFs by reviewing data from a multicenter retrospective cohort. This study may provide a strong basis for the early clinical identification of high-risk patients and the formulation of personalized prevention and treatment programs to improve the prognosis of patients and reduce the burden on society and families by comprehensively analyzing the relevant factors.

Materials and methods

This retrospective cohort study was conducted in four hospitals of a medical center in China, and a unified imaging and measurement protocol was adopted. The study encompassed 1774 OVCF patients from January 2019 to January 2024. The criteria for inclusion were: (1) thoracolumbar OVCF reported for the first time; (2) patients aged ≥ 50 years; (3) complete demographic data, preoperative lumbar MRI, BMD, and other medical information. The criteria for exclusion were: (1) high-energy trauma; (2) history of other spinal operations; (3) other spinal diseases, such as severe spinal malformations, spinal tumors, spinal tuberculosis, and Kummell's disease; (4) neurogenic diseases or other activity disorders that may lead to limited activity, including cerebrovascular accident sequelae, neuromuscular dystrophy, and Parkinson's disease; (5) incomplete data, such as missing MR, unclear MR, incomplete images, and loss of BMD. A total of 652 patients were included in this study, with 482 in the single OVCF group and 170 in the multiple OVCF group (Fig. 1).

Data collection

Demographic and medical variables included age, gender, body mass index (BMI), underlying diseases (hypertension, diabetes, heart disease, pulmonary disease, chronic liver disease, chronic kidney disease, glucocorticoid use, hypertriglyceridemia, hypercholesterolemia, low high-density lipoprotein cholesterol, and mixed hyperlipidemia), BMD (L1-L4), and fracture location.

Lumbar MRI measurement

Lumbar MR images were collected before surgery using a 1.5 T Genesis Signa scanner (GE Healthcare, United Kingdom). T2-weighted MR images in the axial plane were captured at the L4 sub-vertebral endplate, featuring a section thickness of 4 mm and a 1 mm interval between sections. Using GE Healthcare Systems (Chicago, United States), images were captured and analyzed with ImageJ software (version 1.53, National Institutes of Health, United States). The total CSA (Fig. 2a) and functional cross-sectional area (FCSA) (Fig. 2b) of the

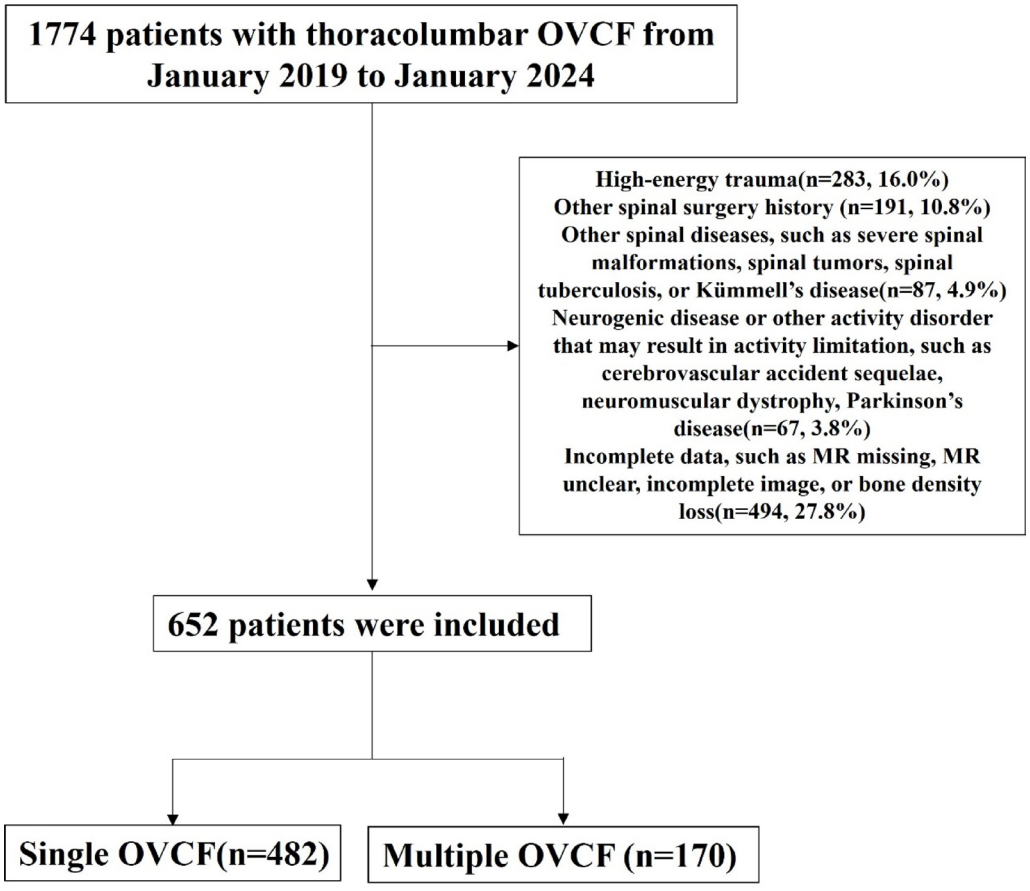

Fig. 1 Flow chart for patient analysis

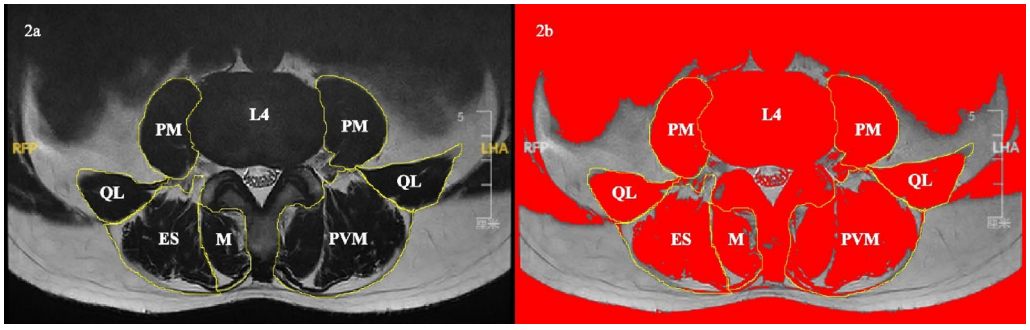

Fig. 2 Schematic of MRI image measurement. **a** The contours of the muscles and vertebrae of interest were traced on axial T2-weighted MR images using the polygon ROI tool to measure the CSA of the M, ES, PM, and QL. **b** Axial T2-weighted imaging presenting the FCSA of the M, ES, PM, and QL

multifidus (M), erector spinae (ES), PVM (M + ES), psoas major (PM), and quadratus lumborum (QL) muscles of each patient were quantitatively measured using the method proposed by Fortin et al. [34]. The fat infiltration rate (FIR) was calculated using the following formula: (FIR = (CSA – FCSA)/CSA × 100), where FIR represents muscle degeneration [35].

Non-contrast T1-weighted MR images were obtained at the median sagittal position and measured using GE Healthcare Systems. Ehresman et al. [11] introduced a traditional VBQ measurement method that included all fat in the spinal medulla, blood vessels, and nerves in the posterior vertebral body, leading to an inflated value. Therefore, the MVBQ measurement method was used, introduced by Li et al. [13]. The region of interest (ROI) was chosen to be the cancellous bone in the anterior half of the vertebral body to minimize the impact of fat cells and vascular nerves located in the posterior half. Each vertebra's signal intensity (SI) was measured, and the average SI was computed (Fig. 3). Since cerebrospinal

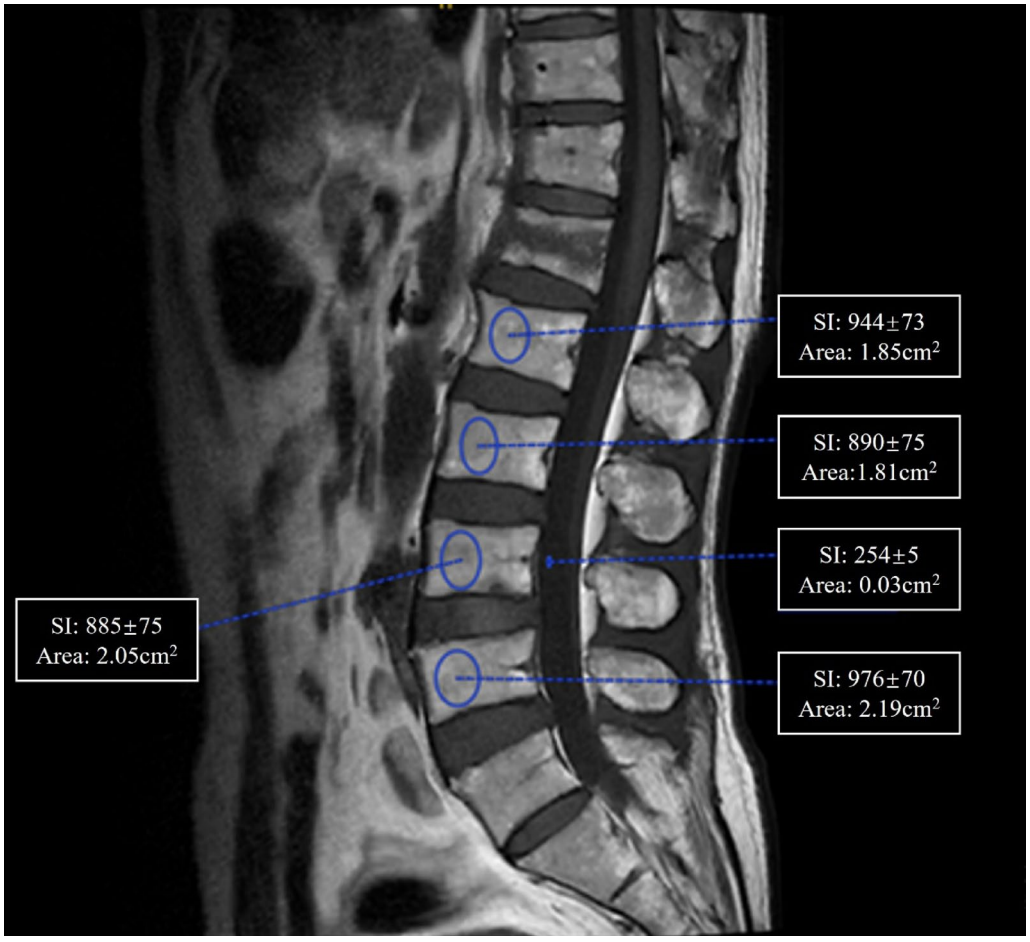

Fig. 3 The MVBQ image measurement principle diagram. The anterior 1/2 cancellous bone of the vertebral body was measured using the polygon ROI tool in the median sagittal position without contrast T1-weighted MR Images, and fat cells and vasculature in the posterior half of the vertebral body were avoided as much as possible. The SI of the L1-L4 vertebrae and L3 CSF were recorded, and if a fracture occurred in the measured vertebrae, only the remaining vertebrae were used for the MVBQ calculation. The formula is as follows: MVBQ = Modified SIL1-L4/SIL3CSF

fluid (CSF) maintains a stable signal and nearly uniform composition across various populations, the SI of L3 CSF was utilized as a standard for calculating the MVBQ. If spinal canal stenosis affects the measurement results, the CSF of adjacent segments is used as a reference index. Severe Modic changes can affect the measurement results of MVBQ and should be avoided when selecting ROI. If this situation cannot be avoided during measurement, the data of this segment needs to be discarded.In the event of a fracture in one of the vertebrae being measured, only the intact vertebrae are considered for the MVBQ calculation. The formula is as follows: MVBQ = Modified $SI_{L1\text{-}L4}/SI_{L3CSF}$.

Three doctors participated in the image measurements. Measurements were taken with a predetermined number of radiological images presented randomly by a research assistant who was not involved in the study. After reliability testing, three orthopedic surgeons analyzed the MR images of all patients.

Statistical analysis

All data were analyzed using the SPSS (version 26.0; IBM, Armonk, New York, United States), according to a previous method [36]. The intra-class correlation coefficient (ICC) was used to assess inter-observer reliability. The receiver operating characteristic (ROC) curve was constructed using MVBQ, and the area under the curve (AUC) was calculated. Continuous variables between the two groups were compared using two independent samples: the t-test and the Mann–Whitney U-test. Categorical variables were compared using the chi-square test. A p-value < 0.05 was considered statistically significant.

Results

Basic information

This study enrolled 652 patients, including 482 in the single OVCF group and 170 in the multiple OVCF group. Age, gender, underlying diseases, and laboratory variables did not differ significantly ($p > 0.05$), whereas BMI (23.42 ± 3.73 vs. 22.29 ± 3.54, $p = 0.001$)

Table 1 Demographic and radiological data for the two groups

Variables	Single OVCF(n = 482)	Multiple OVCF (n = 170)	*P* value
Age(y)	74.59 ± 8.66(52–98)	75.64 ± 8.60(54–97)	0.193
Gender			
Male	112(23.2%)	36(21.2%)	0.581
Female	370(76.8%)	134(78.8%)	
BMI (kg/m^2)	23.42 ± 3.73	22.29 ± 3.54	0.001
Hypertension	239(49.6%)	79(46.5%)	0.485
Diabetes	82(17.0%)	22(12.9%)	0.213
Heart disease	47(9.8%)	15(8.8%)	0.723
Pulmonary disease	36(7.5%)	18(10.6%)	0.205
Chronic liver disease	19(3.9%)	8(4.7%)	0.667
Chronic kidney disease	24(5.0%)	13(7.6%)	0.196
Glucocorticoid	22(4.6%)	12(7.1%)	0.208
Hypertriglyceridemia	130(27.0%)	37(21.8%)	0.181
Hypercholesterolemia	171(35.5%)	47(27.6%)	0.063
Low high-density lipoprotein cholesterol	171(35.5%)	48(28.2%)	0.086
Mixed hyperlipidemia	111(23.0%)	28(16.5%)	0.073
BMD(L1-L4)	−2.71 ± 1.28	−3.47 ± 1.56	< 0.001
Fracture location (n)			
Thoracic	39 (8.1%)		
Thoracolumbar (T12-L1)	251(52.1%)		
Lumbar	192(39.8%)		
Multiple		170	

OVCF, osteoporotic vertebral compression fracture; BMI, body mass index; BMD, bone mineral density

and BMD (L1-L4) differed significantly (−2.71 ± 1.28 vs. −3.47 ± 1.56, $p < 0.001$) between the two groups. In a single OVCF, there were 39 (8.1%) thoracic fractures, 251 (52.1%) thoracolumbar fractures, and 192 (39.8%) lumbar fractures (Table 1). Lumbar MRI image measurements from three orthopedic surgeons exhibited good ICC for inter-observer reliability (Table 2).

Comparison of L4 PVM

The mean CSA and FCSA of the M, ES, and PVM were significantly different (M-CSA: 1196.51 ± 280.94 vs. 1086.96 ± 282.41,$p < 0.001$; ES-CSA: 3270.76 ± 707.99 vs. 3060.46 ± 622.14, *p = 0.001; PVM-CSA: 4467.27 ± 844.10 vs. 4147.42 ± 751.00,* $p < 0.001$; M-FCSA: 743.52 ± 252.02 vs. 589.80 ± 283.35, $p < 0.001$; ES-FCSA: 2045.67 ± 615.16 vs. 1710.45 ± 641.03, $p < 0.001$; PVM-FCSA: 2789.19 ± 773.78 vs. 2300.25 ± 836.30, $p < 0.001$), with the area of the multiple OVCF group being smaller than that of the single OVCF group. However, the difference in PM and QL was statistically non-significant ($p > 0.05$). The mean FIR differences of M, ES, PVM, PM, and QL between the two groups were statistically significant (M: 37.53 ± 16.89 vs. 45.95 ± 21.41, $p < 0.001$; ES: 37.51 ± 13.08 vs. 44.77 ± 14.42, $p < 0.001$; PVM: 37.55 ± 13.04 vs. 45.02 ± 15.23, $p < 0.001$; PM: 6.79 ± 4.74 vs. 9.47 ± 8.32, $p < 0.001$; QL: 14.06 ± 9.80 vs. 22.55 ± 12.26, $p < 0.001$), and the FIR of the multiple OVCF group was greater than that of the single OVCF group (Table 3 and Fig. 4). The MVBQ difference was statistically significant (3.59 ± 0.59 vs. 4.31 ± 0.92, $p < 0.001$), and the MVBQ in the multiple OVCF group was greater than that in the single OVCF group (Table 3 and Fig. 5).

Table 3 Comparison of paravertebral muscle mass and MVBQ in single and multiple OVCF groups

Variables	Single OVCF(n = 482)	Multiple OVCF (n = 170)	*P* value
CSA (mm^2)			
M	1196.51 ± 280.94	1086.96 ± 282.41	< 0.001
ES	3270.76 ± 707.99	3060.46 ± 622.14	0.001
PVM	4467.27 ± 844.10	4147.42 ± 751.00	< 0.001
PM	1271.36 ± 378.42	1250.95 ± 369.28	0.493
QL	748.37 ± 241.67	788.96 ± 268.79	0.057
FCSA			
M	743.52 ± 252.02	589.80 ± 283.35	< 0.001
ES	2045.67 ± 615.16	1710.45 ± 641.03	< 0.001
PVM	2789.19 ± 773.78	2300.25 ± 836.30	< 0.001
PM	1188.86 ± 372.50	1135.67 ± 370.16	0.073
QL	644.37 ± 223.67	616.11 ± 248.03	0.146
FIR			
M	37.53 ± 16.89	45.95 ± 21.41	< 0.001
ES	37.51 ± 13.08	44.77 ± 14.42	< 0.001
PVM	37.55 ± 13.04	45.02 ± 15.23	< 0.001
PM	6.79 ± 4.74	9.47 ± 8.32	< 0.001
QL	14.06 ± 9.80	22.55 ± 12.26	< 0.001
MVBQ	3.59 ± 0.59	4.31 ± 0.92	< 0.001

MVBQ, Modified-Vertebral bone quality; OVCF, osteoporotic vertebral compression fracture; CSA, cross-sectional area; M, multifidus; ES, erector spinae; PVM, paravertebral muscle; PM, psoas major; QL, Quadratus lumborum; FCSA, functional cross-sectional area; FIR, fat infiltration rate

Pearson correlation analysis

The correlations between FCSA and FIR and MVBQ of BMI, BMD (L1-L4), M, ES, and PVM were analyzed. In this study, Pearson correlation analysis revealed a correlation between BMI and ES-FIR and a significant correlation between the other parameters (Table 4).

Table 2 Interobserver reliability of radiographic measurements

Variables	M- CSA (mm^2)	ES-CSA	PM-CSA	QL-CSA	MVBQ
ICC (95%IC)	0.921(0.706–0.970)	0.939(0.314–0.984)	0.936(0.470–0.981)	0.902(0.493–0.967)	0.987(0.975–0.993)

CSA, cross-sectional area; M, multifidus; ES, erector spinae; PM, psoas major; QL, Quadratus lumborum; MVBQ, Modified-Vertebral bone quality; ICC, intraclass correlation coefficient; CI, confidence interval

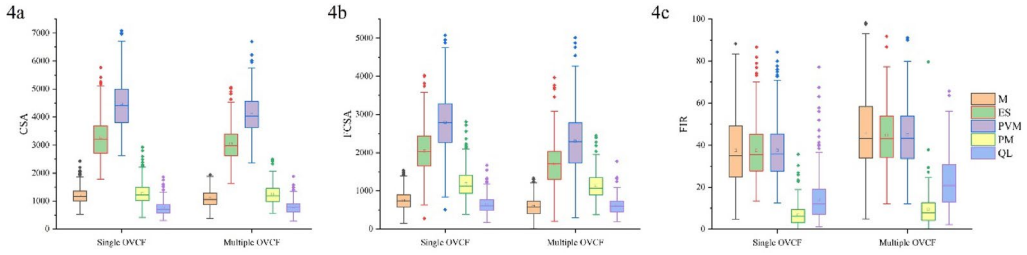

Fig. 4 Comparison of L4 PVM mass and FIR in multiple and single OVCF groups. **a** A comparison of CSA for M, ES, PVM, PM, and QL. **b** Comparison of FCSA for M, ES, PVM, PM, and QL. **c** A comparison of FIR for M, ES, PVM, PM, and QL

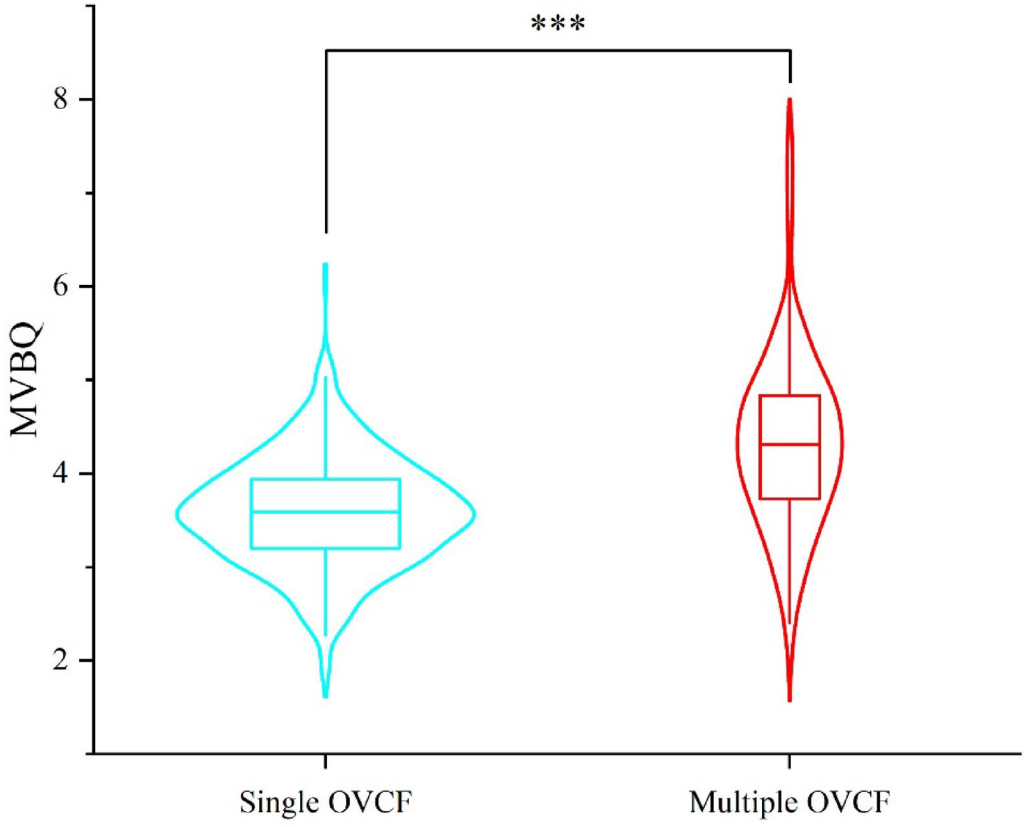

Fig. 5 Comparison of MVBQ scores between multiple and single OVCF groups exhibited significant differences

Multivariate logistic regression analysis

In univariate analysis, variables with a p-value < 0.05 were included in multivariate logistic regression analysis. The analysis indicated that low BMD (L1-L4) (OR = 0.801, 95% CI: 0.670–0.959, $p = 0.015$), low ES-FCSA (OR = 1.002, 95% CI: 1.000–1.005, $p = 0.035$), higher ES-FIR (OR = 1.110, 95% CI: 1.030–1.195, $p = 0.006$), and higher MVBQ score (OR = 3.767, 95% CI: 2.724–5.209, $p < 0.001$) were independent risk factors for multiple OVCF (Table 5).

ROC curve

ROC analysis helps determine the ability of a variable to predict whether a patient will develop multiple OVCFs. The AUC of ES-FCSA was 0.664, the AUC of ES-FIR was 0.655, and the AUC of MVBQ was 0.754, which was > 0.7, indicating a good prediction value. According to the Youden index, the best cut-off of MVBQ was 3.975 [1-specificity = 0.230, sensitivity = 0.665], patients with MVBQ > 3.975 were 3.767 times more likely to have multiple OVCF than those with single OVCF (Fig. 6).

Discussion

This study used a multicenter retrospective cohort study to solve the problem of the relevant factors affecting the occurrence of multiple OVCF not being clear in the current clinic. Low BMD (L1-L4) and ES-FCSA and high ES-FIR and MVBQ scores were identified as independent

Table 4 Pearson's correlation coefficient between continuous variables

Variables	BMI	BMD(L1-L4)	M-FCSA	ES-FCSA	PVM-FCSA	M-FIR	ES- FIR	PVM- FIR	MVBQ
BMI	1	0.325** (P < 0.001)	0.256** (P < 0.001)	0.339** (P < 0.001)	0.349** (P < 0.001)	−0.175** (P < 0.001)	−0.086* (P = 0.028)	−0.121** (P = 0.002)	−0.131** (P = 0.001)
BMD(L1-L4)		1	0.243** (P < 0.001)	0.328** (P < 0.001)	0.336** (P < 0.001)	−0.201** (P < 0.001)	−0.160** (P < 0.001)	−0.181** (P < 0.001)	−0.280** (P < 0.001)
M-FCSA			1	0.552** (P < 0.001)	0.760** (P < 0.001)	−0.775** (P < 0.001)	−0.544** (P < 0.001)	−0.663** (P < 0.001)	−0.196** (P < 0.001)
ES-FCSA				1	0.962** (P < 0.001)	−0.529** (P < 0.001)	−0.751** (P < 0.001)	−0.729** (P < 0.001)	−0.187** (P < 0.001)
PVM-FCSA					1	−0.668** (P < 0.001)	−0.765** (P < 0.001)	−0.786** (P < 0.001)	−0.210** (P < 0.001)
M-FIR						1	0.701** (P < 0.001)	0.855** (P < 0.001)	0.178** (P < 0.001)
ES- FIR							1	0.968** (P < 0.001)	0.177** (P < 0.001)
PVM- FIR								1	0.191** (P < 0.001)
MVBQ									1

BMI, body mass index; BMD, bone mineral density; M, multifidus; ES, erector spinae; PVM, paravertebral muscle; FCSA, functional cross-sectional area; FIR, fat infiltration rate; MVBQ, Modified-Vertebral bone quality

risk factors for multiple OVCF. When the MVBQ was > 3.975, the risk of multiple OVCFs was 3.767 times that of a single OVCF (Table 5, Fig. 6). By jointly evaluating bones and muscles, a more powerful and comprehensive tool is provided for the risk prediction of multiple OVCF, offering a reference for formulating clinical prevention and treatment strategies.

BMD is a key indicator of bone strength. With age and the development of osteoporosis [37–39], bone tissue minerals are lost, and bone trabecular structure changes, resulting in decreased bone density and bone carrying capacity and increased risk of fracture [40–43]. Wang et al. indicated that low BMD is an independent risk factor for osteoporotic vertebral compression refracture [44]. Similarly, in this study, lower BMD (L1-L4) was an independent risk factor for multiple OVCF, and in PVM, lower ES-FCSA and higher ES-FIR were closely correlated with multiple OVCF. This is similar to the conclusions of previous studies. Kim et al. [45] demonstrated that patients with OVCF had reduced CSA in PVM and increased intramuscular fat infiltration compared to patients without OVCF. The PVM is essential for maintaining spinal stability, and decreased FCSA and increased fat infiltration make the muscles less able to buffer external forces effectively, weakening the protective support of the spine and increasing the risk of fracture [14, 45].

The MVBQ score reflects bone quality by measuring the degree of vertebral fat infiltration, and a higher score indicates severe vertebral fat infiltration, damage to the bone trabecular structure, decreased bone quality, and a higher risk of fracture [11–13]. The VBQ score is an independent predictor of OVCF. Our research also confirmed this point. A higher MVBQ score is an independent risk factor for multiple OVCF. When the MVBQ was > 3.975, the risk of multiple OVCFs was 3.767 times that of a single OVCF. The VBQ score can also predict osteoporosis in lumbar degenerative diseases[46). In addition, it is widely used in the assessment of proximal junctional disease [47], cage subsidence [48] and pedicle screw loosening [49].

Muscles and bones are metabolically and functionally interconnected, and PVM plays a crucial role in maintaining the functional movement of vertebrae.These factors also affect each other. Bone mass loss can change the paravertebral load, increase fat infiltration, and decrease CSA [45]. Additionally, the decline in PVM mass affects spinal stability, increases bone burden, accelerates the decrease in bone density, and forms a vicious cycle [50], collectively increasing the risk of multiple OVCFs. Our research found that MVBQ was significantly correlated with BMD (L1-L4), ES-FCSA and ES-FIR. When MVBQ increases, the BMD (L1-L4) and ES-FCSA of the patients decrease, and ES-FIR increases. This is similar to Li W's

Table 5 Multivariate logistic regression analysis of multiple OVCF

Variables	B	SE	Wald X^2	OR	95% CI	P value
BMI	−0.018	0.033	0.309	0.982	0.921–1.047	0.578
BMD(L1-L4)	−0.221	0.091	5.859	0.801	0.670–0.959	0.015
M-CSA	−0.001	0.001	1.267	0.999	0.996–1.001	0.260
ES-CSA	−0.001	0.001	3.724	0.999	0.997–1.000	0.054
M-FCSA	0.000	0.002	0.002	1.000	0.996–1.004	0.968
ES-FCSA	0.002	0.001	4.426	1.002	1.000–1.005	0.035
M-FIR	0.000	0.024	0.000	1.000	0.955–1.048	0.987
ES-FIR	0.104	0.038	7.589	1.110	1.030–1.195	0.006
MVBQ	1.326	0.165	64.331	3.767	2.724–5.209	< 0.001

OVCF, osteoporotic vertebral compression fracture; BMI, body mass index; BMD, bone mineral density; M, multifidus; ES, erector spinae; FCSA, functional cross-sectional area; FIR, fat infiltration rate; MVBQ, Modified-Vertebral bone quality

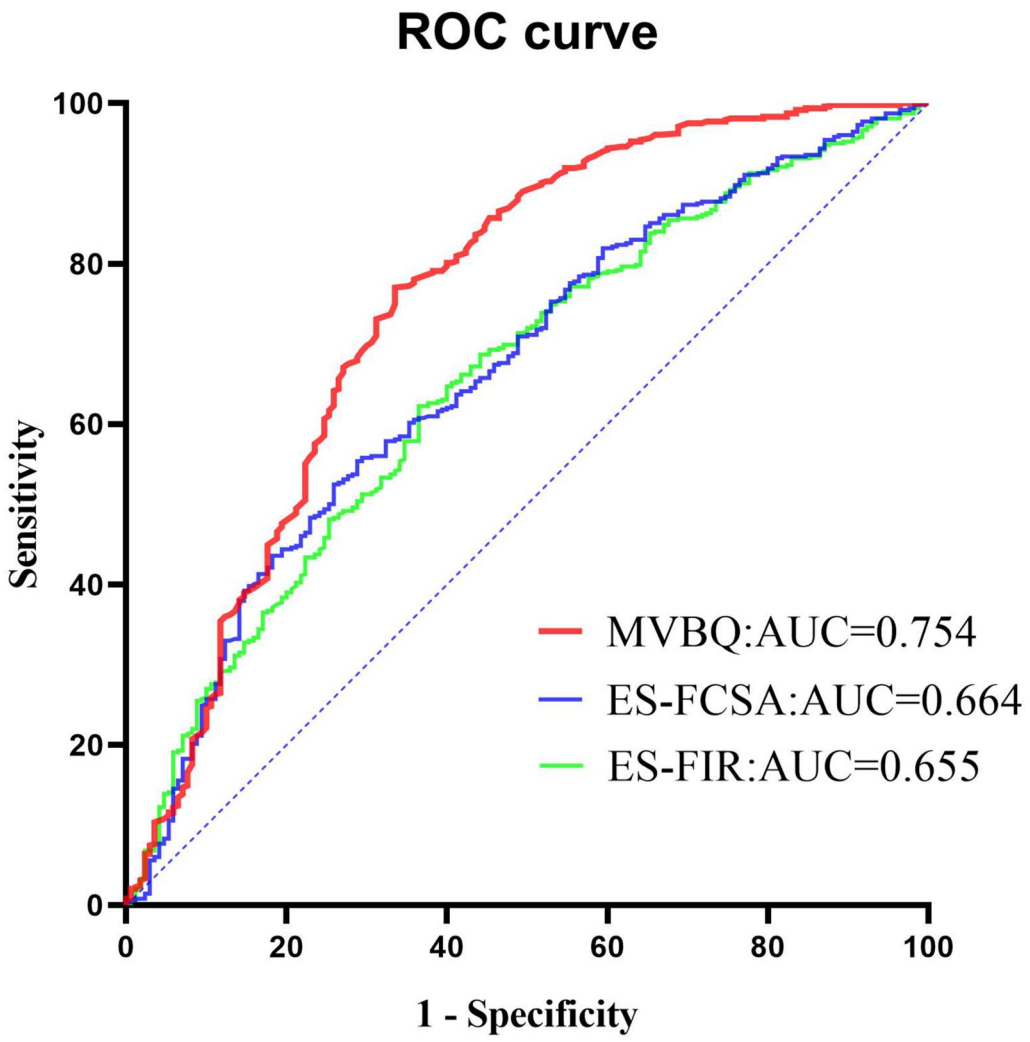

Fig. 6 The ROC curve was used to evaluate the ability of BMD (L1-L4), ES-FCSA, ES-FIR, and MVBQ to predict multiple OVCF in patients

research [51], possibly because the SI of fat in the vertebrae may indirectly reflect the SI of fat in the surrounding tissues, and also proves that the MVBQ score is a comprehensive indicator reflecting the quality of bones and PVM.

This research is important for both theory and practice. From a theoretical perspective, this study confirmed that low BMD (L1-L4) and ES-FCSA, as well as high ES-FIR and MVBQ scores, are independent risk factors for multiple OVCF, further enriching the understanding of the pathogenesis of OVCF. However, the OR = 1.002 reflects

a weak association between ES-FCSA and the outcome. We believe that when using this indicator alone, over-interpretation should be avoided with caution and it is more suitable to be used as a supplementary variable in the multi-factor model.This study provides a new basis for further research on the relationship between bone mass and muscle function and helps improve the theoretical system of osteoporosis-related diseases. The MVBQ score is a comprehensive indicator reflecting the quality of bones and PVM. The combination of MVBQ with BMD (L1-L4) and PVM quality holds the potential for accurately identifying high-risk patients with multiple OVCF in the early stage.

This study also has limitations. First, the retrospective design of this study may have led to selection bias, such as the exclusion of patients with incomplete data, affecting the universality of the results. Secondly, this study only included Chinese patients with thoracolumbar OVCF, and different races had different effects on the incidence of OVCF. The sample type of this study was relatively single and did not cover all osteoporotic vertebral fractures, which limited the extrapolation of the research conclusion. Third, although the measurement process has certain specifications, some errors in manually measuring MRI images may still exist. Fourth, the MVBQ score involves measuring L1-L4 levels, which can be affected by multiple fractures in patients and may result in unmeasurable results in patients with L1-L4 level fractures. In the future, it is necessary to optimize the MVBQ score, reduce the impact of multiple fractures, and conduct prospective, large-sample, and multicenter studies to validate the results of this study further and better guide clinical practice.

Conclusion

Studies have demonstrated that lower BMD (L1-L4) and ES-FCSA and higher ES-FIR and MVBQ scores are independent risk factors for multiple OVCF. The MVBQ score is a comprehensive indicator reflecting the quality of bones and PVM. The combination of MVBQ with BMD (L1-L4) and PVM quality holds the potential for accurately identifying high-risk patients with multiple OVCF in the early stage.

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Author contributions
Yongyong Fan: design of investigation and data collection. Shujun Chen: data analysis and writing paper. Jingjing Li: data analysis. Zhongyi Chen: data collection and data analysis. Lingjun Jiang: data collection, data analysis and writing paper. Chenglong Wang: design of investigation, data collection, data analysis and writing paper. All authors read and approved the final manuscript.

Data availability
The data supporting the results of this study were sourced from relevant medical institutions, but their availability was limited. These data were used under the permission of this study and thus could not be publicly accessed. However, data could be obtained from the corresponding author at the reasonable request and permission of Taizhou Hospital of Zhejiang Province affiliated to Wenzhou Medical University.

Declarations

Ethical approval
This study has been approved by the Central Ethics Committee (Taizhou Hospital of Zhejiang Province affiliated to Wenzhou Medical University) (June 27, 2024, Approval number KL20240631). All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent for publication
Not applicable.

Consent to participate
Written informed consent was obtained from individual or guardian participants.

Informed consent
Written informed consent was obtained from all patients.

Competing interests
The authors declare no competing interests.

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