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Original Article

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Therapeutic Prediction of Osteoporotic Vertebral Compression Fracture Using the AO Spine-DGOU Osteoporotic Fracture Classification and Classification-Based Score: A Single-Center Retrospective Observational Study

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Objective: The treatment of osteoporotic vertebral compression fractures (OVCFs) is based on their severity; however, an efficient prediction tool is lacking. We aimed to evaluate the validity of the osteoporotic fracture classification (OF classification) and scoring system (OF score) in predicting the treatment strategy for patients with OVCF, defined according to the Japanese criteria.
Methods: We retrospectively investigated 487 consecutive patients diagnosed with vertebral body fractures between January 2018 and December 2022. Only patients with their fresh vertebral fracture episode during the study period were included. Patients were classified into 3 groups: conservative treatment, balloon kyphoplasty (BKP), and open surgery. OF classification and OF scores were assessed for each patient.
Results: A total of 237 patients with OVCF were included. There were 127, 81, and 29 patients in the conservative, BKP, and open surgery groups, respectively. The OF score was significantly higher in the BKP and open surgery groups than in the conservative group ($p < 0.001$). Multivariate logistic regression analysis showed that antiosteoporotic drug use, OF classification, progressive deformity, neurological symptoms and mobilization were independent risk factors for operative treatment (all $p < 0.001$). Receiver operating characteristic analysis showed that the cutoff OF score for operative indication was 5.5, with a sensitivity of 91.9%, specificity of 56.5%, and area under the curve of 0.820 (95% confidence interval, 0.769–0.871).
Conclusion: The OF score identified patients who required operative treatment with a high degree of accuracy. This is especially important for ruling out patients who definitely require operative treatment.

Keywords: Osteoporotic fracture, Retrospective study, Vertebral compression fracture, OF score, OF classification, Osteoporosis

INTRODUCTION

Osteoporotic vertebral compression fractures (OVCFs) are increasing in frequency and gaining attention as they increase medical costs and reduce the quality of life for patients, especially in an aging society.[1] Although OVCFs are relatively common, the treatment strategies for individual cases depend on the experience and decision of physicians.

The AO Spine-DGOU osteoporotic fracture (OF) classification system for OVCF, was introduced by the Osteoporotic Fracture Working Group (Spine Division of the German Orthopedics and Trauma [DGOU]) to aid in making comprehensive, simple, and reproducible therapeutic decisions.[2] The modified OF score (0–16) of the AO Spine-DGOU OF classification system is based on the morphological evaluation of the OF and patients' medical history or systemic condition.[3,4] The classification and scoring system is practical and has high inter- and intraobserver reliabilities if the diagnostic prerequisites are met.[5]

With regard to the diagnosis of osteoporosis, the World Health Organization (WHO) classification emphasizes the relationship between bone mineral density and bone fracture. According to the WHO classification, osteoporosis is diagnosed when the T-score determined using dual-energy x-ray absorption (DXA) is ≤ -2.5, implying that the difference in bone density from the average bone density of healthy young adults is more than 2.5 times the standard deviation (SD).[6,7]

Meanwhile, the Japanese guideline for diagnosis criteria of osteoporosis established by the Japanese Society for Bone and Mineral Research (2015) emphasized the occurrence of fragility fractures.[8] Based on these guidelines, primary osteoporosis is diagnosed when patients fulfill the following criteria: (1) fragility fracture in the proximal femur or vertebral body, (2) other fragility fractures with young adult mean (YAM) on DXA of ≤ 80%, or (3) without any fragility fracture, the YAM was ≤ 70%, or the T-score was ≤ -2.5 SD. Several studies have revealed the efficacy and the validity of OF score in OFs diagnosed using WHO classification,[3,5] but the research designed to evaluate the validity of OF score in the Japanese diagnostic criteria for osteoporosis is unavailable.

We aimed to evaluate the reliability of the OF classification and OF score, as predictive tools in determining surgical indication according to the Japanese diagnostic criteria for osteoporosis.

MATERIALS AND METHODS

1. Study Design

This single-center, retrospective, observational study included 487 consecutive outpatients and inpatients diagnosed with vertebral body fractures who were treated at our hospital between January 2018 and December 2022. Data were collected from the medical records at our hospital. The inclusion criterion was the diagnosis of fresh OVCF during the study period based on the diagnostic criteria for primary osteoporosis established by the Japanese Society for Bone and Mineral Metabolism in 2015.[8] The exclusion criteria were as follows: (1) missing data necessary to determine the OF score; (2) presence of other types of fractures that could not be defined as osteoporotic, high-energy injury, malignancy, or infection; and (3) surgical history adjacent to the fracture. The primary outcome was activity of daily living 6 months after the initiation of treatment, which was evaluated based on the degree of independent living.[9] The patients who could not be followed up 6 months after the initial treatment were also excluded. A secondary fracture within 6 months after the treatment initiation despite the treatment was also collected. The study protocol was approved by the Institutional Review Board (IRB) of Fujieda Heisei Memorial Hospital (FHR No. 2023-1). Informed consent was waived by the IRB of Fujieda Heisei Memorial Hospital because this study was a retrospective, observational study and all of the data were anonymously collected and analyzed.

2. Diagnosis of Treatment Strategy Selection for OVCF

We retrospectively surveyed treatments administered to patients: conservative treatment, balloon kyphoplasty (BKP), or open surgery. Conservative treatment indicates nonsurgical treatment, including bedrest, prescription of analgesic drugs, physiotherapy, and/or orthoses use. Patients were indicated for BKP if there was resistance to conservative treatment, failed pain relief or restricted activity of daily living even with sufficient conservative treatment for ≥ 4–6 weeks. Open surgery was selected for patients with neurological deficits, severe spinal instability, or prominent kyphosis because of vertebral fractures. The surgical procedures included laminectomy, open posterolateral fusion, or spinal interbody fusion. Because BKP and open surgery were performed under general anesthesia at our institution, we comprehensively considered the operative indication based on the severity of the OVCF and other systemic conditions in patients. Patients who underwent BKP simultaneously with open surgery were included in the open surgery group. Treatment

strategies for patients were determined by a consensus among 3 certified neurosurgeons.

3. Evaluation of Parameters

Demographic data of the cohort, including age, sex, body mass index (BMI), presence of low-energy traumatic episodes, such as a fall from a standing height or less, steroid use, smoking history, and antiosteoporotic drug use, were collected. Antiosteoporotic drugs included parathyroid hormone (PTH), bisphosphonates (BPs), selective estrogen receptor modulators (SERMs), antireceptor activators of nuclear factor-kappa B ligand antibody (anti-RANKL antibody), calcium, activated vitamin D3, and vitamin K2. Furthermore, other comorbidities, such as hypertension, diabetes mellitus, congestive heart failure, and chronic obstructive pulmonary disease (COPD) were evaluated. The medical backgrounds of the patients were evaluated using the American Society of Anesthesiologists-performance status (ASA-PS, 1–5), modified Frailty Index (mFI, 0–5), and anticoagulant use. The mFI was assessed using 5 items: hypertension, diabetes mellitus, congestive heart failure, functional status, and COPD or recent pneumonia. The patients were classified into conservative, BKP, and open surgery groups. The time interval from the onset to operative treatment (BKP or open surgery) was also calculated. The OVCF of all eligible patients was classified in accordance with AO Spine-DGOU Osteoporotic Fracture Classification System (Table 1). An OF 1 indicated the absence of vertebral deformation on radiographs and computed tomography but the presence of high intensity only in the magnetic resonance imaging-short tau inversion recovery sequence, indicating vertebral body edema. An OF 2 indicated a fracture involving only one endplate, with no or only minor posterior wall involvement, and less than one-fifth of the width of vertebral body involvement. An OF 3 was determined in the presence of a distinct posterior wall involvement, more than one-fifth of the width of the vertebral body, or involvement of only one endplate. In cases involving both endplates and a suspected severe deformity of the vertebral body, we determined the OF 4. Fractures involving not only the anterior column but also posterior structures, such as ligaments, facet joints, or soft tissues, which could result in spinal instability, were classified as an OF 5. The classification was determined using the results of all available imaging examinations, including radiographs, computed tomography, and magnetic resonance imaging.

The modified OF score (0–16), determined according to the AO Spine-DGOU Osteoporotic Fracture Classification System on the AO spine website, was calculated based on morphology (2–10 points), severity of osteoporosis (0–1 points), progressive deformity (1 or -1 point), pain under analgesia (1 or -1), neurological symptoms (0 or 2 points), mobilization under analgesia (1 or -1 point), and health status (3 items, each -1 point, maximum -2 points). All OF score factors were collected and analyzed for each case. The severity of osteoporosis was evaluated using the T-score measured by DXA in the femur and vertebral body from L2 to L4. The quantitative computed tomography was not assessed in this study. The more severe T-score from the vertebral body or femur was considered, with a score of < -3 being scored as 1 point for the calculation of the OF score. Progressive deformity was defined as the progression of kyphotic or scoliotic curves by at least 10 degrees on consecutive radiographs. Pain was assessed under analgesic administration according to the WHO pain ladder using a visual analogue scale for pain (VAS of 0–10.0). A VAS score of ≥ 5 was scored 1 point, and that of < 5 or less was scored -1 point. When the patient had neurological symptoms, 2 points were added. When patients could not move even with sufficient analgesia, 1 point was added, and -1 point was added when patients could move. ASA-PS

Table 1. OF classification[2,4]

OF classification	Definition
OF1	No vertebral deformation was found in radiographs and computed tomography, but the presence of high intensity only in the magnetic resonance imaging-short tau inversion recovery sequence, indicating vertebral body edema
OF2	Involving only one endplate, with no or only minor posterior wall involvement, less than one-fifth of the width of the vertebral body
OF3	The distinct posterior wall involvement; more than one-fifth of the width of the vertebral body, or involvement of only one endplate
OF4	Both endplates involvement, and a suspected severe deformity of the vertebral body
OF5	Involving not only the anterior column but also posterior structures, such as ligaments, facet joints or soft tissues, which could result in spinal instability

OF, osteoporotic fracture.

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Table 2. Modified OF score[4]

Parameter	Evaluation	Points
OF classification (morphology)	1–5	2–10†
Severity of osteoporosis	T-score < -3	1
Progressive deformity	Yes or no	1, -1
Pain‡ (under sufficient analgesia)	VAS: ≥ 5 vs. < 5	1, -1
Neurological symptoms	Yes	2
Mobilization‡ (under sufficient analgesia)	No or yes	1, -1
Health status	ASA-PS > 3, mFI > 2§, anticoagulant use	Each -1, maximum -2

Quantitative computed tomography, the result of which were considered in the original criteria, was not performed in our study. Conservative treatment was recommended for an OF score of 0–5 points, equivalent for 6 points, and surgical treatment for ≥ 7 points.
OF, osteoporotic fracture; VAS, visual analogue scale; ASA-PS, American Society of Anesthesiologists-performance status; mFI, modified Frailty Index.
†OF classification was doubled to calculate the OF score. ‡Pain and mobilization were assessed under sufficient analgesia according to the World Health Organization pain ladder. §mFI was assessed using 5 factors: hypertension, diabetes mellitus, congestive heart failure, functional status, and chronic obstructive pulmonary disease or recent pneumonia.

of ≥ 4, mFI of 3 or more, or the use of anticoagulants was scored -1 point. Conservative treatment was recommended for an OF score of 0–5 points, equivalent for 6 points, and operative treatment for ≥ 7 points (Table 2). Data on other concurrent vertebral fractures and vertebral fracture levels were also collected. The outcome was assessed using the degree of independent living after the initiation of each treatment.[9] Group A indicates no significant disability and ability to go outside without any assistance, regardless of the presence or absence of pain; group B indicates slight disability and ability to go outside with assistance; group C indicates moderate to severe disability and inability to go outside. group D indicates unclear activities of daily living (ADL) in medical records, and group E indicates death. Groups A and B are defined as good outcomes; however, groups C, D, and E are poor outcomes. The groups were determined 6 months after the initiation of each treatment. A secondary fracture was defined as the subsequent symptomatic vertebral fracture within 6 months after the treatment initiation despite the treatment.

4. Statistical Analysis

Summary statistics and frequency distributions were calculated for all demographic data, comorbidities, OF scores, and other variables. Data are expressed as mean ± SD. For each variable, normality and equality of variance were tested using the Shapiro-Wilk and Levene tests, respectively. When normality and equality of variance were evident, a 1-way analysis of variance was applied. When neither normality nor equality of variances could be assumed, the Kruskal-Wallis test was used to confirm statistical differences. If a significant difference was indicated in the test, using the multiple comparison method, Wilcoxon sum-rank test was conducted to compare the variables among groups, deriving p-values that were adjusted by Bonferroni correction. Thus, p-value of < 0.013 (0.05/3) was considered statistically significant. We performed Welch t-test to determine the difference in the time interval from the onset to operative treatment (BKP or open surgery). Multivariate logistic regression analysis was performed with operative (BKP/open surgery) or nonoperative (conservative) as the objective variable to clarify the most relevant risk factor for operative indication. Receiver operating characteristic (ROC) curve analysis was performed to estimate the area under the curve (AUC) and 95% confidence interval (95% CI) to confirm the validity of the OF score for predicting operative indications. In all cases, the significance level was set at 5%. All statistical analyses were performed using the R ver. 4.3.0 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Of the 487 consecutive patients, we reviewed 339 who fulfilled the inclusion criteria: 75 patients lacked the data to determine the OF score, 8 patients had high-energy injury, 4 patients had fractures due to vertebral metastasis of a malignant tumor, and 3 patients had infectious spondylosis and other causative fractures. Seven patients underwent surgery adjacent to the fresh vertebral fracture. Five patients were not followed up within 6 months; therefore, we analyzed 237 patients with OVCF, of which 127 were treated conservatively, 81 underwent BKP, and 29 underwent open surgery (Fig. 1).

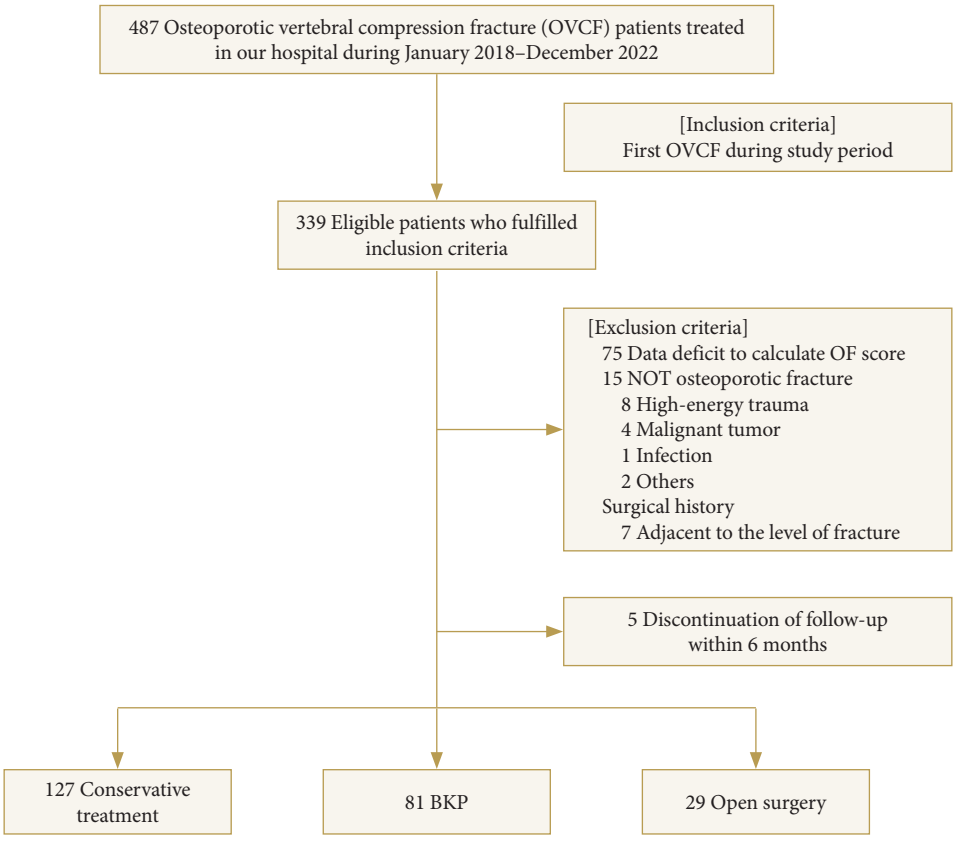

Fig. 1. Flow chart of patient selection in the study. BKP, balloon kyphoplasty; OF, osteoporotic fracture.

1. Demographics of the Study Cohort

The mean ages of participants in the conservative, BKP, and open surgery groups were 77.3 ± 8.0, 78.3 ± 7.3, and 77.4 ± 9.4 years, respectively and the differences between the groups were not significant ($p = 0.685$). The population in the conservative, BKP, and open surgery groups was female dominant with similar BMI. The frequency of low-energy traumatic episodes, steroid use, and smoking history did not significantly differ among the groups. The rate of antiosteoporotic drug use was 14.2% in the conservative group; however, it was 38.3% and 37.9% in the BKP and open surgery groups, respectively ($p < 0.001$). The most frequent comorbidity was hypertension (46.0%) followed by diabetes mellitus (13.9%). Fourteen patients with congestive heart failure (5.1%) were included in the conservative and BKP groups, and 7 patients with COPD (3.0%) were included only in the conservative group. The ASA-PS was not significantly different ($p = 0.108$), but mFI was different ($p = 0.027$). The mean duration of conservative treatment before the operation was 121.6 and 134.9 days in the BKP and open surgery groups, respectively ($p = 0.738$). Furthermore, 105 patients in our cohort had other vertebral fractures (38.5%); however, no significant difference was observed among the groups ($p = 0.365$). Vertebral fractures most frequently occurred at the Th11–L2 level or thoracolumbar junction (54.6%) (Table 3).

2. OF Score/OF Classification

The mean OF score in the conservative, BKP, and open surgery groups was 5.2 ± 3.2, 8.6 ± 2.4, and 11.1 ± 2.1, respectively ($p < 0.001$). The most frequent OF score was 3 points in the conservative group (Fig. 2A), 9 points in the BKP group (Fig. 2B), and 11 points in the open surgery group (Fig. 2C). Pairwise comparisons between groups (conservative treatment-BKP, BKP-open surgery, and conservative treatment-open surgery) showed that all groups were significantly different ($p < 0.001$) (Fig. 2D).

The mean OF classification was 2.9 ± 1.1, 3.5 ± 0.5, and 4.5 ± 0.8 in the conservative, BKP, and open surgery groups, respectively ($p < 0.001$). The most frequent OF classification was OF 2 in the conservative group (Fig. 3A), OF 4 in the BKP group (Fig. 3B), and OF 5 in the open surgery group (Fig. 3C). The T-scores of the femur were -2.32 ± 1.07, -2.52 ± 1.01, and -2.23 ± 0.97, and those of the vertebral body were -2.15 ± 1.56, -2.13 ± 1.34, and -1.71 ± 1.80 for the 3 groups, respectively; however, the differ-

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Table 3. Demographics of the study cohort

Variable	Conservative treatment (n = 127)	BKP (n = 81)	Open surgery (n = 29)	p-value
Age (yr)				0.685
Mean ± SD	77.3 ± 8.0	78.3 ± 7.3	77.4 ± 9.4	
Range	44–93	54–91	39–92	
Female sex	87 (68.5)	62 (76.5)	20 (69.0)	0.441
BMI (kg/m^2)	21.2 ± 3.8	21.6 ± 3.7	21.7 ± 3.95	0.683
Low-energy trauma (%)	40 (31.5)	36 (44.4)	15 (51.7)	0.050
Steroid use (%)	7 (5.5)	5 (6.2)	5 (17.2)	0.080
Smoking history (%)	25 (19.7)	15 (18.5)	4 (13.8)	0.765
Anti-osteoporotic drug use (%)	18 (14.2)	31 (38.3)	11 (37.9)	< 0.001*
The time interval between the onset to operative treatment (day)				0.738
Mean ± SD	-	121.6 ± 139.5	134.9 ± 196.0	
Range	-	13–833	10–1,009	
Medical condition				
HT (%)	50 (39.4)	43 (53.1)	16 (55.2)	0.088
DM (%)	15 (11.8)	14 (17.3)	4 (13.8)	0.542
CHF (%)	9 (7.1)	4 (4.9)	1 (3.4)	0.683
COPD (%)	7 (5.5)	0 (0)	0 (0)	0.044*
ASA-PS (1–5)	1.9 ± 0.7	2.1 ± 0.6	2.1 ± 0.7	0.108
mFI (0–5)	0.8 ± 0.8	1.0 ± 0.6	1.2 ± 0.9	0.027*
Anticoagulant use (%)	22 (17.3)	14 (17.3)	7 (24.1)	0.673
Other vertebral fracture (%)	55 (43.3)	40 (49.4)	10 (34.5)	0.365
Level of fracture (%)				
≤ Th10	15 (12.4)	5 (6.2)	0 (0)	
Th11–L2	73 (60.3)	55 (67.9)	21 (72.4)	
L3–5	39 (32.2)	21 (25.9)	8 (27.6)	

Values are presented as number (%) unless otherwise indicated.
BKP, balloon kyphoplasty; BMI, body mass index; HT, hypertension; DM, diabetes mellitus; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; ASA-PS, American Society of Anesthesiologists-Performance Status; mFI, modified Frailty Index.
The time interval between the onset and operative treatment was tested with Welch t-test.
*$p < 0.05$, statistically significant differences.

ences were not statistically significant ($p = 0.297$ and $p = 0.361$ in each group).

Deformity ($p < 0.001$), VAS score ($p = 0.021$), neurological symptoms ($p < 0.001$), and mobilization ($p < 0.001$) were significantly different among the 3 groups (Table 4). Multivariate logistic regression analysis was performed to evaluate the most efficient operative indicators. Of the variables, antiosteoporotic drug use (odds ratio [OR], 4.01; 95% CI, 1.74–9.27), OF classification (OR, 1.69; 95% CI, 1.12–2.55), deformity (OR, 3.17; 95% CI, 1.45–6.91), neurological symptoms (OR, 6.22; 95% CI, 2.22–17.44), and mobilization (OR, 6.95; 95% CI, 2.13–22.66) were significant clinical indicators of operative management. Other factors such as age (OR, 0.97; 95% CI, 0.92–1.01), sex (OR, 0.76; 95% CI, 0.35–1.64), mFI (OR, 1.17; 95% CI, 0.78–1.74) and VAS (OR, 1.12; 95% CI, 0.99–1.28) were not statistically significant indicators (Table 5).

ROC analysis was performed to assess the validity of the OF score as a predictive tool for operative indications. This showed that the ROC for a cutoff OF score of 5.5 to differentiate between nonoperative and operative management (BKP and open surgery) indicated a sensitivity of 88.9%, specificity of 56.7%, and AUC of 0.786 (95% CI, 0.725–0.846) (Fig. 4A). When a cutoff OF score was set at 5.5 to differentiate between conservative treatment and BKP, ROC showed a sensitivity of 91.8%, specificity of 56.7%, and AUC of 0.823 (95% CI, 0.772–0.874) (Fig. 4B). The ROC for a cutoff OF score of 8.5 to differentiate be-

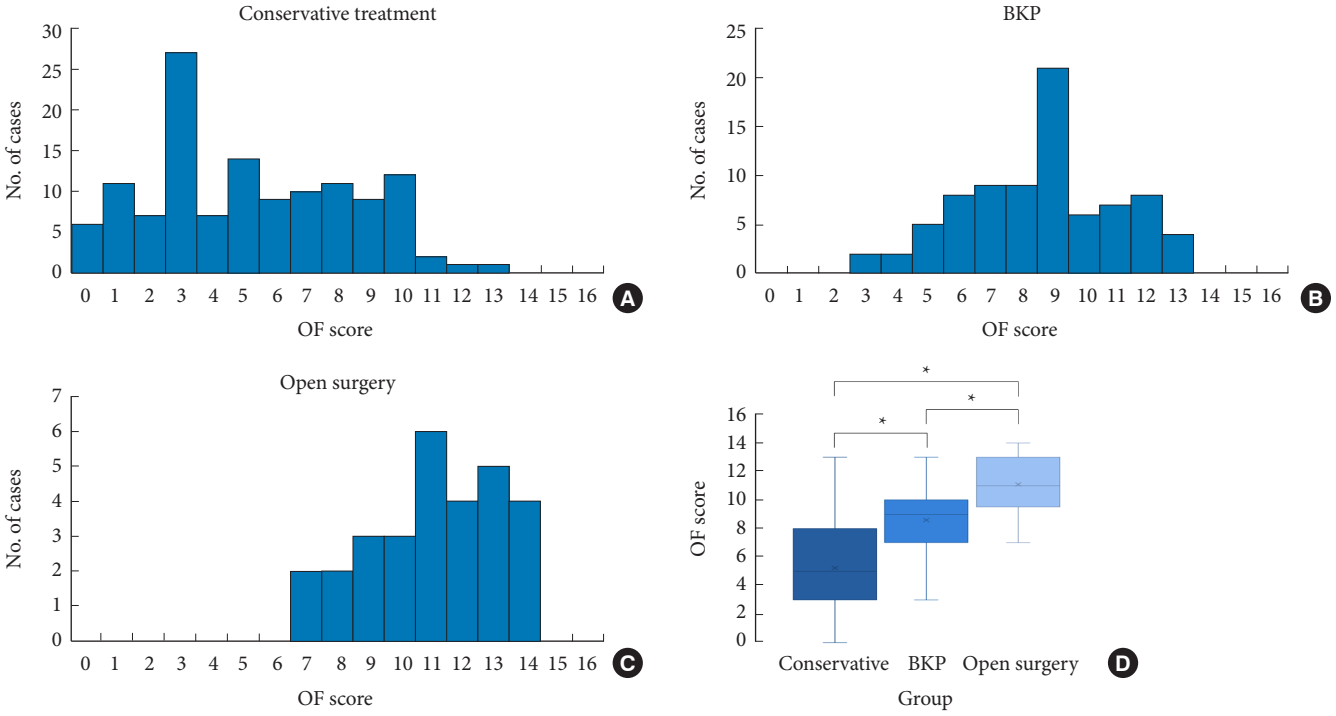

Fig. 2. Histogram of OF score (of 0–16) distribution in the 3 groups: (A) conservative group, (B) BKP group, and (C) open surgery group. Panel D shows the boxplot of the OF score in each group. Wilcoxon sum-rank test was conducted to compare group variables, deriving p-values adjusted by Bonferroni correction. A p-value < 0.013 (0.05/3) was considered statistically significant. OF, osteoporotic fracture; BKP, balloon kyphoplasty. *p < 0.001.

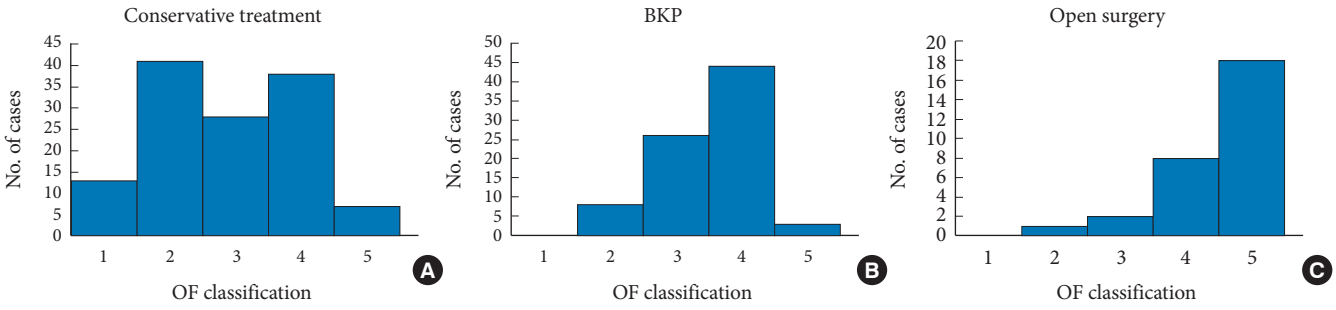

Fig. 3. Histogram of OF classification (of 1–5) distribution among the 3 groups: (A) conservative group, (B) BKP group, and (C) open surgery group. OF, osteoporotic fracture; BKP, balloon kyphoplasty.

tween conservative treatment and open surgery showed a sensitivity of 86.2%, specificity of 80.3%, and AUC of 0.929 (95% CI, 0.886–0.972) (Fig. 4C). The outcome evaluation using the degree of independent living showed that group A had 83 (65.4%), 45 (55.6%), and 14 patients (48.3%); group B had 13 (10.2%), 14 (17.3%), and 11 patients (37.9%); group C had 8 (6.3%), 12 (14.8%), and 2 patients (6.9%); group D had 20 (15.7%), 10 (12.3%), and 1 patient (3.4%); group E had 3 (2.4%), 0 (0%), and 1 patient (3.4%) in the conservative, BKP, and open surgery groups, respectively (Fig. 5). Furthermore, 180 patients (75.9%) had good outcomes, whereas 57 patients (24.1%) had poor outcomes. A secondary fracture was detected in 0 (0%), 13 (16.0%), and 5 patients (17.2%) in the conservative, BKP, and open surgery groups, respectively (p < 0.001). When the cutoff of OF score was set at 5.5, and the indication was determined based on the score, the proportion of good outcomes was 77.2% among the patients treated operatively and scored ≥ 5.5 and 79.2% among those treated conservatively and scored < 5.5. However, when the indication was not determined based on the score, the proportion of good outcomes was 66.7% among the patients treated opera-

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Table 4. Relationship between OF scores and various factors in the 3 groups

Variable	Conservative treatment (n = 127)	BKP (n = 81)	Open surgery (n = 29)	p-value
OF score	5.2 ± 3.2	8.6 ± 2.4	11.1 ± 2.1	< 0.001*
OF classification	2.9 ± 1.1	3.5 ± 0.5	4.5 ± 0.8	< 0.001*
1	13 (10.2)	0 (0)	0 (0)	
2	41 (32.3)	8 (9/9)	1 (3.4)	
3	28 (22.0)	26 (32.1)	2 (6.9)	
4	38 (29.9)	44 (54.3)	8 (27.6)	
5	7 (5.5)	3 (3.7)	18 (62.1)	
T-score				
Femoral	-2.32 ± 1.07	-2.52 ± 1.01	-2.23 ± 0.97	0.297
Vertebral body, L2–4	-2.15 ± 1.56	-2.13 ± 1.34	-1.71 ± 1.80	0.361
Deformity (%)	51 (40.2)	61 (75.3)	24 (82.8)	< 0.001*
VAS (0–10.0)	5.8 ± 2.9	6.8 ± 2.4	6.8 ± 2.6	0.021*
Neurological symptom (%)	8 (6.3)	23 (28.0)	18 (62.1)	< 0.001*
Mobilization (%)	4 (3.1)	16 (19.8)	22 (75.9)	< 0.001*

Values are presented as mean ± standard deviation or number (%).
OF, osteoporotic fracture; BKP, balloon kyphoplasty; VAS, visual analogue scale.
*p < 0.05, statistically significant differences.

Table 5. Multivariate logistic regression analysis for the association between each factor and operative treatment

Variable	Odds ratio	95% CI	p-value
Age	0.97	0.92–1.01	0.142
Sex	0.76	0.35–1.64	0.484
Antiosteoporotic drug	4.01	1.74–9.27	0.001*
mFI	1.17	0.78–1.74	0.452
OF classification	1.69	1.12–2.55	0.012*
Deformity	3.17	1.45–6.91	0.004*
VAS	1.12	0.99–1.28	0.074
Neurological symptom	6.22	2.22–17.44	< 0.001*
Mobilization	6.95	2.13–22.66	0.001*

CI, confidence interval; mFI, modified Frailty Index; OF, osteoporotic fracture; VAS, visual analogue scale.
*p < 0.05, statistically significant differences.

tively but scored < 5.5, and 70.9% among those treated conservatively but scored ≥ 5.5 (Table 6).

DISCUSSION

The study results showed that the OF score tended to be higher for conservative treatment, followed by BKP and open surgery. In our retrospective study cohort, the OF scores were consistent with operative indications; consequently, we selectively performed BKP or open surgery in patients with high OF scores. However, we did not perform open surgery in patients with an OF score ≤ 6. Many of these patients were treated with open surgery because the OF score was invariably higher in patients with a high OF classification and potential spinal instability. In the conservative treatment group, the OF classification grade distribution had 2 distinct peaks. In patients with OF 4 or 5, among which some were treated conservatively.

In most cases, conservative treatment is a common choice, with a high rate of healing, minor residual deformity, and functional recovery; however, some cases may have prolonged pain, nonunion, neurological deficits, and kyphotic deformity.[10] Scheyerer et al.[10] reported that the risk factors for conservative treatment failure were patient-specific, such as age > 73 years, T-score < -2.93, BMI > 23 kg/m^2 and mFI > 2.5, and radiological, such as involvement of the posterior wall or initial height loss. In our study, patient demographics were not significantly different among groups; however, morphological factors that can lead to conservative treatment failure were evaluated using the OF classification.

In the present study, antiosteoporotic drug use, OF classification, progressive deformity, neurological symptoms, and mobilization were independent risk factors for the need for operative procedures, according to the results of multivariate logistic regression analysis. Antiosteoporotic drugs, including BPs, ana-

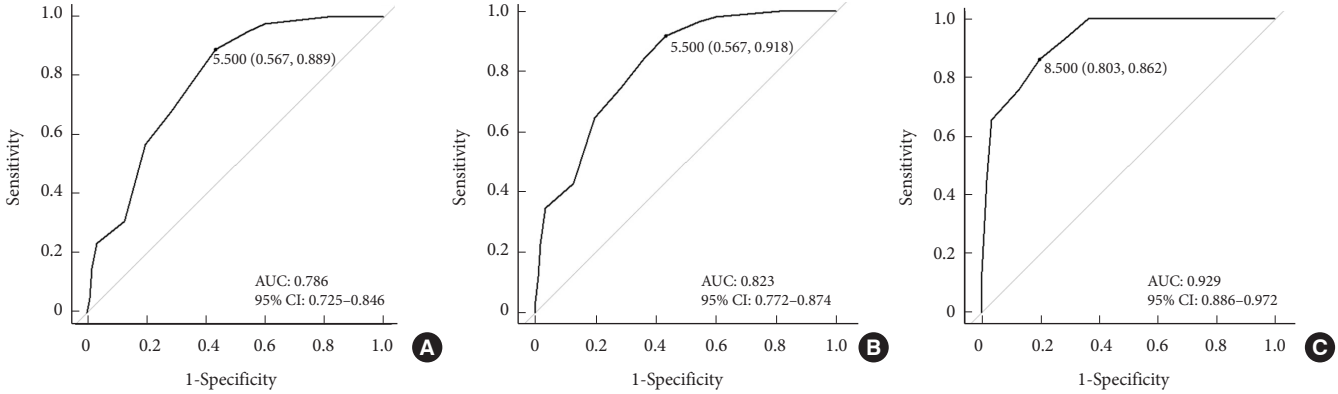

Fig. 4. Receiver operating characteristic curve of OF score for predicting nonoperative (conservative) and operative management (BKP and open surgery). The cutoff value was identified using the Youden index. (A) Conservative treatment versus operative management, (B) conservative treatment versus BKP, and (C) conservative treatment versus open surgery. The cutoff is depicted as a point on the curve, and the numbers in brackets show specificity on the left and sensitivity on the right. BKP, balloon kyphoplasty; AUC, area under the curve; CI, confidence interval.

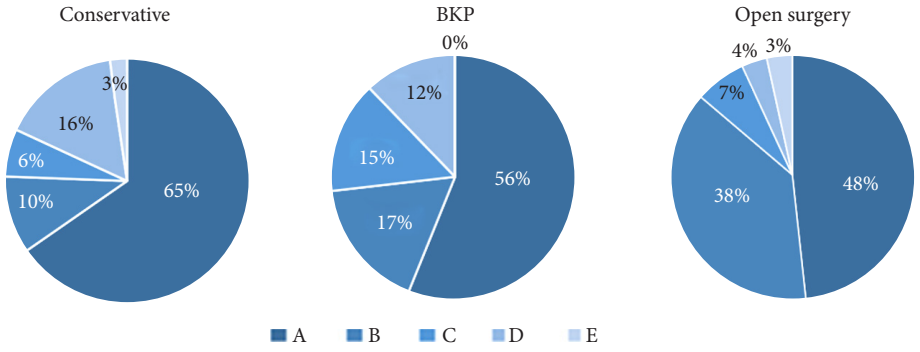

Fig. 5. Pie chart of the degree of independent living 6 months after the initial treatment in each treatment group. Group A: no significant disability. Able to go outside without assistance with or without symptoms; Group B: slight disability. Able to go outside with assistance; Group C: moderate to severe disability. Unable to go outside; Group D: activities of daily living were not clarified in records; Group E: Dead. BKP, balloon kyphoplasty.

Table 6. The proportion of good outcomes in the patients who were treated based on OF score (cutoff: 5.5)

OF score	Operative management	Conservative management
≥5.5	78/101 (77.2)*	39/55 (70.9)
<5.5	6/9 (66.7)	57/72 (79.2)*

Values are presented as number (%).
OF, osteoporotic fracture.
*Denotes that the treatment was performed based on the indication of OF score.

bolic agents, anti-RANKL antibody, and PTH, have been widely used for primary and secondary prevention of OF and are effective medications.[11-15] In the present study's cohort, the rate of antiosteoporotic drug use was high in the BKP and open surgery groups, suggesting the patients at high risk of OF received antiosteoporotic drugs.

In the Evaluation of the Osteoporotic Fracture Classification, Treatment Score and Therapy Recommendations (EOFTT) study, Ullrich et al.[16] reported that subjective parameters such as VAS scores were worse in patients in whom conservative treatment was recommended but surgery was adopted. Our study showed that pain was not a significant indicator of the need for operative procedures, but the cutoff of the VAS score in the EOFTT study (VAS score ≥4/<4) was different from that in our study (VAS score ≥5/<5).[16] Progressive deformity, neurological symptoms and mobilization are more likely indicators of the need for operative management when present, and the OF score tended to be higher.

In the EOFTT study, ROC analysis showed that the cutoff OF score of 6.5 had a sensitivity of 60%, specificity of 68%, and AUC of 0.684 ($p<0.001$) in predicting the treatment that was actually

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conducted. In contrast, our study's ROC analysis showed that the AUC of the OF score in predicting nonoperative and operative procedures was as high as 0.786 when the cutoff value was 5.5, indicating outstanding diagnostic performance. In particular, the sensitivity was 88.9%; therefore, the OF score is practical for ruling out patients with OVCF who do not require an operative procedure. While comparing the conservative and BKP groups, the cutoff value was 5.5, the same as when comparing operative and nonoperative treatments, indicating that the OF score showed a similar diagnostic performance. Furthermore, while comparing conservative treatment and open surgery, the cutoff was as high as 8.5, and the AUC of the OF score was elevated to 0.929, demonstrating exceptional efficiency. Therefore, the results of ROC analysis showed that the OF score can be considered an effective tool for determining the need for operative procedures in patients with OVCF.

The outcome determined using the degree of independent living showed that 180 of 237 patients (75.9%) had good outcomes at 6 months follow-up. The ratio of operative management to conservative management was 110:127, indicating a similar outcome proportion. According to previous reports, conservative treatment is considered for most OVCF patients, presenting a sufficient rate of fracture healing and satisfactory functional recovery. Teriparatide, a mainstay medication, significantly enhances fracture healing, improving morbidity and mortality.[13,15] However, in some cases, operative treatment is necessary for patients with a severely collapsed vertebral body, chronic intractable pain, nonunion, and spinal instability.[9,15,17,18] Osterhoff et al.[18] reported that the short-term outcome in 19 patients, classified as having type OF 5 fractures and who underwent surgical treatment showed no surgical complications. However, the rate of general postoperative complications reached 45%. Since the perioperative complication risks should be considered, operative indications should be carefully decided. In the present study, only the conservative treatment group included patients with COPD, none in the BKP and open surgery groups. This may indicate that the conservative treatment was chosen because of the risk of general anesthesia. No single standard treatment strategy has been suggested; therefore, the treatment plan should be determined based on the severity of OVCF and the patient's systemic condition.

This study had several limitations. This retrospective study recruited patients from a single-center cohort. Moreover, most patients were outpatients treated conservatively, and data deficits are frequent in conservatively treated patients owing to follow-up dropouts. Therefore, selection bias should be considered. Regarding OF score calculation, quantitative computed tomography was considered in the original criteria to determine osteoporosis severity; however, this could not be considered in this study because these data were not available for all patients. Therefore, the severity of osteoporosis may have been underestimated. Furthermore, BKP was only performed under general anesthesia in Japan due to insurance restrictions, implying that patients who were originally indicated to undergo BKP could have been treated conservatively in cases with a high risk of general anesthesia. In addition, the outcomes were evaluated using the qualitative score, or degree of independent living in 6 months, because quantitative evaluation, such as VAS, Oswestry disability index, or Japanese orthopedic association score, was lacking in the follow-up period after the treatment initiation. In addition, group D in the score denotes the lack of data on the ADL in medical records and was defined as a poor outcome; therefore, the number of patients with good outcomes may be underestimated. The follow-up period was 6 months; therefore, the long-term outcome remains unknown. The ADL before the onset of OVCF was not evaluated, because we could not obtain sufficient information for ADL evaluation before the treatment and it was difficult to maintain consistency of the assessment within each group regarding of the assessment timing. Due to the study's retrospective nature and short follow-up period, a further prospective study is needed.

CONCLUSION

OF classification and OF score are useful prediction tools for determining treatment strategies in patients with OVCF diagnosed using the Japanese diagnostic criteria. According to the results of the ROC analysis in our cohort, the score could be useful, especially to rule out patients who do not need operative management, including BKP, when the cutoff OF score was set at 5.5.

NOTES

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