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RESEARCH

# OF-score for osteoporotic thoracolumbar fractures– which parameter is decisive for the therapy decision? - a prospective multicentric cohort study

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## Abstract

**Introduction** Various treatment strategies for osteoporotic vertebral compression fractures (OVCF) have been proposed, with the OF-score being a promising tool for therapeutic decision-making. *The aim of this study is to determine the significance of the individual components of the OF-score for the therapy recommendation. Furthermore, score modifications will be sought that lead to improved agreement between the score recommendation and clinically successful therapy.*

**Methods** Data from the prospective multicenter study "Clinical evaluation of the OF-score for therapy planning and treatment recommendation for osteoporotic fractures of the thoracolumbar spine" (EOFTT) with 518 patients (128 male, 390 female), including 344 surgically and 174 conservatively treated, were used. Binary discriminant analysis and logistic regression models were applied to analyze the predictive power of OF-score variables for the treatment decision. ROC analysis determined the predictive value of VAS pain, with thresholds defined using the Youden index.

**Results** A total of 508 patients were analyzed. Binary discriminant analysis showed an explanatory power of 79.7%, and logistic regression showed 80.4%. The most powerful variables were VAS pain (0.809), mobilization (−0.405), and OF classification (0.302). ROC analysis identified a VAS threshold of 5.5 for surgical treatment (AUC = 0.811, $p < 0.001$). A VAS threshold of ≥5 yielded the highest accuracy (71.5%), while thresholds ≥4 had the highest sensitivity (71.9%) and ≥6 the highest specificity (82.0%).

**Conclusions** A modified OF-score with a VAS pain threshold of ≥5 improves accuracy and balances specificity and sensitivity. Despite this adjustment, the OF-score's predictive power of 80% remains underutilized. Further research could enhance the clinical utility of the modified score and explore the potential of other variables.

**Keywords** Osteoporotic thoracolumbar fracture · Vertebral body compression fracture · Treatment decision · OF-score · OF-classification · Factors for therapy decision

## Introduction

The treatment of osteoporotic vertebral compression fractures has changed steadily in recent years [1]. The continuously increasing number of cases and the growing demand from patients for effective treatment have led to a more nuanced assessment of these fractures. Consequently, diverse treatment protocols and surgical techniques have been proposed [2–4] *and classification systems are still under discussion* [5].

The Osteoporotic Fracture working group (AG OF) of the spine section of the German Society of Orthopedics and Trauma Surgery (DGOU) developed a specific classification for osteoporotic thoracolumbar fractures (OF classification) [6] *which has been evaluated by other working groups internationally* [7–10] *or integrated in disease management*

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*workflows* [4]. *A* treatment decision score (OF-score) was also developed using a scientific iterative process to identify the most important parameters [11]. The OF-score can be used as an aid in deciding whether to undergo conservative or surgical treatment. It includes several clinical and radiological parameters [11].

The OF-score has been validated in a prospective multicenter study. The "Clinical evaluation of the OF-score for therapy planning and treatment recommendation for osteoporotic fractures of the thoracolumbar spine" (EOFTT) examined the score in a real-world scenario and showed a high degree of correlation with the chosen therapy [12]. In addition, treatment according to the OF-score regularly showed clinically good short-term results [12–15]. As a result, the OF-score itself has gained national and international acceptance [16–18].

In addition to the fracture classification, the parameters of the OF-score are primarily clinical information such as pain, mobilization, neurological status and state of health. It is still unclear which parameters have a particularly strong influence on the overall result and therefore the treatment recommendation.

Comparison with real-world practice shows that a certain proportion of patients are not treated according to the OF-score. In particular, pain and mobility are shown to be potentially very strong triggers for the treatment decisions [12, 13].

However, a detailed analysis of the potential of the variables included in the OF-score to predict therapy has not yet been investigated. Their selection has so far been based on clinical experience.

**Table 1** Osteoporotic vertebral fracture score (OF-score)

| Parameter | Grade | Points |
|---|---|---|
| OF Classification (morphology) | 1–5 | 2–10 |
| Severity of osteoporosis | T-Score < −3 | 1 |
| Deformity progression | Yes/No | 1/−1 |
| Pain (under adequate analgesia) | VAS ≥4/<4 | 1/−1 |
| Fracture related neurological deficit | Yes | 2 |
| Able to mobilize without help | Yes/No | −1/1 |
| Health status | ASA > 3, BMI < 20 kg/m$^2$, nursing case, anticoagulation | Each parameter −1; maximum −2 |

The OF classification grade is doubled and combined with the assessments on osteoporosis, deformity progression, pain, neurological deficits, mobility, and general health state. If a parameter is unknown or cannot be determined, it receives a score of 0 points. A score between 0 and 5 points indicates a recommendation for Conservative treatment, a score of 6 points is neutral, and score > 6 points recommends surgical treatment. ASA: American society of anesthesiologists (1–5), BMI: body mass index, VAS: pain, recorded with a visual analogue scale from 0–10. Adequate analgesia refers to the prescription of medication in accordance with the WHO pain ladder

The aim of this study is to test the predictive value of each variable included in the OF-score using the data base of the EOFTT study and whether adjusting the weighting of the variables leads to a better explanation of the therapy performed.

## Methods

The OF-score for treatment recommendation is based on seven categories with 10 variables (Table 1). The variables are weighted differently and then combined into a sum score. An OF-score of < 6 recommends conservative therapy, while an OF-score > 6 recommends surgical therapy. No specific recommendation is made for an OF-score of 6. Both, the variables used and the threshold value of 6 were determined through a modified Delphi process conducted by an expert panel.

This study analyzes prospective data from the EOFTT study [12]. *This study was conducted prospectively and multicentrically. Inclusion criteria were admission to a hospital due to an osteoporotic vertebral fracture, regardless of the treatment performed, as a total cohort study. Exclusion criteria were metastatic fractures, spondylitis, and polytrauma. The data was collected in the participating centers using a comprehensive questionnaire and sent to the lead project center for consolidation in a data matrix. The data analyzed here from the prospective EOFTT study includes all data used in the context of the OF score for therapy recommendations (*Table 1*)*. A total of 518 patients (128 (25%) male, 390 (75%) females) with osteoporotic spine fractures could be included in the EOFTT study, of whom 344 (66%) were treated surgically and 174 (34%) conservatively [12, 13]. In addition to the variables used in the OF-score, the therapy carried out was also recorded. In the EOFTT study, the treating physicians made the treatment decision, independently of the OF-score value.

### Statistical methods

A binary discriminant analysis was conducted to examine the potential of the variables used in the OF-score to explain the therapy performed. For the logistic regression, the received therapy was coded with 0 or 1 for conservative therapy or surgical therapy, respectively. The 10 variables of the OF-score were coded as follows:

The interval-scaled variable was pain, measured using the Visual Analog Scale (VAS) ranging from 0 (Zero) to 10. The following ordinal variables were also included:

The OF classification (1 to 5), with OF1 as the reference category. Mobility, assessed using a Likert scale from 1 to 5, where 1 represents "completely mobile without aids" and

**Table 2** Descriptive parameters of the examined patients and the variables used in the OF-score

| OF-score variables | |
|---|---|
| Pain (VAS 0–10) | 5.9 ± 2.1 (range: 0–10) |
| OF classification | |
| OF1 | 3 (1%) |
| OF2 | 119 (23%) |
| OF3 | 214 (42%) |
| OF4 | 149 (29%) |
| OF5 | 23 (5%) |
| ASA | |
| I | 55 (11%) |
| II | 184 (36) |
| III | 253 (50%) |
| IV | 16 (3%) |
| Deformity progression | 186 (37%) |
| Fracture related neurological deficit | 17 (3%) |
| BMI < 20 kg/m$^2$ | 30 (6%) |
| Anticoagulation | 146 (29%) |
| Severe osteoporosis | 326 (64%) |
| Nursing case | 58 (11%) |
| Able to mobilize without help | 320 (63%) |

**Table 3** Standardized canonical discriminant coefficients, sorted by their value

| | Standardized canonical discriminant coefficients |
|---|---|
| Pain | 0.809 |
| OF classification | 0.302 |
| ASA | 0.227 |
| Deformity progression | 0.063 |
| Fracture related neurological deficit | 0.038 |
| BMI < 20 kg/m2 | 0.014 |
| Anticoagulation | −0.043 |
| Severe osteoporosis | −0.106 |
| Nursing case | −0.227 |
| Able to mobilize without help | −0.405 |

5 represents "bedridden." Level 1 (completely mobile) was used as the reference category. The ASA classification (1 to 5), with ASA 1 as the reference category.

Additionally, the following dichotomous variables were considered, where 0 indicates "no" and 1 indicates "yes."

Severity of osteoporosis, defined as a T-score of less than −3 or a Hounsfield Units (HU) value below 110; progression of deformity; fracture-related neurological deficits; a BMI of less than 20 kg/m²; nursing case and anticoagulation therapy.

The binary discriminant analysis was used because it allows for a direct comparison of the variables in terms of their weighting through the standardized canonical discriminant coefficients. These coefficients indicate the strength and direction of the relationship between each variable and the discriminant function. High values (positive or negative) suggest that the variable significantly impacts group separation, with positive values increasing the likelihood of belonging to a particular group, and negative values decreasing it. Low values near zero imply that the variable contributes little to the group differentiation. The correlation coefficients between the original variables and the canonical discriminant function reveal the degree to which each variable is associated with the function that separates the groups. High positive or negative correlations indicate a strong contribution to group distinction, while low correlations suggest minimal influence.

A logistic regression model was used to test the OF-score variables on the day of the treatment decision for their explanatory power for the treatment carried out. This serves to evaluate the potential of the variables to orient the subsequent optimization of the score accordingly.

The influence of pain on the treatment was investigated using ROC analysis. The cut off value was calculated using the Youden index. In the modified OF-score, the new threshold for VAS is used and its weighting is adjusted in an iterative process until its accuracy in the prediction is maximized.

The agreement between the correctly predicted treatment based on the OF-score and the modified OF-score was checked using Chi² test. Statistical analyses were performed using SPSS software (Version 29; IBM Corp., Armonk, NY, USA), and the significance threshold was set at $p = 0.05$.

## Results

A total of 508 patients (126 male, 382 females, mean age: 75 ± 10 years, range 41–97 years) with complete datasets were included in the discriminant analysis, which yielded significant results ($p < 0.001$) for 337 patients who underwent surgical treatment (66%) and 171 patients who received conservative treatment (34%). Ten patients have been excluded due to missing values. The descriptive statistics of the patients and the analyzed data for the variables used in the OF-score are presented in Table 2.

The standardized canonical discriminant coefficients are presented in Table 3, with pain and the OF classification showing the highest positive values. Mobility achieved the second highest absolute but negative discriminant coefficient. Using all the variables of the OF-score, the linear model demonstrated an accuracy of 79.7% in predicting the therapy performed. This represents the maximum explanatory power achievable, as 79.7% of the therapy performed can be explained by the linear model using the variables included in the OF-score.

**Table 4** Comparison of the OF-score and the modified OF-score (using VAS = 6 as threshold) recommendation and the therapy observed

| | Performed treatment | OF-score recommendation | | | Total |
|---|---|---|---|---|---|
| | | Surgery | Neutral | Conservative | |
| OF-score VAS ≥ 4 | Surgery | 202 | 56 | 79 | 337 |
| | Conservative | 49 | 21 | 101 | 171 |
| Modified OF-score VAS ≥ 5 | Surgery | 197 | 54 | 86 | 337 |
| | Conservative | 37 | 23 | 111 | 171 |
| Modified OF-score VAS ≥ 6 | Surgery | 178 | 62 | 97 | 337 |
| | Conservative | 27 | 21 | 123 | 171 |

In comparison, the logistic regression, using all the variables of the OF-score, resulted in a predictive accuracy of 80.4% for the therapy performed at all, and for surgical therapy 86,5% and 70,8% for conservative treatment ($p < 0.001$). This is slightly higher than the accuracy obtained by the discriminant analysis.

The ROC-analyses showed significant cut off value for VAS = 5.5 for surgical treatment (AUC = 0.811, $p < 0.001$) with a sensitivity 0.74 and specificity 0.76. The distribution of the OF-score recommendations by change in VAS threshold to 5 or 6, compared with VAS ≥ 4 as the threshold is given in Table 4.

Using the OF-score with a VAS threshold of ≥4, 251 patients had surgical and 180 had conservative treatment recommendations, with 20% and 44% of patients, respectively, treated against these recommendations. The sensitivity and specificity of the OF-score at this threshold were 71.9% and 67.3%, respectively. The accuracy of the OF-score is 70.3%. In addition, 77 patients (15%) received no specific therapy recommendation.

Using a VAS threshold of ≥5, 234 patients were recommended surgical treatment, and 197 patients were recommended conservative treatment, with 16% and 44% of these patients, respectively, treated contrary to the recommendations. In comparison to the OF-score with VAS ≥ 4, there was a higher number of conservative recommendations and a reduced number of surgical recommendations, with a difference of 17 patients in each group, although this difference was not statistically significant ($p = 0.271$). This corresponds to an overall accuracy of 71.5%. The sensitivity and specificity at this threshold were 69.6% and 75.0%, respectively. Additionally, 77 patients with an OF-score of 6 did not receive a specific therapy recommendation.

Using a VAS threshold of ≥6, the OF-score resulted in 205 patients being recommended surgical treatment and 220 patients being recommended conservative treatment. This represents a decrease in surgical recommendations by 46 patients and a simultaneous increase in conservative recommendations by 40 patients compared to the OF-score with a threshold of ≥4 ($p = 0.004$). When compared to the threshold of VAS ≥ 5, surgical treatment was recommended less frequently, and conservative treatment more often ($p < 0.087$). Of the patients with a surgical recommendation, 13% were treated non-compliantly, while 44% of the patients with a conservative recommendation underwent surgical treatment. An accuracy of 70.8% was achieved, with a sensitivity of 64.7% and a specificity of 82.0%. For 83 patients (16%), no specific therapy recommendation was provided.

Using VAS ≥ 5 in the OF-score yields the highest overall accuracy. The VAS ≥ 4 provides the highest sensitivity, while the VAS ≥ 6 achieves the highest specificity (Table 5).

**Table 5** The revised OF-score with increased VAS pain threshold

| Parameter | Grade | Points |
|---|---|---|
| OF classification (morphology) | 1–5 | 2–10 |
| Severity of osteoporosis | T-Score < −3 | 1 |
| Deformity progression | Yes/No | 1/−1 |
| Pain (under adequate analgesia) | VAS ≥5/<5 | 1/−1 |
| Fracture related neurological deficit | Yes | 2 |
| Able to mobilize without help | Yes/No | −1/1 |
| Health status | ASA > 3, BMI < 20 kg/m$^2$, nursing case, anticoagulation | Each parameter −1; maximum −2 |

## Discussion

The aim of this study was to evaluate the predictive value of each variable in the OF-score and assess whether adjusting their weights can improve the alignment with actual treatment decisions.

The EOFTT study included 518 patients. For an OF-score cut-off of 6.5, the sensitivity and specificity for predicting actual treatment were 60% and 68%, respectively [13]. A significantly higher sensitivity was reported by Mekariya et al. [17]. The authors retrospectively studied a cohort of 157 patients. Using the same cutoff OF-score of > 6.5, the sensitivity and specificity for predicting surgical treatment were 87.9% and 61.0%, respectively. In the EOFTT study, 71% were treated according to the score recommendations. Mekariya et al. reported an adherence rate of 83%. However, both study groups reported good discriminative ability for surgical decision making.

Using all the variables of the OF-score, the discriminant linear model demonstrated an accuracy of 79.7% in predicting the therapy performed. In comparison, the logistic regression, using all the variables of the OF-score, resulted

in a predictive accuracy of 80.4% for the therapy performed. Similary, Mekariya reported an accuracy of 82.88% [17].

Both, discriminant linear and logistic regression models have a similar predictive accuracy (79.7% vs. 80.4%), indicating that both approaches can predict treatment recommendations well. The difference in accuracy between the two methods could be considered small but significant. However, logistic regression showed slightly better predictive accuracy, supporting the use of nonlinear models in predictive analysis.

The results of the discriminant analysis show that pain (VAS) has the greatest influence on the prediction of treatment, followed by the OF classification and mobility. *This finding underlines the importance of this subjective parameter in decision-making in the treatment of OVCF. For this reason it seems very interesting to adjust this parameter to its optimal level.* For patients with severe pain, a higher OF classification and limited mobility, the probability of surgical treatment increases.

The accuracy of the discriminant analysis (79.7%) and the logistic regression (80.4%) is very close. The difference between the two methods is that discriminant analysis is based on a linear calculation, while logistic regression uses a non-linear logit function. However, both models achieve a comparable prediction accuracy of about 80%. The accuracy of the prediction for surgical treatments is 86.5%, while for conservative treatments it is 70.8%. So far, the accuracy of the therapy prediction of the OF-score overall is 70.3%, which is about 10% lower than the accuracy that is possible based on the statistical analyses. Compared to the other variables, the parameter pain is apparently not given enough consideration, although it is the factor with the strongest influence on the therapy decision.

Looking at the variable with greatest decisive value (VAS), the ROC-analyses showed significant cut off value for VAS = 5.5 for surgery therapy (AUC = 0.811, $p < 0.001$) with a sensitivity 0.74 and specificity 0.76. The results of the ROC analysis (with a VAS threshold of 5.5 for surgical treatment) and the different thresholds for the VAS in the OF-score (4, 5 and 6), show that the threshold of VAS ≥ 4 has the highest sensitivity and the threshold of VAS ≥ 6 has the highest specificity, the VAS ≥ 5 threshold could be considered an optimal compromise as it provides the highest accuracy.

The highest prediction accuracy is achieved by adjusting the pain threshold to ≥ 5 while maintaining the basic structure of the OF-score. This adjustment ensures higher specificity (75%) than with a threshold of ≥ 4 (67.3%,) in the prediction of surgical treatments and improves the accuracy of therapy recommendations.

The highest specificity (82%) is achieved by adjusting the pain threshold to ≥ 6. However, this would lower the sensitivity to 64.7%. Pain on VAS ≥ 5 is considered to be severe, over 6 is considered very severe. From a clinical point of view, therapy should lead to the elimination of severe pain. Therefore, a threshold of 5 is preferable to 6 although still not optimal. This realization has already led to a revised version of the score [19].

Evaluation of the data revealed a discrepancy between the recommendation and the observed therapy. 20% of patients (for VAS ≥ 4) and 16% (for VAS ≥ 5) were treated against score recommendations. This raises questions about the factors influencing this discrepancy between recommended and actual treatment. It is possible that physician clinical judgment, patient preference, or other medical factors may play a role that were not specifically assessed as part of the study design. A recently published retrospective cohort study validated the OF-score's recommendation with actual treatments received [17]. 82.9% of patients received treatments concordant with the OF-score recommendation. 13.5% of patients received conservative treatment despite of an OF-score of over 7. Because these patients had good outcomes, the authors expressed the concern that the score could lead to a surgical overtreatment. Raising the threshold of VAS from 4 to 5 may reduce the risk of overtreatment.

The importance of pain in the treatment decision process in patients with OVCF has also been reported by other authors [20–23]. In contrast to the OF-score, these recommendations are more general and favor nonoperative treatment in most cases. In a recently published Dutch survey, a unanimous consensus among respondents was reported that the care of patients with OVCF is still inadequate [22]. In general, published diagnostic and therapeutic recommendations are inconsistent because the evidence available to guideline developers is still limited in quantity and quality [22]. The EOFTT study and its subsequent subanalyses are helpful in this regard because they are based on a large number of prospectively enrolled patients [12–15].

*We think that the modified OF-Score could increase the quality of the decision for surgical or conservative treatment and could help the physician to improve the outcome and reduce the effort in decision-making. While the overall improvement in predictive accuracy achieved by the modified OF score is modest, its practical value lies in enhancing decision-making in borderline cases. The adjustment slightly increases the likelihood of conservative treatment recommendations in patients with moderate fractures and high subjective symptom burden. This subtle shift may help avoid unnecessary surgery and promote individualized, patient-centered care. However, we acknowledge that further validation in larger, prospective clinical settings is required.*

*VAS pain is a subjective parameter but very crucial from the patients point of view. Due to the subjective character*

*of the VAS pain concerns have been raised for its sustainability as a score parameter. A study analyzing the OF-score and its components found an almost perfect inter- and intra rater reliability in using the VAS pain as parameter* [17].

*We also believe that the significance of the current modification of the score cannot be conclusively assessed by the present study. This question must be answered in future clinical care studies. In the authors' opinion, this study in its current form can only formulate a suggestion for score modification that is potentially suitable for recommending a clinically successful therapy with a higher probability in the short term.*

### Limitations

In this study, only inpatients were analyzed, and twice as many patients were treated surgically as conservatively. This asymmetry is a limitation because it means that patients with less severe fractures or less pronounced symptoms were potentially not included.

The significance of the factors fracture-related neurological deficit, BMI and nursing case could not be reliably assessed statistically due to the small number of cases.

This study includes patients with a wide variety of age (41–97 years). This is a potential bias because of potential social factors influencing VAS perception. Aging itself can decrease sensitivity for pain of low intensity but has no strong effect on pain tolerance [24] (19).

The patient's medical history, previous consultations and experiences with their injury, social factors, their pain and associated functional limitations can also influence the choice of treatment or even lead to rejection of the recommended therapy. Future studies should investigate the impact of age and medical history on treatment recommendations to better understand their influence on the treatment offered.

Although the modified OF-score with VAS≥5 shows higher accuracy, it tends to recommend conservative treatment more frequently as the threshold for surgical recommendation is raised, though not significantly more often across the entire cohort. In individual cases, this would result in more frequent recommendations for conservative treatment, which may be more appropriate based on the cohort studied. From a surgical perspective, this could lead to potential undertreatment. Therefore, the individual circumstances for conservative treatment should be carefully considered.

*The proportion of patients with neurological deficits was very low, so the low canonical discrimination coefficient is probably due to selection bias. Considering the total cohort of 508 patients and bearing in mind that 66% of these are represented by OF1-3 fractures, in which a fracture-related neurological deficit is very unlikely, this bias seems plausible.*

It is important to mention in conclusion that the OF score has so far only been prospectively clinically validated with the VAS threshold of ≥4. Consequently, evidence currently exists only for the original score demonstrating that adherence to the score leads to better outcomes for patients. It is therefore essential that future multicenter prospective studies be conducted with the adjusted VAS threshold of ≥5 before this is implemented in clinical guidelines.

## Conclusion

When testing the variables included in the OF-score, pain was found to have the highest predictive value. Based on the data from the ROC analysis, a modified OF-score with a VAS pain threshold≥5 is proposed, resulting in a higher accuracy. This also results in a balanced specificity and sensitivity. Consequently, the OF-score has been revised. Future evaluation may further improve the validity of the OF-score.

**Author contributions** BWU and PS: Conception and study design-BWU and KS: wrote the manuscript and conducted the literature research, PS: performed statistics, created figures and tables, wrote the result section, performed data management and manuscript revisionMAS, MM, GO, GS, MJS, UJS, FS, AF VZ and MB: revised the manuscript.

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**Data availability** No datasets were generated or analysed during the current study.

## Declarations

**Competing interests** The authors declare no competing interests.

**Ethics approval and consent to participate** This study was approved by the research ethics committee of the Medical Association of SaxonyAnhalt Germany (14. June 2017, file number 31/17) and was performed in accordance with the principles laid down in the current revision of the Declaration of Helsinki.

**Consent for publication** The authors give consent for publication of all contents of this manuscript.

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