

Prediction of patient-reported outcomes after proximal humerus fractures in elderly patients does not appear to be a credible option

a secondary analysis of two randomized controlled trials

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Aims
The aim of this study was to investigate which patient- and fracture-related factors predict functional outcome at two years in patients aged 60 years or older with a proximal humerus fracture, and to assess the possible evidence in favour of treatment effect heterogeneity in these patients.

Methods
This was a secondary analysis of a prior randomized controlled trial. We included patients from a Nordic multicentre trial including two trial cohorts (two-part and multipart): 88 patients with a two-part fracture (nonoperative vs locking plate), and 160 patients with a multipart fracture (nonoperative vs locking plate vs hemiarthroplasty) recruited between February 2011 and December 2019. The outcomes were Disabilities of Arm, Shoulder and Hand (DASH) questionnaire score, Oxford Shoulder Score (OSS), and Constant-Murley score (CS) at two years. Ordinary least squares regression was used to estimate 24 months of functional outcomes. We used the methodology described in the Predictive Approaches to Treatment effect Heterogeneity (PATH) statement for the assessment of treatment effect heterogeneity.

Results
A total of 248 patients were included in the trials. Dizziness frequency was the most important predictor for DASH and OSS at 24 months. Dominance of the injured arm was the most important predictor for Constant score. R^2, describing the variation explained by the baseline variables, showed moderate model fit for all outcomes, i.e. DASH (0.395), OSS (0.363), and CS (0.387). When operative treatments were compared with nonoperative treatments, the interactions between predicted outcome and treatment assignment were small and had high uncertainty, implying a lack of heterogeneous treatment effect.

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Conclusion
We found that dizziness at baseline is the strongest predictor for DASH and OSS at 24 months. Our results showed that patient selection, based on the covariates available to us, does not seem to be a credible possibility in older patients with proximal humerus fractures, and thus nonoperative treatment should remain the gold standard.

Article focus
- Moderate-certainty evidence suggests that operative treatment for proximal humerus fractures is not superior to nonoperative treatment in patients aged > 60 years.
- Some patients are more likely to benefit from operative treatment.
- Evidence for a heterogeneous treatment effect would facilitate a personalized approach in patients with proximal humerus fractures.

Key messages
- The 24-month functional outcomes in elderly patients with proximal humeral fractures can be predicted with moderate accuracy.
- Patient selection is not feasible for elderly patients with proximal humeral fractures.
- Nonoperative treatment should remain the gold standard.

Strengths and limitations
- The study data were based on a randomized controlled trial, meaning that we minimized the residual confounding between treatment choices.
- Patients with prostheses underwent hemiarthroplasty and not reverse shoulder arthroplasty, which is the current choice of procedure.

Introduction
Proximal humeral fractures (PHFs) are frequently observed in older individuals and are the second most common type of upper limb fracture.[1-3] The treatment for PHFs has evolved widely in recent years. In the late 1990s, hemiarthroplasty (HA) gained popularity, particularly for multipart fractures. Operative treatment with modern locking plates (LPs) peaked in the early 2000s as the philosophy of anatomical restoration was the prevailing treatment paradigm, and the LP technique enabled this approach.[1] During the last decade, reverse shoulder arthroplasty (RSA) has become popular, while the incidence of HA has decreased.[4]

Since the early 2000s, several high-quality trials have investigated the effectiveness of operative treatment for displaced PHFs.[5-10] Studies have primarily focused on patients aged ≥ 60 years because PHFs are endemic in this patient cohort. Moderate-certainty evidence suggests that operative treatment is not superior to nonoperative treatment in patients aged > 60 years.[10] However, RSA may provide clinically relevant benefits in displaced multipart fractures and fracture dislocations compared with nonoperative treatment and LPs.[11,12]

Our previous trials showed that operative treatment did not provide additional benefits over nonoperative treatment for displaced PHFs in older patients.[7,8] In these randomized controlled trials (RCTs), we estimated the average treatment effect in a selected patient cohort at the group level. Therefore, our trial results describe group-level effectiveness when all patients are treated in the same manner. Our trials and other previous evidence on the operative treatment of PHFs show that if all patients (like those included in the trials) were treated operatively, the benefit would be negligible, on average, compared with treating all patients nonoperatively. Regardless of the average null effect, some patients may be more likely to benefit from operative treatment. However, this design does not account for individual variations, known as heterogeneous treatment effects (HTEs).[13,14] To address HTEs, responder analysis can be used to identify patients benefitting from treatment, and subgroup analysis can be used to examine the treatment effectiveness across patient subgroups defined by specific covariates, thus enhancing the personalized medicine approach.

The aim of this secondary analysis study was to investigate which patient- and fracture-related factors predict the two-year functional outcomes after PHF, and if there is evidence for a HTE favouring the idea of patient selection for operative treatment in patients aged ≥ 60 years.

Methods
Study design
This study was a secondary analysis of a Nordic multicentre RCT including two trial cohorts (two-part and multipart diagnosed with CT scans) investigating the effectiveness of operative treatment for PHFs in patients aged ≥ 60 years.[15]

Patients
We included all randomized patients from both trials: 88 from stratum 1 and 160 from stratum 2. Patients were recruited between February 2011 and December 2019. The inclusion criteria were low-energy, two-part proximal (stratum 1), or three- to four-part (stratum 2) humerus fractures displaced > 1 cm or 45° in which the fracture line emerges through the surgical (or anatomical) neck. The exclusion criteria are described in the original protocol. Patients who were willing to participate were randomized in a 1:1 fashion to either nonoperative treatment or surgical treatment with LPs (stratum 1), or nonoperative treatment, surgery with LPs, or HA in a 1:1:1 fashion (stratum 2). A total of 250 patients were included in this study. The mean age was 69.3 years (SD 7.5), and 90% (n = 225) were female. The characteristics of the patients in each treatment group are shown in Table I.

Study setting
The following baseline data were recorded: age, sex, arm dominance, side of injury, smoking (yes/no), need for a walking aid (yes/no), dizziness (daily, weekly, monthly, less than monthly, or never), height, weight, and comorbidities. Patients receiving operative treatment had either Philos LPs (Synthes, Switzerland) or HA (various brands) operated on by a shoulder orthopaedic trauma surgeon (AL, JP, OW, HB, ML, AM) with a minimum of five years of experience to prevent

Table I. Baseline characteristics of the three study groups included in this study.

Characteristic	Nonoperative	Plate	Prosthesis
Mean age, yrs (SD)	73.5 (7.1)	73.5 (7.6)	74.8 (7.9)
Mean BMI, kg/m^2 (SD)	27 (5.5)	27.8 (5.0)	27.2 (4.7)
Sex, n (%)			
Female	86 (87.8)	88 (91.7)	51 (94.4)
Male	12 (12.2)	8 (8.3)	3 (5.6)
Fracture type, n (%)			
2-part	44 (44.4)	44 (44.8)	0 (0)
3- to 4-part	54 (55.6)	52 (55.2)	54 (100)
Injury in dominant hand, n (%)			
Yes	44 (44.4)	50 (52.1)	31 (56.4)
No	55 (55.6)	46 (47.9)	24 (43.6)
Smoking, n (%)			
Yes	10 (11.2)	11 (12.1)	2 (4)
No	79 (88.8)	80 (87.9)	48 (96)
Dizziness, n (%)			
Never	30 (34.5)	29 (32.2)	25 (50)
Less than monthly	39 (44.8)	31 (34.4)	19 (38)
Monthly	6 (6.9)	8 (8.9)	1 (2)
Weekly	5 (5.7)	12 (13.3)	2 (4)
Daily	7 (8)	10 (11.1)	3 (6)
Uses a walking aid, n (%)			
Yes	20 (22.2)	24 (27)	9 (17.6)
No	70 (77.8)	65 (73)	42 (82.4)

learning curve problems. All groups underwent the same rehabilitation programme. We used an open-label, blinded endpoint design: the patients, knowing their allocation, were encouraged not to reveal it to the outcome assessors who were blinded to the allocated treatment, physiotherapists, or occupational therapists assessing the outcomes. The assessors did not participate in the trial. Furthermore, patients were instructed to wear a shirt to cover any possible scars.

All patients were prospectively followed up at three, six, 12, and 24 months. The primary outcome of the trial was the two-year functional outcome measured using the Disabilities of Arm, Shoulder, and Hand (DASH) questionnaire;[16] a lower score indicates a better outcome. Secondary outcomes included the Oxford Shoulder Score (OSS) and Constant–Murley Score (CS),[17,18] where higher scores indicated better outcomes. We included two-year data for the DASH, OSS, and CS for this study.

Statistical analysis

We used ordinary least squares regression for the first study aim to estimate 24 months of functional outcomes. All

Table II. Patient-rated outcome measures (PROMs) at 24 months.

PROM	Nonoperative	Plate	Prosthesis
Mean DASH (SD)	23 (21.6)	25.7 (23.3)	25.1 (17.4)
Mean OSS (SD)	38.9 (10.2)	37.1 (10.8)	36.5 (9.2)
Mean CS (SD)	68.3 (16.2)	70.9 (19.1)	59.3 (22.2)

CS, Constant-Murley Score; DASH, Disabilities of the Arm, Shoulder and Hand questionnaire; OSS, Oxford Shoulder Score.

baseline variables were input as predictors in a single global model. Among the comorbidities, we chose only diabetes, as the frequency of other comorbidities was quite low (< 10%), which could result in a possible convergence problem. The side of the injury and arm dominance were combined into a single binary variable indicating whether the dominant hand was injured. Height and weight were used to calculate BMI. The fracture type was binary (two-part vs three/four-part).[19] R^2 was used to assess the overall model fit. For linear models, R^2 is a standard metric used to describe the explained variation in the outcome variable using the available baseline or predictor variables. It can also be used to describe the model fit; the higher the R^2, the better the variable predicts the outcome of interest. Variable importance was assessed using the Wald chi-squared test minus the degrees of freedom. QQ plots were used to assess the assumptions of error-term normality. We used the methodology described in the PATH statement in the second study aim.[13] First, a multivariable model similar to the one described above was built, except that the treatment was not included as a predictor. The fitted values from the model were calculated for each patient. Given all other baseline variables, these values provided a predicted baseline outcome when treatment was not considered. A regression model that included the interaction between the fitted outcome and treatment allocation was built in the second phase. This model offered the possibility of assessing whether treatment effects varied across different outcome estimates based on baseline covariates. All analyses were performed using the RStudio in rms package. The statistical significance threshold was set to 0.05.

Results

At 24 months, the mean DASH score was 25.1 points (median 18.3 (IQR 7.5 to 85.8)). The mean OSS was 36 points (median 39.5 (IQR 32 to 46)), and the mean CS was 67.4 (median 71.2 (IQR 57.2 to 82.2) (Table II). The DASH and OSS scores were missing in 43 patients, and CS was missing in 80 patients. The DASH and OSS varied within a few points in the treatment groups; however, the prosthesis group had a markedly poorer CS compared to nonoperative treatment (–8.9 points, 95% CI –16.6 to –1.3).

Predicting two-year functional outcomes

For the DASH and OSS at 24 months, dizziness frequency (DASH: χ = 38.4, p < 0.001; OSS: χ = 38.1, p < 0.001) was the single most important predictor, followed by BMI (DASH: χ = 12.1, p < 0.001; OSS: χ = 12.8, p < 0.001) (Figures 1a and 1b, Supplementary Tables i and ii). Injured arm dominance was

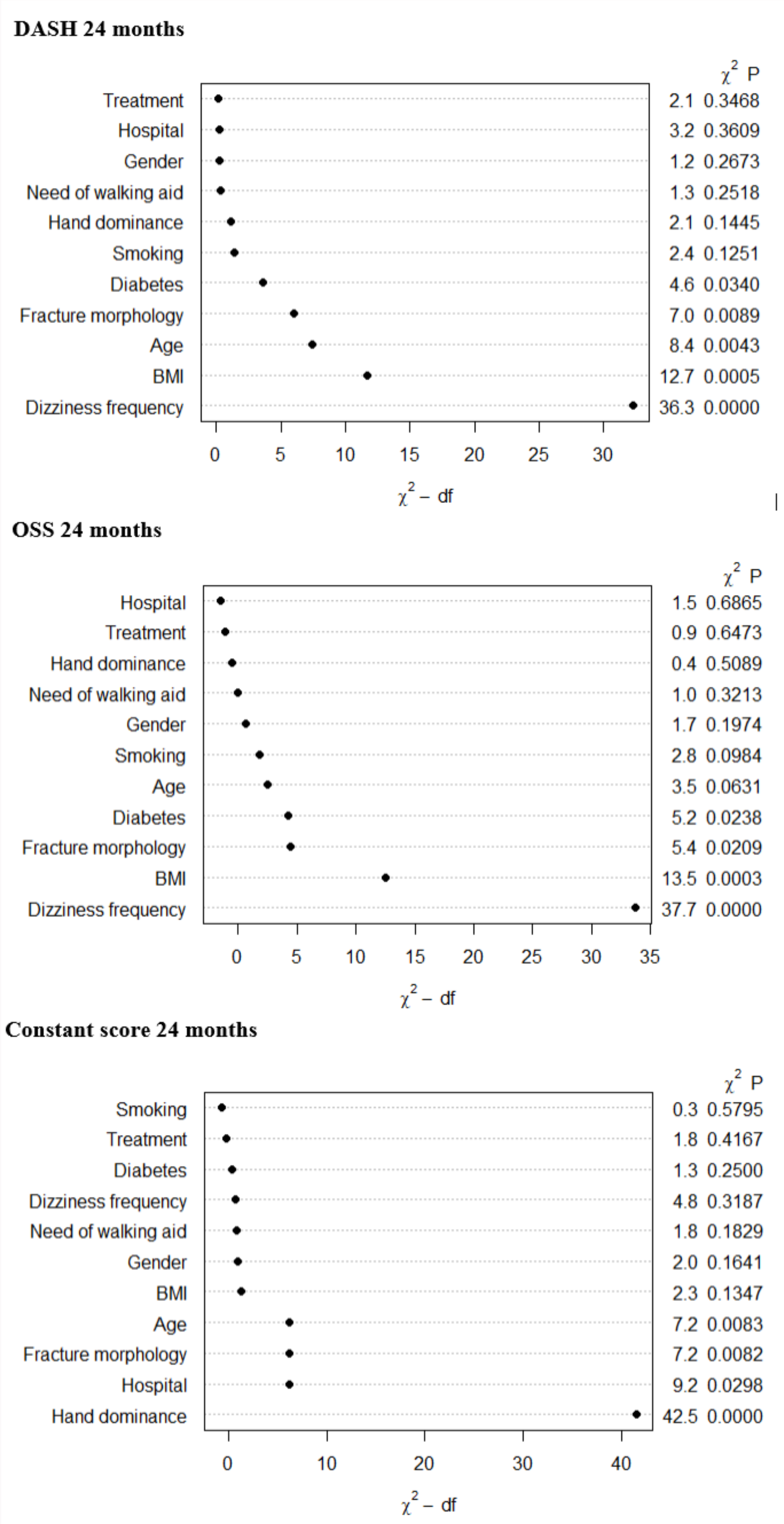

Fig. 1

Variable importance. The x-axis represents the relative variable importance based on Wald chi-squared analysis, adjusted for degrees of freedom. The higher the value, the more important the variable is for overall predictions. DASH, Disabilities of the Arm, Shoulder and Hand questionnaire; OSS, Oxford Shoulder Score.

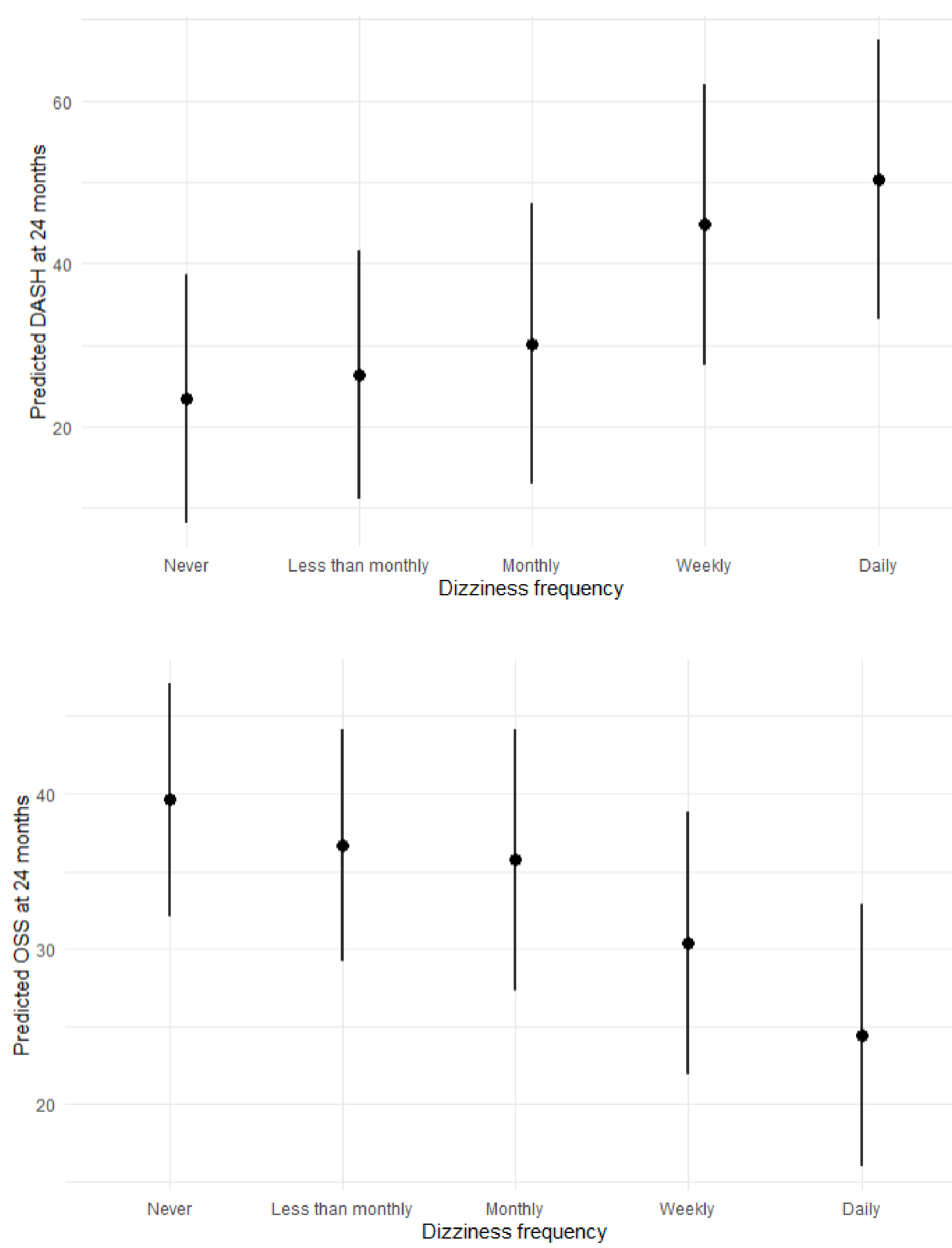

Fig. 2
Predicted outcomes for different baseline levels of dizziness. The lines represent 95% prediction intervals. DASH, Disabilities of the Arm, Shoulder and Hand questionnaire; OSS, Oxford Shoulder Score.

the single most important predictor for CS (χ = 43.2, $p < 0.001$) (Figure 1c, Supplementary Table iii). The predicted mean CS on the dominant side was 87.1 points, and that on the non-dominant side was 69.7 points. The R^2 showed a moderate model fit for all outcomes: DASH (0.418), OSS (0.381), and CS (0.387). Figure 2 shows the predicted values of the DASH and OSS for varying dizziness frequencies.

Treatment effect heterogeneity

When operative and nonoperative treatments were compared, the interactions between the predicted outcome and treatment assignment were small and had high uncertainty. For DASH, plating provided 0.32 points (95% CI –0.1 to 0.73) and HA 0.13 points (95% CI –0.52 to 0.80) as a lower score for each baseline outcome point. For OSS, plating provided 0.21 points (95% CI –0.23 to 0.65) and HA 0.21 points (95% CI –0.39 to 0.95) as higher scores compared to nonoperative treatment.

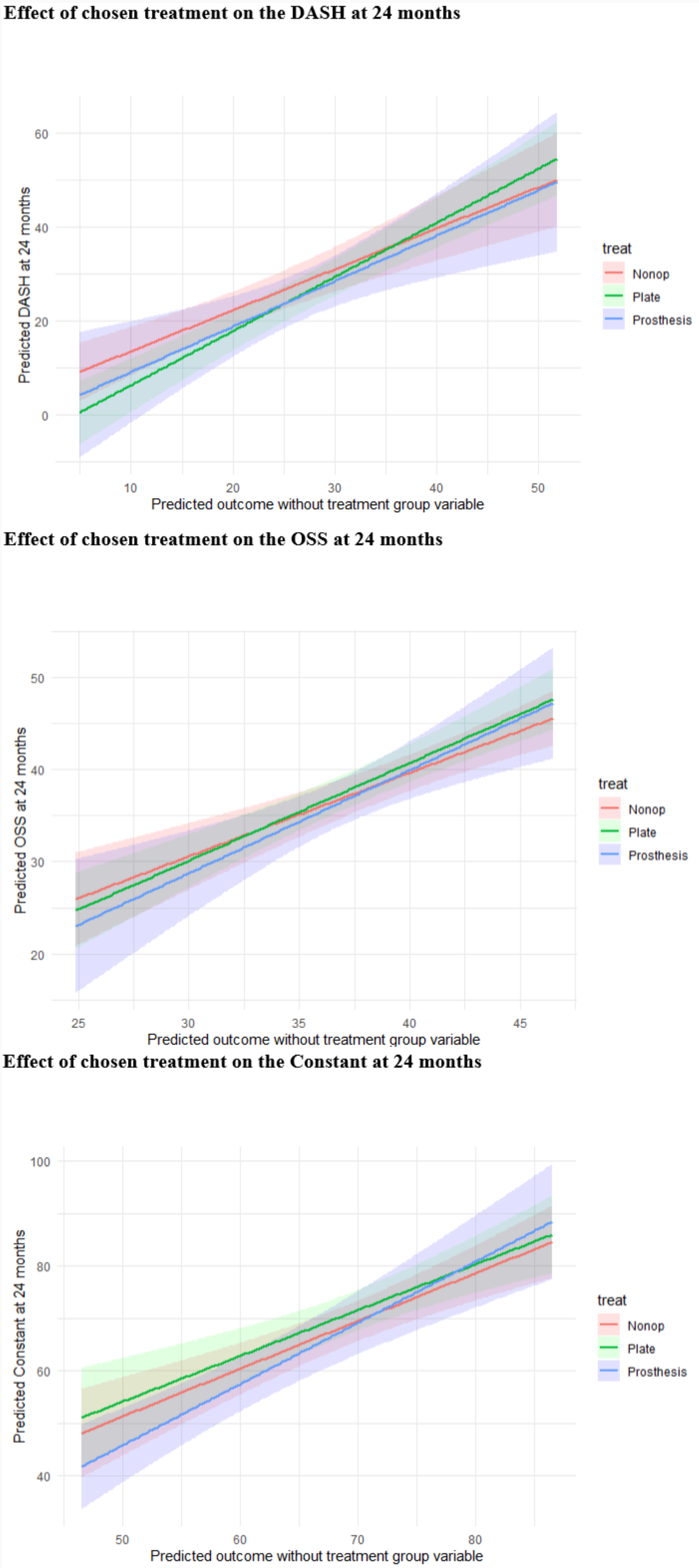

Fig. 3

Graphical visualizations of treatment effect heterogeneity. Statistically significant interaction terms, indicative of varying treatment effects, manifest as clearly uncorrelated lines. DASH, Disabilities of the Arm, Shoulder and Hand questionnaire; OSS, Oxford Shoulder Score.

For CS, plating provided 0.19 points (95% CI –0.34 to 0.73) and HA 0.47 points (95% CI –0.12 to 1.07) as a higher score per each predicted baseline outcome point. A visualization of the interaction terms is shown in Figure 3.

Discussion

In this secondary analysis of previously reported RCT results on the treatment of PHFs in patients aged ≥ 60 years, we sought to examine the predictive factors for the outcome of PHFs in older patients and to determine if there is a subgroup of patients who would benefit from surgical treatment. We found that dizziness at baseline was the strongest predictor of the DASH score and OSS at 24 months. We could not show the presence of a HTE in PHF treatment in patients aged ≥ 60 years.

Personalized, individualized, or precision-based medicine is one of the most widely discussed topics in medicine.[14,20,21] This means that the most suitable treatment for each patient with a specific disease or condition is selected based on certain patient-specific and individual variables and aspects.[22] This concept differs from the more traditional school of thought in which specific patient populations, not individuals, are treated similarly using the best external evidence describing the average treatment effects at a group level.[23] In orthopaedics and traumatology, the concept of personalized treatment is a common consideration when deciding between nonoperative and operative treatments.[21] These decisions are usually based on the radiological appearance of the fracture, patient characteristics, preferences, and clinical experience.[24] In older patients, physical activity and comorbidities are often considered important factors for decision-making, as active and healthier patients may benefit more from operative treatment.[25] However, clinicians do not have a clear way to measure the physical activity of patients, and there is little evidence to support treatment decisions based on their activity levels.[26,27] Overall, very little evidence is available in favour of and against the concept of patient selection for the surgical treatment of PHFs in older patients.

For the OSS and DASH, the frequency of dizziness, BMI, and fracture classification were the most important predictors of the 24-month outcomes, among which dizziness was found to be the strongest predictor. Dizziness and the frequency of dizziness were subjective factors. In previous studies, chronic dizziness has been associated with poorer physical and mental health-related quality of life;[28-30] however, the exact cause of these measures remains unknown. Evidence is inconclusive whether chronic dizziness results in poor mental health or whether poor mental health is an aetiological factor for chronic dizziness. We postulated that both could be possible because dizziness is a very subjective variable, and when a patient has many psychosocial challenges, various bodily sensations may be somaticized more strongly than in patients without psychosocial challenges. However, the vestibular system declines with age; thus, our findings could serve as a proxy for an age-related association.[31] As dizziness was the strongest predictor of functional outcomes in our study, we postulated that subjective wellbeing and psychosocial factors play a major role in determining the outcomes of PHF treatment. As pain and functional disability show very high adaptivity across different individuals, it is likely that dizziness is a surrogate factor that simply describes a patient's physical and mental wellbeing. Regardless of objective findings, patients with frequent symptoms had poorer subjective outcomes.

Our results showed that patient selection, based on the available covariates, does not seem to be a credible possibility for older patients with PHFs. This was based on the analysis of HTEs using recent expert guidelines.[13] HTEs indicate a considerable interaction between patient baseline characteristics and treatment. The interaction terms in our study were imprecise and statistically insignificant. Figure 3 shows a visual depiction of the patient-treatment interaction. First, the predicted outcome for each patient was calculated using the study data. For example, when the patient's age, sex, smoking status, BMI, need for a walking aid, dizziness, fracture classification, and injured arm dominance were considered, the predicted DASH score at 24 months could be 15 points. Using this as a baseline, the predicted outcome in nonoperative treatment was 18 points (95% CI 13 to 22), 12 points (95% CI 7 to 17) with a plate, and 14 points (95% CI 6 to 23) with a prosthesis. Hence, there was no clinically relevant heterogeneity in the predicted outcomes. If so, the figures would show diverging lines for the different treatment choices. Therefore, these results clearly indicate that optimal patient selection is not feasible for older patients with PHF.

The main strength of this study was that our data were based on RCTs; therefore, we minimized residual confounding factors between treatment choices. This analysis would be problematic in observational settings, as unexplained confounding factors could explain the observed differences between the treatments. However, our study had some limitations. First, the sample size was limited as we relied on trial data. This is mainly observed in the CIs, as they become narrower with increasing sample sizes. In theory, with a two- or three-fold increase in the sample size, we may have observed statistically significant interaction terms; however, this may be clinically irrelevant. Second, our prosthesis was HA. Currently, RSA is the primary treatment option. When the trials began in 2011, HA was the gold standard; hence, HA was also used in this study. Future studies should replicate our study setting and include the RSA as a surgical option.

We conclude that the 24-month functional outcomes in older patients with PHFs can be predicted with moderate accuracy, considering the R^2 values observed in this study. However, the essential predictors, such as BMI, are fixed and unmodifiable. As dizziness is the most important factor, aspects related to physical and mental health-related quality of life are likely to play a significant role in determining the final outcomes. A defined set of baseline variables was the strongest predictor, and treatment modality had almost no significant effect on the outcome. Our study adds significant evidence to the assertion that patient selection is not feasible in elderly patients with PHFs. Nonoperative treatment remains the gold standard for the treatment of PHFs in older patients.

Supplementary material

Regression coefficients with 95% CIs.

References

1. **Sumrein BO**, **Huttunen TT**, **Launonen AP**, **Berg HE**, **Felländer-Tsai L**, **Mattila VM**. Proximal humeral fractures in Sweden-a registry-based study. *Osteoporos Int*. 2017;28(3):901–907.
2. **Launonen AP**, **Lepola V**, **Saranko A**, **Flinkkilä T**, **Laitinen M**, **Mattila VM**. Epidemiology of proximal humerus fractures. *Arch Osteoporos*. 2015;10:209.
3. **Ponkilainen V**, **Kuitunen I**, **Liukkonen R**, **Vaajala M**, **Reito A**, **Uimonen M**. The incidence of musculoskeletal injuries: a systematic review and meta-analysis. *Bone Joint Res*. 2022;11(11):814–825.
4. **Leino OK**, **Lehtimäki KK**, **Mäkelä K**, **Äärimaa V**, **Ekman E**. Proximal humeral fractures in Finland: trends in the incidence and methods of treatment between 1997 and 2019. *Bone Joint J*. 2022;104-B(1):150–156.
5. **Olerud P**, **Ahrengart L**, **Ponzer S**, **Saving J**, **Tidermark J**. Internal fixation versus nonoperative treatment of displaced 3-part proximal humeral fractures in elderly patients: a randomized controlled trial. *J Shoulder Elbow Surg*. 2011;20(5):747–755.
6. **Olerud P**, **Ahrengart L**, **Ponzer S**, **Saving J**, **Tidermark J**. Hemiarthroplasty versus nonoperative treatment of displaced 4-part proximal humeral fractures in elderly patients: a randomized controlled trial. *J Shoulder Elbow Surg*. 2011;20(7):1025–1033.
7. **Launonen AP**, **Sumrein BO**, **Reito A**, **et al**. Surgery with locking plate or hemiarthroplasty versus nonoperative treatment of 3-4-part proximal humerus fractures in older patients (NITEP): an open-label randomized trial. *PLoS Med*. 2023;20(11):e1004308.
8. **Launonen AP**, **Sumrein BO**, **Reito A**, **et al**. Operative versus non-operative treatment for 2-part proximal humerus fracture: a multicenter randomized controlled trial. *PLoS Med*. 2019;16(7):e1002855.
9. **Rangan A**, **Handoll H**, **Brealey S**, **et al**. Surgical vs nonsurgical treatment of adults with displaced fractures of the proximal humerus: the PROFHER randomized clinical trial. *JAMA*. 2015;313(10):1037–1047.
10. **Handoll HH**, **Elliott J**, **Thillemann TM**, **Aluko P**, **Brorson S**. Interventions for treating proximal humeral fractures in adults. *Cochrane Database Syst Rev*. 2022;6(6):CD000434.
11. **Fraser AN**, **Bjørdal J**, **Wagle TM**, **et al**. Reverse shoulder arthroplasty is superior to plate fixation at 2 years for displaced proximal humeral fractures in the elderly: a multicenter randomized controlled trial. *J Bone Joint Surg Am*. 2020;102-A(6):477–485.
12. **Haws BE**, **Samborski SA**, **Karnyski S**, **et al**. Superior outcomes with reverse shoulder arthroplasty versus nonoperative management for proximal humerus fractures: a matched cohort analysis. *J Orthop Trauma*. 2023;37(6):e247–e252.
13. **Kent DM**, **Klaveren D**, **Paulus JK**, **et al**. The Predictive Approaches to Treatment effect Heterogeneity (PATH) Statement: explanation and elaboration. *Ann Intern Med*. 2020;172(1):W1–W25.
14. **Cortés J**, **González JA**, **Medina MN**, **et al**. Does evidence support the high expectations placed in precision medicine? A bibliographic review. *F1000Res*. 2018;7:30.
15. **Launonen AP**, **Lepola V**, **Flinkkilä T**, **et al**. Conservative treatment, plate fixation, or prosthesis for proximal humeral fracture. A prospective randomized study. *BMC Musculoskelet Disord*. 2012;13:167.
16. **Hudak PL**, **Amadio PC**, **Bombardier C**, **et al**. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder, and head). [corrected]. *Am J Ind Med*. 1996;29(6):602–608.
17. **Dawson J**, **Fitzpatrick R**, **Carr A**. Questionnaire on the perceptions of patients about shoulder surgery. *J Bone Joint Surg Br*. 1996;78-B(4):593–600.
18. **Constant CR**, **Murley AH**. A clinical method of functional assessment of the shoulder. *Clin Orthop Relat Res*. 1987;214:160–164.
19. **Sumrein BO**, **Mattila VM**, **Lepola V**, **Laitinen MK**, **Launonen AP**, **NITEP Group**. Intraobserver and interobserver reliability of recategorized Neer classification in differentiating 2-part surgical neck fractures from multi-fragmented proximal humeral fractures in 116 patients. *J Shoulder Elbow Surg*. 2018;27(10):1756–1761.
20. **Senn S**. Mastering variation: variance components and personalised medicine. *Stat Med*. 2016;35(7):966–977.
21. **Senn S**. Statistical pitfalls of personalized medicine. *Nature*. 2018; 563(7733):619–621.
22. **Wijn SRW**, **Hannink G**, **Østerås H**, **et al**. Arthroscopic partial meniscectomy vs non-surgical or sham treatment in patients with MRI-confirmed degenerative meniscus tears: a systematic review and meta-analysis with individual participant data from 605 randomised patients. *Osteoarthritis Cartilage*. 2023;31(5):557–566.
23. **Blackstone EH**. Precision medicine versus evidence-based medicine. *Circulation*. 2019;140(15):1236–1238.
24. **Murray IR**, **Foster CJ**, **Eros A**, **Robinson CM**. Risk factors for nonunion after nonoperative treatment of displaced midshaft fractures of the clavicle. *J Bone Joint Surg Am*. 2013;95-A(13):1153–1158.
25. **Jayaram M**, **Wu H**, **Yoon AP**, **Kane RL**, **Wang L**, **Chung KC**. Comparison of distal radius fracture outcomes in older adults stratified by chronologic vs physiologic age managed with casting vs surgery. *JAMA Netw Open*. 2023;6(2):e2255786.
26. **Nelson GN**, **Stepan JG**, **Osei DA**, **Calfee RP**. The impact of patient activity level on wrist disability after distal radius malunion in older adults. *J Orthop Trauma*. 2015;29(4):195–200.
27. **Harper CM**, **Model Z**, **Xiong G**, **Hegermiller K**, **Rozental TD**. Do surgeons accurately predict level of activity in patients with distal radius fractures? *J Hand Surg Am*. 2023;48(11):1083–1090.
28. **Weidt S**, **Bruehl AB**, **Straumann D**, **Hegemann SCA**, **Krautstrunk G**, **Rufer M**. Health-related quality of life and emotional distress in patients with dizziness: a cross-sectional approach to disentangle their relationship. *BMC Health Serv Res*. 2014;14:317.
29. **Lindell E**, **Odhagen E**, **Tuomi L**. Living with dizziness impacts health-related quality of life among older adults. *Laryngoscope Investig Otolaryngol*. 2024;9(1):e1194.
30. **Lindell E**, **Kollén L**, **Johansson M**, **et al**. Dizziness and health-related quality of life among older adults in an urban population: a cross-sectional study. *Health Qual Life Outcomes*. 2021;19(1):231.
31. **Iwasaki S**, **Yamasoba T**. Dizziness and imbalance in the elderly: age-related decline in the vestibular system. *Aging Dis*. 2015;6(1):38–47.

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K. Jonsson: Data curation, Methodology, Resources, Writing – original draft, Writing – review & editing.
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Data sharing

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