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Proposal for a new treatment algorithm for proximal humerus fractures based on a clinical survey among 340 surgeons

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Background: The increasing incidence of proximal humeral fractures poses complex challenges in determining the optimal therapeutic strategies due to the diverse fracture patterns and individual patient characteristics. Traumatologists and orthopedic surgeons face significant decisions, as potential consequences such as pain, functional limitations, and complications may significantly affect patients' quality of life. Given the varying viewpoints on appropriate treatment modalities, a thorough examination of current care practices is crucial.
Methods: An adaptive online survey was conducted to present realistic case scenarios, aimed at elucidating decision-making processes in the management of proximal humeral fractures. This survey encompassed relevant patient and fracture-related variables, employing a dynamic querying algorithm that featured up to 48 conceivable case scenarios.
Results: Analysis of 7012 case scenarios unveiled significant differences in treatment preferences across distinct patient age groups. Plate osteosynthesis emerged as the preferred modality for individuals below 50 years of age with complex fracture patterns. On the other hand, a balanced consideration between plate osteosynthesis and reverse shoulder arthroplasty was observed in the 50-70 age cohort. Notably, respondents favored reverse shoulder arthroplasty as the treatment modality of choice for individuals older than 70 years of age. A treatment algorithm was developed to outline decision pathways concisely, considering these patient age groups and the option of reverse shoulder arthroplasty.
Discussion and conclusion: This study provides clinically relevant insights into therapeutic decision-making processes in the management of proximal humeral fractures. The illustration of treatment preferences through a visualized algorithm serves as a crucial tool for evidence-based clinical decision-making, offering potential in enhancing the individualized care spectrum for patients with proximal humeral fractures.
Level of evidence: Level V; Survey Study Using Delphi and Adaptive Methods and Experts

Keywords: Proximal humeral fractures; humeral head fractures; shoulder; shoulder surgery; shoulder injuries; shoulder fractures

Institutional review board approval was not required as this work is derived from anonymized data.

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Proximal humeral fractures (PHFs) pose a multifaceted challenge due to their prevalence and clinical significance, constituting approximately 8% of all fractures in adults.[25] Particularly in the elderly population, where about 60-70% of these fractures occur,[16] their importance is

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continually growing due to demographic changes and associated factors such as osteoporosis and minor falls.[20,27] Within the context of proximal humeral fractures, fracture sequelae can result in impairments in shoulder function and mobility, thus adversely affecting quality of life.[13] Considering these long-term consequences is crucial for developing comprehensive and patient-centered therapies.[28] The diversity of fracture patterns and individual patient characteristics necessitates a differentiated approach for tailored, patient-centered therapy.[29]

While most cases of PHF are managed nonsurgically,[30] surgical approaches are utilized for complex fractures or those involving the joint.[1] Surgical options are either joint-preserving surgery, such as intramedullary nail osteosynthesis or plate osteosynthesis, or joint-replacing therapy using endoprosthetic replacement. However, decision-making in PHF remains inconsistent in clinical practice and marked by significant controversy.[23] Despite the frequency of this injury, the absence of universally accepted guidelines contributes to diverse therapeutic approaches and resultant uncertainties among traumatologists and orthopedic surgeons.[10] The debate over the merits of nonsurgical interventions or surgical methods[8] results in inconsistent outcomes and varying experiences for patients.

Given these challenges, a thorough analysis of the care reality of PHF is essential. The development of evidence-based therapy algorithms that consider the complexity of fracture patterns and individual patient requirements is crucial to ensure consistent and optimal care for patients with proximal humeral fractures. In this context, the present study, based on an adaptive online survey of German surgeons, contributes to deepening the understanding of decision-making in PHF and illustrating the current care reality.

Methods

The present observational study was designed as an adaptively structured, case-based online survey to gain comprehensive insights into decision-making processes in proximal humeral fractures among German-speaking traumatologists and orthopedic surgeons. The participant group included physicians specializing in orthopedics and trauma surgery who were members of the German Society of Orthopedics and Trauma Surgery (DGOU). Recruitment was voluntary and conducted through targeted electronic invitations sent to all physician DGOU members.

The survey consisted of clinically relevant scenarios based on native radiographic (including anteroposterior projection and Y-view) and computed tomographic images (both 2D CT scans in coronal, sagittal, and axial planes as well as 3D volumetric views) of shoulders of patients with proximal humeral fractures. The scenarios were presented in an adaptive structure that allowed for dynamic adjustment of questions by considering relevant patient- and fracture-associated factors (Supplementary S1). Participants had the opportunity to request additional pertinent information regarding the patient or further imaging details through computed tomography scans of the fracture. Upon requesting this additional information, the number of case scenarios presented in the survey increased, allowing for a more comprehensive assessment of each participant's clinical decision-making process in response to enhanced details. At the conclusion of each case scenario, participants were asked to elect their treatment approach for the patient, considering the presence of rotator cuff arthropathy. The total number of possible constellations per case was up to 48.

Prior to the actual survey, a Delphi consensus was conducted with recognized experts in the field of traumatology and orthopedics.[15] Here, the relevant factors were defined and then established in this survey as patient-associated (age, cuff arthropathy) and fracture-associated (displaced tuberosity, headsplit fracture, and dislocation fracture) factors. The various treatment decisions regarding fracture-associated factors could be queried based on the morphological case examples. The selectable treatment options included nonsurgical treatment, intramedullary nail osteosynthesis, plate osteosynthesis, anatomical shoulder arthroplasty (including hemiarthroplasty), and reverse shoulder arthroplasty. If necessary for the respective decision, additional computed tomographic images could be shown. Through targeted additional information in the text, provided upon request, the indication choice regarding patient-associated factors could also be evaluated in the dynamic setting.

Classification into 3 age groups consisted of under 50 years, 50-70 years, and over 70 years and was based on well-established evidence in relevant literature.[8,28] In case of additional information or the necessity of additional computed tomographic images, the survey was adapted for the participant, and further case scenarios were added. Only after answering all questions were the individual surveys terminated and included in the analysis.

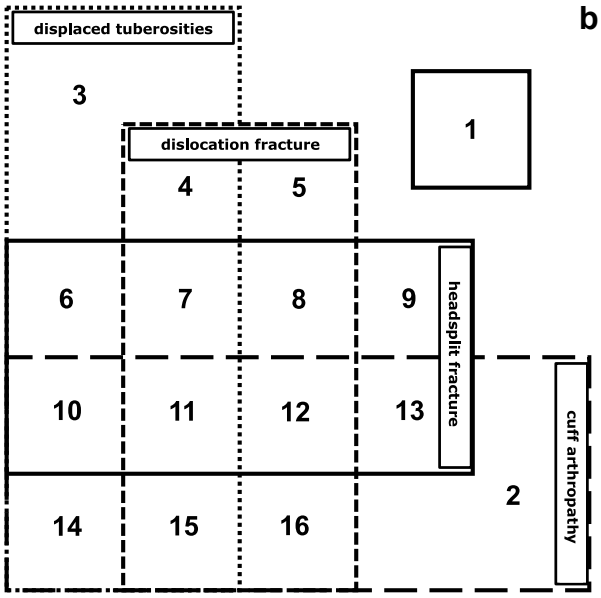
In a Venn diagram, the preferred therapy choice was then schematically depicted (see Fig. 1). If a treatment option was favored by more than 50%, the corresponding field in the diagram was uniformly marked. In the event that none of the response options in a constellation reached a majority of over 50% for a therapeutic procedure, the 2 most frequently selected treatment options were marked with the corresponding colors.

The collected data were evaluated with strict anonymization of the participants. Prior to answering, all participants consented to the survey and the statistical analysis thereof. Statistical analysis was performed using SPSS (version 25; IMB, Armonk, NY, USA).

Results

In this adaptive online survey among members of the German Society of Orthopedics and Trauma Surgery (DGOU), a total of 340 surgeons participated, who evaluated 7012 case scenarios of PHFs. The participants, all actively practicing surgeons, reported their annual case volumes for surgical treatment of proximal humeral fractures as follows: 36.5% (124/340) managed over 100 cases annually, 18.2% (62/340) handled between 50 and 100 cases, 32.1% (109/340) treated between 20 and 50 cases, and 13.2% (45/340) addressed fewer than 20 cases per year. Regarding their years of professional experience, 48.8% (166/340) had more than 20 years of experience, 31.2% (106/340) had between 10 and 20 years, 13.5% (46/340)

a



b

case scenario	displaced tuberosities	dislocation fracture	headsplit fracture	cuff arthropathy
1	x	x	x	x
2	x	x	x	✓
3	✓	x	x	x
4	✓	✓	x	x
5	x	✓	x	x
6	✓	x	✓	x
7	✓	✓	✓	x
8	x	✓	✓	x
9	x	x	✓	x
10	✓	x	✓	✓
11	✓	✓	✓	✓
12	x	✓	✓	✓
13	x	x	✓	✓
14	✓	x	x	✓
15	✓	✓	x	✓
16	x	✓	x	✓

Figure 1 Venn Diagram concept (**a**) as a visual representation of the collected response options for the queried case scenarios (**b**).

had 5 to 10 years, and 6.5% (22/340) had less than 5 years of experience.

The number of 7012 reflects the total number of case scenarios presented across all responses which were dynamically adapted based on participant interactions and additional information requests, rather than representing 7012 unique scenarios. Analysis by age groups revealed the following concise therapeutic preferences.

For patients under 50 years old, there was a clear tendency toward joint-preserving plate osteosynthesis, particularly in complex fracture patterns (Fig. 2 and Table I). This preference for osteosynthetic treatment approaches in younger patients is especially evident in constellations of displaced tuberosities with (85%) or without (95%) dislocation fractures. However, in cases combining a dislocation fracture with a headsplit component and displaced tuberosities, there was a clear preference (63%) for implantation of a reverse shoulder arthroplasty (Fig. 2 and Table I).

In the age group of 50-70 years, there was a heterogeneous selection among the available treatment options. Joint-preserving plate osteosynthesis is preferred in patients without pre-existing cuff arthropathy, while endoprosthetic replacement using a reverse shoulder arthroplasty is preferred in patients with cuff arthropathy (Fig. 3 and Table II). In fracture constellations without tuberosity dislocation, dislocation, or headsplit components, nonsurgical treatment was predominantly preferred in this age group (61% and 56%). This reflects a nuanced balance between reconstructive and joint-replacing approaches in this age cohort.

For patients over 70 years old, there was a clear preference for joint-replacing treatment with a reverse shoulder arthroplasty, particularly in cases of combined injuries involving dislocation fractures (87%), displaced tuberosities (94%), and headsplit injuries (70%) with pre-existing cuff arthropathy (Fig. 4 and Table III). In cases of isolated tuberosity dislocation, respondents preferred osteosynthetic treatment with plate osteosynthesis (73%). In the presence of coexisting headsplit components and tuberosity dislocation, nonsurgical treatment was predominantly chosen (55%) as the preferred procedure (Fig. 4).

Discussion

In this adaptive online survey involving 340 surgeons, preferred treatment strategies were identified from over 7000 case scenarios of PHFs. For individuals below 50 years old, a trend toward joint-preserving therapy via plate osteosynthesis was observed. Among patients aged 50-70 years, a heterogeneous pattern of response options emerged, including nonsurgical interventions, plate osteosynthesis, or reverse shoulder arthroplasty. For those older than 70 years old, reverse shoulder arthroplasty was identified as the treatment of choice in cases of complex fracture patterns.

The current study on decision-making in PHF management is positioned against the backdrop of an ongoing scientific debate on the optimal treatment of this complex traumatic condition[23] and, to our knowledge, represents the first of its kind.

Particularly in cases of dislocation fractures and headsplit fractures, as well as in patients under 60 years old, there remains a very limited evidence base, making treatment selection particularly challenging.[8] Open reduction and plate osteosynthesis procedure remains the treatment of choice for grossly displaced PHF, headsplit fractures, or

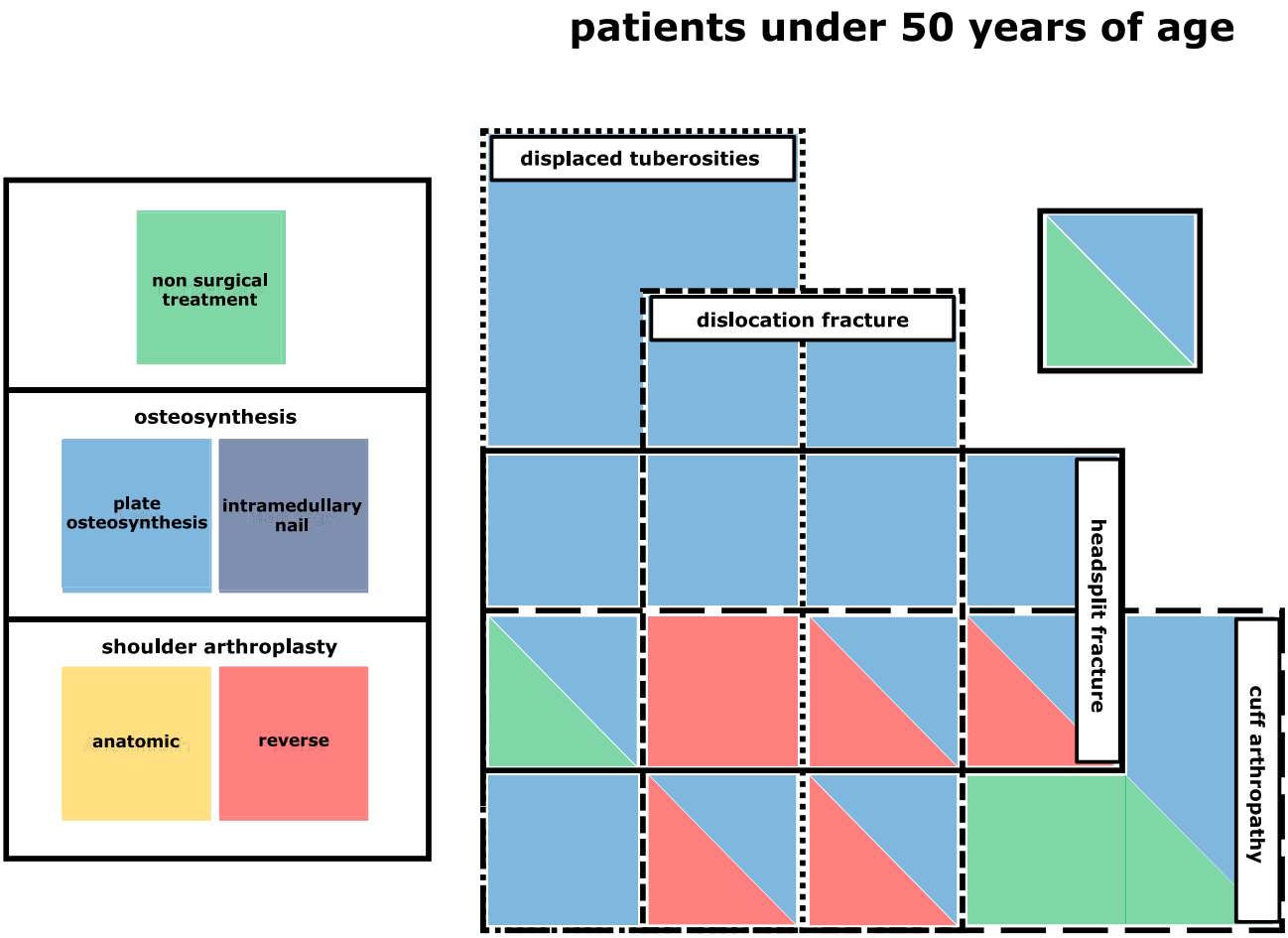


Figure 2 Visualized treatment preferences for patients with proximal humerus fractures younger than 50 years of age.

Table I Listed choice of treatment for patients younger than 50 years old

Below 50 yrs of age [n = 2345][%]						
	n	Nonsurgical	Osteosynthesis		Arthroplasty	
			Plate osteosynthesis	Intramedullary nail	Reverse	Anatomic
1	286	**46**	**46**	8	0	0
2	286	**48**	**28**	6	12	5
3	303	1	**95**	3	1	0
4	289	0	**85**	4	5	6
5	292	1	**78**	3	8	10
6	303	32	**65**	3	0	0
7	283	1	**53**	0	14	32
8	293	2	**83**	2	4	10
9	296	13	**75**	3	4	6
10	303	**38**	**33**	3	19	7
11	283	0	21	0	**63**	16
12	293	2	**44**	1	**42**	10
13	296	12	**44**	2	**34**	9
14	303	2	**63**	2	29	5
15	289	0	**46**	2	**41**	10
16	292	1	**45**	1	**42**	11

*Highlighted fields indicate treatment options with over 50% consensus. In instances of no majority (>50%), top 2 selections are indicates as bold.

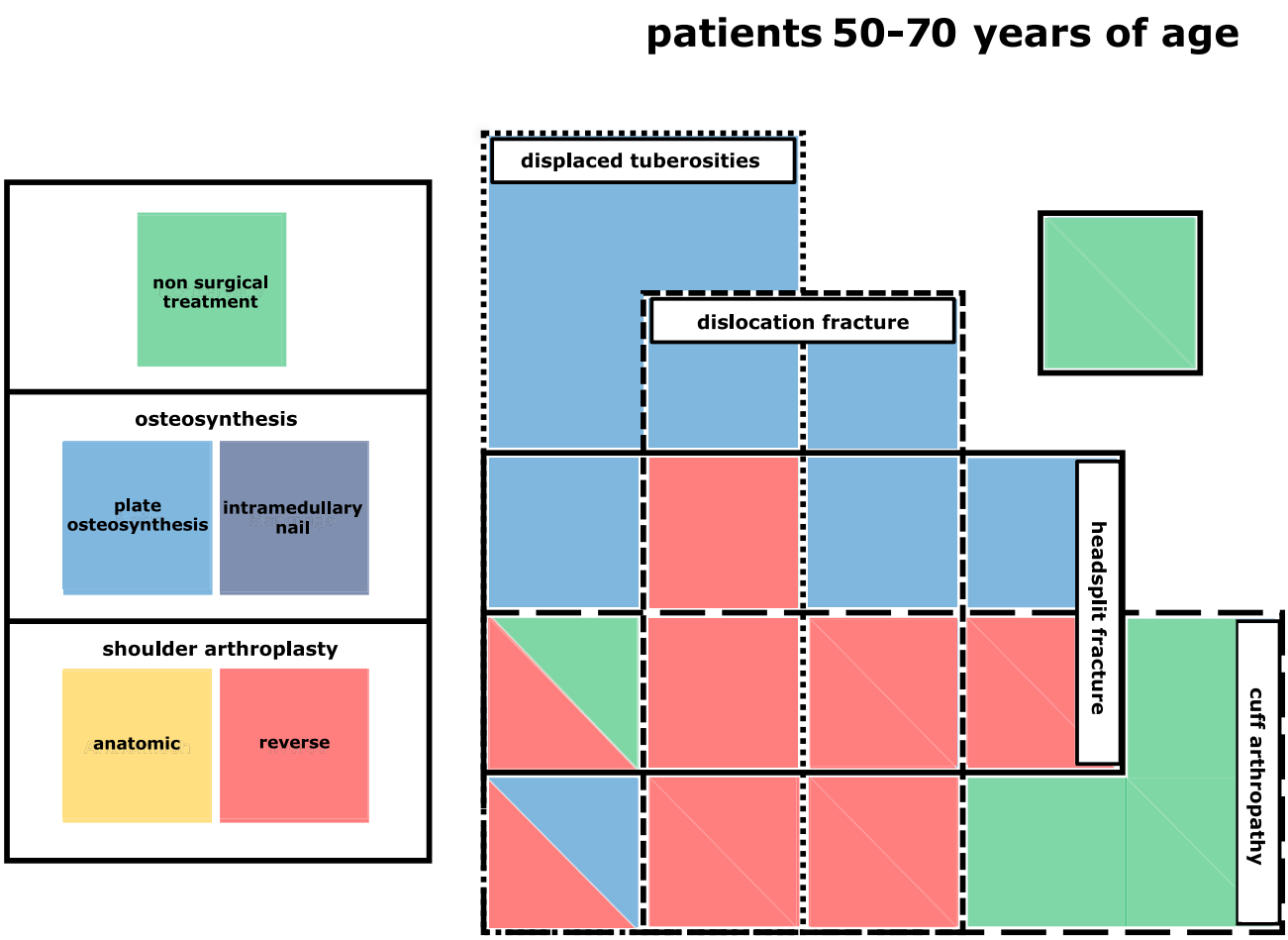


Figure 3 Choice of treatment for patients 50-70 years of age in case of proximal humerus fractures.

dislocation fractures in young patients, as also reflected in the results of this survey.[14,17] Plate osteosynthesis has gained considerable significance in both clinical and scientific contexts in Germany in recent years.[14] This increased importance is evidenced by a growing number of publications over recent years and clinical usage despite ongoing challenges such as high revision rates due to material removal and arthrolysis.[17,21] Unfortunately, there is still insufficient evidence regarding the optimal therapy in these cases.[8] The use of intramedullary nail osteosynthesis for proximal humeral fractures has declined in Germany in recent years, despite studies demonstrating consolidated fracture conditions with satisfactory functional outcomes.[26] Yet, precise indication and surgical experience remain key aspects.[5,6] Implantation rates of anatomical shoulder arthroplasty have markedly decreased in Germany,[14] primarily due to increased failure rates in patients with cuff arthropathy and postoperative restricted range of motion.[22] Our survey results reflect this trend, as they indicate a notable decline in the use of anatomical shoulder arthroplasty for proximal humeral fractures. However, anatomical shoulder arthroplasty retains clear indications in younger patients and those over 70 years old with an intact rotator cuff.[3,4] This aligns with our survey's observation that, while the overall popularity of anatomical shoulder arthroplasty has waned, it remains undeniably relevant for cases of destroyed humeral head fractures in younger patients.[14] The increasing use of reverse shoulder arthroplasty in Germany, particularly in the context of fractures in older patients, can be explained by positive functional outcomes.[12,31] Moreover, positive results have been observed in conversions from initial plate osteosynthesis or anatomical shoulder arthroplasty for PHF and fracture sequelae.[2,18] Lu et al found that initial treatment with a reverse shoulder arthroplasty in older patients resulted in significantly better functional outcomes and significantly less pain.[19] Thus, the authors concluded that in these scenarios, implantation of the reverse shoulder arthroplasty should be recommended to ensure a rapid return to independence and minimal subsequent surgeries.[19]

This is also reflected in the clear preference for this treatment option in the results of our survey. Furthermore, these findings underscore the relevance of our study in corroborating established clinical guidelines and

Table II Answers for patients between 50 and 70 years of age

50-70 yrs of age [n = 2332][%]						
	n	Nonsurgical	Osteosynthesis		Arthroplasty	
			Plate osteosynthesis	Intramedullary nail	Reverse	Anatomic
1	287	**61**	31	7	0	1
2	287	**56**	19	5	15	5
3	293	3	**90**	3	3	0
4	288	0	**59**	5	26	10
5	298	0	**57**	5	26	12
6	295	38	**59**	2	1	1
7	279	0	26	0	**51**	23
8	295	2	**61**	1	24	12
9	297	17	**60**	3	14	5
10	295	**39**	25	1	**30**	4
11	279	0	8	0	**87**	5
12	295	1	20	1	**71**	7
13	297	15	21	2	**56**	5
14	293	3	**49**	1	**43**	4
15	288	0	14	2	**75**	8
16	298	0	21	1	**70**	8

*Highlighted fields indicate treatment options with over 50% consensus. In instances of no majority (>50%), top 2 selections are indicates as bold.

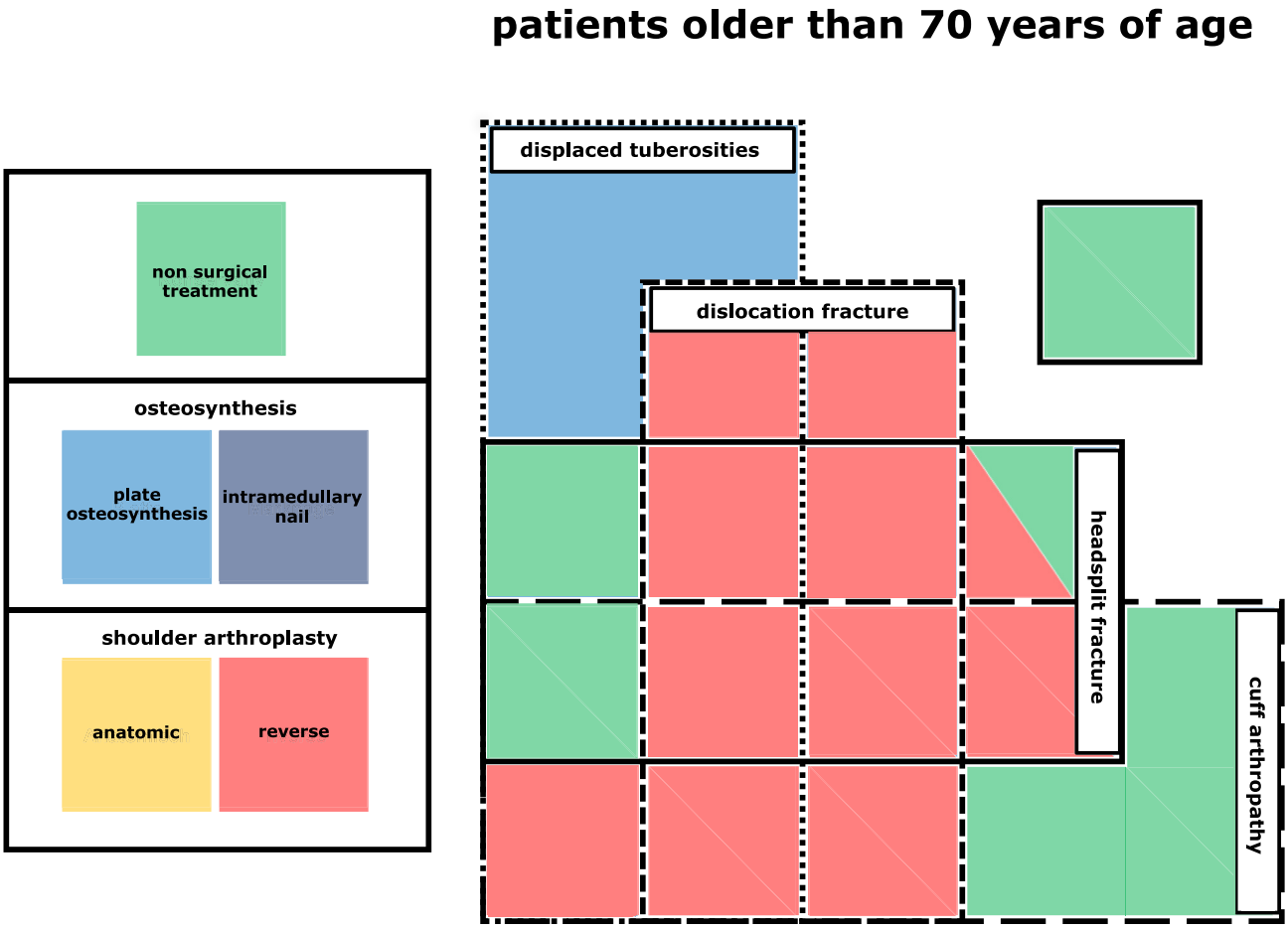


Figure 4 Preferred treatment for patients older than 70 years of age.

Table III Obtained responses for treatment in PHF for patients that are older than 70 years

Older than 70 yrs of age [n = 2335][%]						
	n	Nonsurgical	Osteosynthesis		Arthroplasty	
			Plate osteosynthesis	Intramedullary nail	Revers	Anatomic
1	287	**78**	17	4	1	0
2	287	**66**	7	3	22	2
3	295	5	**76**	3	16	0
4	288	1	22	4	**72**	2
5	285	0	16	3	**75**	6
6	301	**55**	38	1	5	0
7	290	0	6	1	**88**	5
8	285	2	20	1	**70**	6
9	304	**33**	21	1	**42**	3
10	301	**50**	13	1	34	2
11	290	1	3	0	**94**	2
12	285	2	6	1	**87**	5
13	304	22	5	0	**70**	2
14	295	4	35	2	**56**	3
15	288	1	2	1	**94**	2
16	285	0	6	1	**91**	21

*Highlighted fields indicate treatment options with over 50% consensus. In instances of no majority (>50%), top 2 selections are indicates as bold.

preferences for managing proximal humerus fractures. They also provide insight into prevailing treatment trends, which can guide clinicians in aligning their practices with current evidence-based recommendations.

The significance of nonsurgical interventions in the discussion surrounding the optimal management of displaced PHFs remains highly relevant, especially given the lack of clear superiority of surgical therapy thus far.[9] The ProFHER study from England demonstrated no difference in functional outcomes at 2 and 5 years between nonsurgical and surgical treatment for displaced proximal humeral fractures.[7,9] However, Germany has seen a 39% increase in surgical interventions over the last 2 decades, underscoring the lack of scientific consensus regarding PHF management.[14,23] Given this controversy, careful consideration of the benefits of surgical interventions compared to the ongoing high complication rates associated with operative procedures for PHFs is essential.[24]

The adaptive structure of the conducted online survey and the integration of relevant factors allowed for comprehensive data collection and precise representation of treatment preferences. Characteristic of this work is the impressive number of participants and the careful analysis of over 7000 case scenarios, which not only provide a solid foundation for the study but also lend it high external validity. The developed treatment algorithm may therefore potentially contribute innovatively to the visualization and standardization of decision-making processes in proximal humeral fractures. The next step would be a prospective validation of this algorithm.

Of course, the limitations of the study must also be carefully evaluated. This work primarily reflects the preference of each surgeon, which is largely based on individual competence and certain clinic-specific standards.[10,11,19] Patient preference is not relevant in the setting designed here, so the visualized treatment algorithm should be seen as a recommendation that must be further discussed in patient consultations. While the use of the term ''algorithm'' reflects the structured approach to analyzing preferences, we acknowledge that this framework represents an initial step in decision support and will benefit from further integration of evidence and patient context in future developments.

Furthermore, despite its dynamic adaptation to case scenarios, the survey may not capture all subtle nuances of decision-making, especially regarding individual preferences and specific patient-associated factors. Additionally, the physiological age of an individual must be carefully considered in each case, so the classification into age groups conducted here can only serve as a rough guide. This highlights the importance of developing an individualized concept for optimal proximal humeral fracture therapy.

Conclusion

This study has enabled the development of a treatment algorithm based on the current preferences of German-speaking surgeons. The identified age-specific treatment preferences offer not only clinically relevant insights but also starting points for further improvement in standardization of care. Overall, this work can contribute to advancing research on optimized management of PHFs

and promoting patient-centered, evidence-based decision-making in trauma surgery and orthopedics.

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Supplementary Data

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