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INTEGRATED STUDY MASTER'S THESIS

Treatment of Proximal Humerus Fractures in the Elderly

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1. ABBREVIATIONS

- **AO/OTA** – Arbeitsgemeinschaft für Osteosynthesefragen / Orthopaedic Trauma Association
- **BMD** – Bone Mineral Density
- **ORIF** – Open Reduction and Internal Fixation
- **PHF** – Proximal Humerus Fracture
- **QoL** – Quality of Life
- **RCT** – Randomized Controlled Trial
- **ROM** – Range of Motion
- **RSA** – Reverse Shoulder Arthroplasty
- **DASH** – Disabilities of the Arm, Shoulder, Hand
- **ASES** – American Shoulder and Elbow surgeons

2. ABSTRACT

2.1 Abstract in English

Proximal humerus fractures are among the most common fragility fractures in elderly patients and represent a growing clinical challenge due to increasing life expectancy, reduced bone quality, and frequent comorbidities. Although there have been great advancements in surgical technique, it remains controversial which treatment approach is most appropriate. The evidence concerning functional outcomes, complication rates, and the relative benefits of operative compared to non-operative treatment strategies is inconsistent. The aim of this literature review was to compare and evaluate conservative and surgical treatment options for proximal humerus fractures in elderly patients by analysing clinical evidence published between 2010 and 2025. Using major medical databases, a structured literature search was carried out that included PubMed, Embase, and Google Scholar. Randomized controlled trials, systematic reviews, meta-analyses, and large cohort studies focusing on patients aged 60 years and older were incorporated. Particularly important outcomes which have been used to evaluate treatment success included functional recovery, complications, reintervention rates, and patient-centred measures such as pain control and independence. The objectives included summarising the epidemiology and classification of PHFs, comparing conservative and surgical treatment modalities, evaluating outcomes and complications, and identifying crucial factors for clinical decision-making. The findings indicated that conservative management provides acceptable functional outcomes for a significant proportion of elderly patients, especially in cases with minimally displaced or stable fracture patterns. The same applies for patients with low functional demands. Surgical management should be guided by fracture complexity, bone quality, and rehabilitation potential since it is very context-dependent. One of the key findings from this review is the importance of tailoring surgical interventions according to individual patient characteristics. Since every intervention has benefits and risks it is important to evaluate all details. Head-preserving fixation techniques are associated with high complication and revision rates, especially in osteoporotic bone. Despite the long recovery period reverse shoulder arthroplasty offers more predictable functional outcomes in patients with complex or unstable fractures. Since there is no single treatment modality demonstrating universal superiority, it remains one of the main tasks for clinicians to choose the treatment approach most beneficial for every individual.

Overall, the evidence supports a shift from fracture-centred treatment algorithms towards biologically informed decision-making. Optimal management of proximal humerus fractures in elderly patients requires individualized strategies that balance mechanical feasibility, physiological reserve, functional goals, and postoperative care capacity to achieve meaningful clinical outcomes.

2.2 Abstract in Lithuanian

Proksimaliniai žastikaulio lūžiai yra vieni iš dažniausiai pasitaikančių trapumo lūžių vyresnio amžiaus pacientams ir kelia vis didesnį klinikinį iššūkį dėl ilgėjančios gyvenimo trukmės, blogėjančios kaulų kokybės ir dažnų gretutinių ligų. Nors chirurginės technikos srityje pasiekta didelė pažanga, vis dar kyla ginčų dėl to, kuris gydymo metodas yra geriausias. Įrodymai, susiję su funkciniais rezultatais, komplikacijų dažniu ir operacinio gydymo strategijų santykine nauda, palyginti su neoperacinėmis, yra prieštaringi. Šios literatūros apžvalgos tikslas buvo palyginti ir įvertinti konservatyvaus bei chirurginio gydymo galimybes vyresnio amžiaus pacientų proksimalinių žastikaulio lūžių atveju, analizuojant 2010–2025 m. paskelbtus klinikinius įrodymus. Naudojantis pagrindinėmis medicinos duomenų bazėmis, buvo atlikta struktūrizuota literatūros paieška, apimanti PubMed, Embase ir Google Scholar. Buvo įtraukti atsitiktinių imčių kontroliuojami tyrimai, sisteminės apžvalgos, metaanalizės ir didelio masto kohortiniai tyrimai, skirti pacientams, vyresniems nei 60 metų. Ypač svarbūs vertinant gydymo sėkmę rezultatai apėmė funkcinį atsigavimą, komplikacijas, pakartotinių intervencijų dažnį ir į pacientą orientuotus rodiklius, tokius kaip skausmo kontrolė ir savarankiškumas. Tyrimo uždaviniai apėmė proksimalinių žastikaulio lūžių epidemiologijos ir klasifikacijos apibendrinimą, konservatyvių ir chirurginių gydymo metodų palyginimą, rezultatų ir komplikacijų įvertinimą bei svarbiausių klinikinių sprendimų priėmimo veiksnių nustatymą. Tyrimo rezultatai parodė, kad konservatyvus gydymas užtikrina priimtinus funkcinius rezultatus didelei daliai vyresnio amžiaus pacientų, ypač minimaliai pasislinkusių arba stabilių lūžių atvejais. Tas pats pasakytina ir apie pacientus, kuriems keliami nedideli funkciniai reikalavimai. Sprendimas dėl chirurginio gydymo turėtų būti grindžiamas lūžio sudėtingumu, kaulų kokybe ir reabilitacijos galimybėmis, nes jis labai priklauso nuo konkrečių aplinkybių. Viena iš pagrindinių šios apžvalgos išvadų yra chirurginių intervencijų pritaikymo pagal individualias paciento charakteristikas svarba. Kadangi kiekviena intervencija turi privalumų ir riziką, svarbu įvertinti visas aplinkybes. Galvos išsaugojimo fiksavimo technikos yra susijusios su dideliu komplikacijų ir pakartotinių operacijų dažniu, ypač esant osteoporoziniams kaulams. Nepaisant ilgo atsigavimo laikotarpio, atvirkštinė peties endoprotezavimo operacija užtikrina labiau nuspėjamus funkcinius rezultatus pacientams, sergantiems sudėtingais ar nestabiliais lūžiais. Kadangi nėra vieno gydymo būdo, kuris būtų visuotinai pranašesnis, viena iš pagrindinių klinicistų užduočių išlieka pasirinkti kiekvienam pacientui naudingiausią gydymo metodą.

Apibendrinant galima teigti, kad turimi duomenys patvirtina palaipsnį perėjimą nuo lūžių centrinių gydymo algoritmų prie biologiniais duomenimis pagrįsto sprendimų priėmimo. Siekiant pasiekti reikšmingų klinikinių rezultatų, optimalus vyresnio amžiaus pacientų, patyrusių proksimalinių žastikaulio lūžių, gydymas reikalauja individualizuotų strategijų, kuriose suderinami mechaninio

įgyvendinamumo aspektai, fiziologinis rezervas, funkciniai tikslai ir pooperacinės priežiūros galimybės.

Keywords: proximal humerus fractures, elderly, conservative treatment, reverse shoulder arthroplasty, surgical outcomes, individualized decision-making

3. INTRODUCTION

3.1 Background

Proximal humerus fractures (PHFs) are amongst the most prevalent fragility fractures in older adults and present a clinical challenge in orthopaedic and geriatric patients. After the age of 60 their incidence rises, particularly amongst postmenopausal women because of the age related decline in bone mineral density (BMD) and increased susceptibility to falls(1). After hip and distal radius fractures, PHFs are recognized as the third most common osteoporotic fracture type accounting for roughly 5-6% of all adult fractures(2). Most PHFs in elderly individuals result from low-energy mechanisms with falls from standing height being a common injury mechanism. Major contributors to the fall risk in this population are frailty, sarcopenia and chronic comorbidities(2). It is significant that these injuries are not resulting only from isolated events but are frequently associated with a decline in overall mobility, a reduction of independence and the growing need for social or caregiver support(3).

3.2 Clinical Significance and Burden

The consequences of a proximal humerus fracture, which affected individuals are facing, extend beyond the acute injury episode. Pain, stiffness and functional limitations can often persist for months and may influence the ability to perform basic everyday activities such as dressing, personal hygiene, and household tasks, which demand for the use of the affected arm(3). Many elderly patients are confronted with prolonged rehabilitation requirements and subsequently may never fully return to their pre-injury functional status.

Analysing PHFs from the perspective of the healthcare system shows that they impose a considerable burden due to their increase in emergency visits, hospital admissions, the need for surgical intervention and extended rehabilitation services. In general fragility fractures are associated with

increased mortality within the first year, stressing the vulnerability of this patient group(4). As the global life expectancy is continuously on the rise, the incidence and associated demands on healthcare systems of PHFs are projected to grow accordingly.

3.3 Pathophysiology and Treatment Dilemma

The biological and structural circumstances of the proximal humerus present a unique challenge in the fracture management of elderly patients. The decreasing trabecular bone volume and cortical thinning, progressing with age, diminish the load bearing capacity and possibility to anchor fixation devices. Equally challenging is the progressively compromised vascular supply to the humeral head and tuberosities which reduces healing potential and increases the risk of avascular necrosis or delayed union. Combined with sarcopenia, fall-related trauma mechanisms and comorbidities such as osteoporosis, cardiovascular disease or diabetes these developments make fracture healing and rehabilitation more uncertain (1,3). Therefore, it has become increasingly complex to make clear treatment decisions for PHFs in this patient group suffering from comorbidities.

Conservative (non-operative) management remains a viable option for patients suffering from minimally displaced fractures or with low functional demands since it provides acceptable outcomes when early mobilization is ensured. The evolution of surgical techniques has brought invasive (operative) management further into the discussion although it is not free of concern. Fixation failure, screw cut-out, secondary displacement and implant loosening are more common in individuals with osteoporotic bone when using angular stable plates, intramedullary nails or traditional hemiarthroplasty(1). Recent high-level evidence paints a mixed picture, making it difficult to establish firm recommendations that are generally applicable. Similar results were reported in a 2024 systematic review and meta-analysis by Lai comparing arthroplasty (reverse shoulder arthroplasty, RSA) with non-surgical management in PHFs. No significant difference in everyday functional ability was reported(5). Subgroup analysis indicated that RSA might produce superior functional results with a mean difference in the Constant-Murley score (Shoulder function assessment score) of 6 when compared to conservative care.

These findings stress the core dilemma that surgical interventions offer theoretical advantages in terms of anatomical restoration and a quicker return to mobilization but regularly do not produce the desired outcome. Especially patients with osteoporosis, comorbidities and after a certain age are at peri- and post-operative risk. Global practice patterns reveal substantial variation due to surgeon preferences, institutional expertise, the availability of resources and patient specific factors like frailty, cognitive impairment and rehabilitation potential. It is important that treatment is selected in consideration of fracture healing amongst return of function, maintenance of independence and risk

minimization since poor management adds to mortality and dependency in a vulnerable group(4). Due to all the described circumstances that must be considered, treatment of PHFs in elderly patients remains controversial. While advancements such as RSA and locking-plate osteosynthesis provide new options, the evidence remains inconsistent. Clinical practice guidelines display significant variability and decision-making needs to integrate patient physiology, fracture complexity and systemic factors rather than simply fracture pattern alone.

3.4 Knowledge gap

Despite the significant clinical and socioeconomic impact that PHFs represent, there is only fragmented and heterogenous evidence that is insufficient to guide clear decision making. Many high quality randomized controlled trials include broad age ranges, making it difficult to generalize findings to frail, osteoporotic patients above 60. The inconsistency of conclusions across literature can also be traced back to variability in study design, fracture classification, rehabilitation protocols and outcome measures. In recent years surgical options such as reverse shoulder arthroplasty (RSA) have gained popularity. Nevertheless, long-term comparative data in elderly derived from cohorts remain scarce leading to conflicting results from systematic reviews. This inconsistency highlights a persisting knowledge gap concerning which treatment strategies are truly producing the best functional results under given circumstances. Optimal strategies for recovery, independence and quality of life for older adults remain unclear.

Another limitation is the inconsistent reporting of patient centred outcomes, such as return to independence, need for long-term care, and ability to perform activities of daily living. All being important to geriatric patients and their ability to navigate life independently. Direct associations between PHF treatment modality and long-term outcomes remain underexplored, although broader fragility fracture research indicates elevated mortality and morbidity following low-energy fractures in elderly populations(4). The variation in global treatment practices is perhaps the clearest indicator that no universally accepted, evidence-based algorithm for managing displaced PHFs in older adults currently exists. Those differences stress the need for high-quality studies, focused specifically on elderly patients, evaluating the contemporary treatment strategies applied.

3.5 Aim

The aim of this thesis is to evaluate and compare current conservative and surgical treatment strategies for proximal humerus fractures in the elderly by analysing high-quality evidence published between 2010 and 2025.

3.6 Objectives

1. To summarize the epidemiology, clinical relevance, and the systems commonly used to classify PHFs in elderly individuals.
2. To review conservative and surgical treatment strategies used to treat proximal humerus fractures in elderly patients.
3. To compare outcomes, complications, and reintervention rates between the different treatment modalities.
4. To identify the most relevant factors influencing clinical decision making and formulate evidence-based recommendations regarding treatment selection.

4. METHODS

4.1 Design and Search Strategy

This thesis is designed as a literature review with the goal to analyse and evaluate the latest evidence on the management of proximal humerus fractures (PHFs) in elderly patients. Studies published within the defined timeframe were identified, selected and analysed in a structured manner. Although it does not fully adhere to all criteria of a systematic review, a structured and transparent methodology was applied to ensure reproducibility.

The four major scientific databases upon which the literature search was conducted are PubMed, Embase, Cochrane Library, and Google Scholar. These were selected to capture a wide range of peer-reviewed publications such as randomized controlled trials, cohort studies, systematic reviews and meta-analyses. The search targeted articles published between January 2010 and December 2025. Of those only the ones reflecting up to date developments in PHF management were included. Particularly of interest was research on advanced fixation methods alongside reverse shoulder arthroplasty (RSA). To make sure that only studies of relevance and consistency were incorporated, predefined medical subject headings (MeSH) as supplied by the U.S. National Library of medicine (NLM) were used. The search terms combined anatomical, population specific, and treatment related keywords. The following combinations have been used in the full search:

1. “Proximal humerus fracture” or “proximal humeral fracture”
2. “elderly” or “aged” or “geriatric”

3. “treatment” or “surgery” or “conservative” or “arthroplasty”

Furthermore, only human studies published in the English language were eligible for inclusion. The reference list of key articles and systematic reviews was screened manually to identify further additional studies of value. In the process their adherence to the scientific standards underlying this thesis was assured. The search strategy was developed to balance sensitivity and specificity. It ensures that potentially relevant studies on PHFs in elderly patients were captured while maintaining a dataset that is manageable for detailed evaluation.

4.2 Selection Criteria

The application of a predefined set of inclusion and exclusion criteria was crucial to ensure only high-quality, relevant, and state-of-the-art evidence has been used for the development of this review. Research specifically focused on elderly patients with proximal humerus fractures (PHFs) reflecting modern treatment practices and developments after the year 2009 was analysed.

Inclusion Criteria

Studies meeting the following criteria were eligible for inclusion:

1. Population: Human participants above 60 years of age, or studies explicitly reporting elderly subgroup analysis meeting this age threshold.
2. Condition: Proximal humerus fractures (PHFs) or fragility fractures involving the proximal humerus.
3. Language: Published in English
4. Publication period: January 2010 to December 2025, to ensure contemporary relevance in surgical techniques, implant technology and clinical approaches.
5. Study design: Randomized controlled trials (RCTs), systematic reviews, meta-analyses, cohort studies with adequate sample size.
6. Outcome measures: Studies reporting functional outcomes, complication rates, mortality, re-intervention, radiographic results, or other clinically relevant endpoints.
7. Availability: Full-text accessible through institutional access, PubMed, PMC or publisher platforms.

Exclusion Criteria

Studies were excluded for any of the following reasons:

1. Population outside the target age group, or studies not specifying data specifically on patients aged over 60 years.
2. Study type not meeting methodological standards: Case reports or series with fewer than 5 patients, cadaver, animal, biomechanical, and laboratory studies. Narrative reviews without systematic methodology, expert opinion articles or surgical technique descriptions without clinical data.
3. Publication characteristics: non-English language, published before January 2010, and abstract-only publications.
4. Irrelevance to the research aim: Studies focusing on shoulder pathology unrelated to PHFs or populations with high-energy trauma mechanisms not representative of typical elderly fragility fractures.

Rationale for the Criteria

These criteria were put in place to maximize the validity and applicability of the evidence included. To ensure the focus of the review on elderly patients with reduced bone quality and comorbidities typical for fragility fractures, the population is restricted to individuals above 60 years of age. Limiting publication years to 2010-2025 excludes outdated practices and captures modern developments. This includes the widespread use of locking plates and reverse shoulder arthroplasty (RSA). Biomechanical and cadaveric studies are excluded to avoid evidence that is not directly applicable to clinical practice. High-level evidence designs such as RCTs, systematic reviews, meta-analyses and large cohort studies are prioritized to minimize bias and maximize reliability of comparisons between the treatment modalities.

4.3 Data extraction and Study screening

After the identification of eligible publications, a screening and selection process followed in two stages. Abstracts and titles were reviewed to exclude all studies not in line with the inclusion criteria. Afterwards, a full text analysis was conducted with particular attention to patient age, study design, fracture type, treatment modality, and reported outcomes. Before evaluation, all duplicate studies were removed. Only the research in line with the predefined in- and exclusion criteria was reviewed for further uncertainties or academic errors before incorporation. Data were extracted in a structured manner to systemically capture relevant characteristics and outcomes.

The information extracted included:

- Author and year of publication
- Study design (RCT, cohorts, systematic reviews, meta-analysis)
- Population characteristics (sample size, mean age, inclusion criteria)
- Fracture classification
- Treatment modality (conservative, ORIF, intramedullary nailing, hemiarthroplasty, reverse shoulder arthroplasty)
- Outcome measures (Constant-Murley score, DASH, ASES, Range of Motion, pain, QoL)
- Complications (Fixation failure, infection, avascular necrosis, reoperation rates)
- Length of follow-up
- Key findings and conclusions

To enhance transparency a table summarizing the key studies with their extracted study characteristics is presented. This table provides an overview of the evidence base and facilitates the ability to compare treatment modalities across different study designs. This review does not fully replicate a systematic PRISMA process but aims to remain aligned with academic principles to improve methodological clarity and reproducibility.
The extracted data have been organized into categories corresponding to the Findings, Discussion, and Conclusion chapters. All studies addressing the same treatment modalities or outcomes were grouped to improve their analysis and comparison. This process ensured that the analysis remained focused on clinically meaningful endpoints and the appropriate patient population.

Study selection summary:
Identified: 182 records through database searching
Screened: 85 records after removal of duplicates
Included: 24 studies in the final analysis

5. FINDINGS OF THE LITERATURE REVIEW

5.1 Anatomy and Biomechanics of the proximal humerus

It is crucial to understand the anatomy and biomechanical characteristics of the proximal humerus. When it comes to fracture patterns, predicting healing potential and the appropriate treatment strategy, a deep understanding of the circumstances is important, especially in elderly patients. Age-related

structural degeneration, impaired vascularity, and the influence of muscular force are amongst the main contributing factors that make proximal humerus fractures (PHFs) complex in this population (6).

Osseous Anatomy

The proximal humerus involves the humeral head, the anatomical and surgical necks, the greater and lesser tuberosities, and the metaphyseal region of the shaft. The surgical neck is the connection between head and shaft and represents a biomechanical transition zone that is particularly susceptible to low energy fractures in elderly patients due to decreased cortical thickness in this location (7). The muscles of the rotator cuff are connected at the tuberosities which serve as insertion sites. This connection is important for shoulder stability and biomechanics. Displacement of these structures is of great significance for postoperative function, external rotation, and abduction strength (7). Particularly the greater tuberosity is of importance since it serves as an insertion site for three out of four rotator cuff muscles.

Osteoporosis is one of the main age-related factors that can lead to a reduction in trabecular bone density, thinning of cortical bone, and weakening of the metaphyseal architecture. All these processes may directly influence the susceptibility to fractures from low impact trauma. They also complicate attempts to achieve stable fixation since osteoporotic bone provides insufficient anchorage for implants compared to younger, healthier bone (7). The risk of fixation failure is increased.

Vascular supply

For determining fracture healing and the risk of developing avascular necrosis (AVN), the vascularity of the humeral head is important. Modern anatomical studies show the posterior humeral circumflex artery (PHCA) as the dominant blood supplying vessel to the humeral head. The anterior humeral circumflex artery (AHCA) and its arcuate branch contribute a smaller but clinically relevant amount of the blood supply (6). A significant risk to vascular integrity comes from fractures involving medial calcar disruption, displacement, or head-splitting patterns. Patients with any of these features are at increased likelihood of humeral head ischemia which is very relevant to elderly patients with diminished microvascular perfusion (6).

Biomechanics and Age-Related Degeneration

Osteoporotic bone shows decreased trabecular connectivity, increased porosity, and reduced mechanical strength. All these structural features impair the bone's ability to withstand deformation and to serve as anchorage for screws. Complications such as varus collapse, screw cut-out, and

secondary displacement following internal fixation are more likely to develop (8). The medial calcar plays a key stabilizing role. Its integrity is essential for resistance to varus forces. A strong predictor for fixation failure is loss of medial column support which can be frequently observed in elderly patients with multifragmentation fractures (8).

Muscular Forces and Fracture Displacement

Muscular attachments extensively influence the displacement patterns of PHFs. The greater tuberosity tends to displace superiorly due to the supraspinatus muscle, while the subscapularis rotates the lesser tuberosity internally. The deltoid and pectoralis major tend to create varus angulations and medial displacement of the shaft fragment (7). The risk of these muscular forces creating displacement is elevated in osteoporotic bone, even after low-energy trauma. This may lead to complex multi-fragmented fractures that are typical in elderly patients (9).

Mechanism of Injury in elderly patients

Low-energy falls, especially onto the outstretched hand or laterally onto the shoulder are the main causes for PHFs in individuals over 60. The axial and bending forces generated by these traumatic falls injure the weakened metaphyseal bone. Especially in frail individuals, sideways falls occur which often lead to varus-impacted fractures due to direct force impact across the humeral head and metaphysis (9,10).

Clinical Relevance

Many of the challenges clinicians face when dealing with PHFs in elderly patients can be explained by the interplay of anatomy, vascularity, bone quality, and muscular forces. Conservative treatment is favoured if vascularity and minimal displacement are ensured. Fractures that involve calcar comminution, displacement of a tuberosity, or compromised blood perfusion may require surgical intervention (7,8). Since fixation strength is limited in osteoporotic bone, it is reasonable to consider arthroplasty, especially RSA, in cases where anatomical reconstruction has low chances of success due to heavy fragmentation.

5.2 Classification

Fracture classifications are important in the assessment of PHFs since they provide a structured description of fracture morphology, easier communication between clinicians, and enable comparison of outcomes across studies. They are also used to support treatment planning in elderly patients. Their reliability and clinical relevance in osteoporotic bone however remain debated (7).

Neer Classification

The Neer classification is the most applied system for the assessment of PHFs. It is based on the concept of fracture parts alongside their displacement and angulation. This system categorizes fractures into one-part (minimally displaced), two-part, three-part, and four-part fractures depending on the involvement and displacement of humeral head, shaft and tuberosities (7). Osteoporotic bone presents greater challenge in achieving stable fixation. Increasing fracture complexity is generally associated with worse functional outcomes and higher rates of complications, making the Neer classification relevant for elderly patients. Typically, one-part fractures are managed conservatively, while displaced three- and four-part fractures often require surgical intervention (7).

Even though it is widely used, there are limitations to the Neer classification. Several studies demonstrate only moderate interobserver (between different observers), intraobserver (observer at different points in time) reliability(11). These limitations are especially pronounced in elderly patients with complex fracture patterns complicated by comminution and poor bone quality that may be difficult to identify on conventional radiographs (12).

AO/OTA Classification

The AO/OTA classification provides a more comprehensive framework for fracture description. PHFs are classified within the proximal humerus segment and grouped according to increasing severity and complexity. Typically, it reflects extra-articular unifocal patterns, extra-articular bifocal patterns, and articular fractures that include dislocations and head-splitting fractures. This method provides greater detail than the Neer classification and improves consistency for research, data registries, and reporting across different organizations (13).

Despite these advantages, the AO/OTA classification can be perceived as excessively complex for daily clinical use, and reliability is challenged by fractures fitting between two categories, osteoporotic comminution, and limited visualization on standard imaging. Therefore it is common to use the AO/OTA system in combination with descriptive terminology, especially when treatment-relevant features are communicated (7,13).

Reliability and practical Implications for the Elderly

Regardless of the classification system used, interobserver reliability remains a limitation. This is influenced by the three-dimensional nature of fracture displacement, osteoporotic metaphyseal comminution, and variability in radiographic interpretation (7,11,12).

Concerns about the reliability are clinically relevant since treatment decisions in elderly patients are sensitive to circumstances such as tuberosity displacement, medial calcar integrity, varus

malalignment, fracture-dislocation, and head ischemia. It is the reason why classification results should always be interpreted amongst patient factors and a structured assessment of treatment-relevant morphological features (1,7).

In cases of insufficient plain radiographic imaging, it is valuable to do computed tomography to improve morphological understanding, support consistent classification, and surgical planning. This applies especially in cases of three- or four-parted fractures, dislocated fragments, head-splitting patterns, or unclear tuberosity involvement. Due to the increased tendency for fixation failure this applies to elderly patients (13).

5.3 Epidemiology and Mechanisms of Proximal Humerus Fractures in the Elderly

PHFs are amongst the most common fragility fractures and account for a large portion of upper extremity injuries in older individuals. Epidemiological data show a strong correlation between increasing age and fracture incidence. Especially in individuals over the age of 60 the incidence rises noticeably. Women are more susceptible in comparison to men which can be explained by the increased prevalence of osteoporosis and a longer life expectancy(1,2).Following hip and distal radius fractures, PHFs are recognized as the third most frequent osteoporotic fracture type. According to population-based analyses they account for approximately 5-6% of all adult fractures and their incidence is expected to rise due to aging populations in the future (2,4). Large registry studies indicate that those elderly individuals sustaining PHFs often present with multiple comorbidities, reduced baseline functional capacity, and increased frailty. All of these factors directly influence treatment choices and functional outcomes (2).

Age- and Sex-Specific Distribution

As the incidence of PHFs is rising with advanced age, it does so particularly after the seventh decade of life. Females are about two to three times more likely to sustain a fracture of the proximal humerus. This can be explained by postmenopausal bone loss and higher rates of osteoporosis-related fragility fractures (1,9). In young patients, PHFs often result from high-energy trauma forces produced by the likes of traffic accidents or sports injuries. This population differs in fracture characteristics and healing potential from elderly individuals that are predisposed to get injured by lower forces such as simple falls from standing height (9). The fractures in elderly patients are more frequently multi-fragmentary and impacted, which reflects the diminished bone quality and altered transmission of load through the proximal humerus. This mixture of predispositions contributes to the complexity of fracture patterns observed in this age group and partially explain the increased rate of displacement and fixation failure in osteoporotic bone (1,2).

Injury Mechanisms

The predominant mechanism of injury in the elderly population is low-energy falls which typically occur from standing height. Often, they lead to impact onto the outstretched hand or the lateral aspect of the shoulder. The forces generated through these most commonly are not strong enough to injure younger individuals but produce enough force to cause fractures in elderly patients with osteoporotic metaphyseal bone (9).

Especially lateral falls are of concern since they are frequently associated with varus-impacted fracture patterns in frail elderly people. The axial load in combination with bending forces across the surgical neck region can cause a collapse of the weakened metaphysis which is often accompanied by disruption of the medial calcar integrity. It is the mechanism that explains the high prevalence of varus deformity and medial comminution observed in elderly PHFs (1,2).

Clinical and Epidemiological Significance

PHFs are not isolated events but rather are regarded as markers of underlying skeletal fragility and increased future fracture risk. They are similar in that regard to hip and vertebral fractures, which also are associated with increased morbidity, prolonged functional impairment, and elevated mortality within the first year following the injury. This applies especially to elderly and comorbid patients (2,4).

An understanding of the epidemiology and injury mechanisms of PHFs in the elderly is essential for both prevention and management. When it comes to fragility fractures fall prevention strategies, osteoporosis assessment and multidisciplinary care are of great importance. The recognition of typical low-energy mechanisms and age-specific fracture characteristics provides essential context for the interpretation of fracture patterns, risk of complications, and the appropriate treatment choice for this vulnerable population (1,2).

5.4 Conservative Treatment of Proximal Humerus Fractures in the Elderly

Although there are new operative treatment methods developed each year, conservative (non-operative) treatment remains a cornerstone in elderly patients. Because of the high prevalence of cases where patients display minimally displaced fracture patterns, reduced bone quality, advanced age and comorbidities, non-operative treatment is frequently selected in this population as first-line treatment that avoids perioperative risk of complications (1,3).

Indications

Refraining from invasive treatment and following the conservative approach is indicated in cases of minimally displaced one-part fractures, impacted surgical neck fractures, and fractures without

tuberosity displacement or humeral head ischemia. As long as acceptable alignment and joint integrity can be ensured, it is possible to utilize this approach also for elderly individuals with low functional demands, limited rehabilitation potential, or substantial comorbidities (1).

It is important to indicate that clinical decision-making must account for patient-related factors apart from fracture morphology. Key factors to navigate are frailty, cognitive function, pre-injury independence, and the compliance that can be expected from the patient regarding rehabilitation protocols. Therefore, conservative management is favoured to avoid surgical complications, which may outweigh potential functional gains (2,3).

Treatment Protocols

Conservative treatment does usually consist of short-term immobilization followed by early progressive mobilization. Generally, the immobilization period takes about one to three weeks and is done utilizing a sling or shoulder brace. The duration is individualized and dependent on fracture stability and patient comfort. It is not recommended to prolong immobilization further on as it is associated with increasing risk of shoulder stiffness, muscle atrophy, and delayed functional recovery (3).

In the early phases of physiotherapy, the focus is on passive-assisted range-of-motion exercises, which gradually and pain-adapted progress to active movements and muscle strengthening once fracture consolidation allows. Clinicians are required to follow up and provide adequate analgesia since these are important components of conservative care to facilitate mobilization. The development of secondary displacement or other complications are also to be monitored (1,3).

Functional Outcomes

In a considerable number of randomized controlled trials and systematic reviews, it has been documented that, particularly in minimally displaced fractures, satisfactory functional outcomes in a large proportion of elderly individuals with PHFs can be achieved. The Constant-Murley score and DASH, which are functional outcome scores, have shown no clinically meaningful differences between non-operative and operative management modalities in elderly (3,14).

An important part of functional recovery and the outcome is the baseline functional status and rehabilitation adherence rather than a perfect radiographic repositioning on imaging. It is common for elderly patients to achieve acceptable pain relief and functional independence despite residual deformity or malunion that may be well tolerated in low-demand individuals (1,3).

Complications and Limitations

Despite having the advantage of avoiding surgical risks like infection or implant-related complications, there are still limitations to non-operative treatment modalities. Common issues for patients include shoulder stiffness, malunion, and persistent pain, which manifest particularly in individuals with unrecognized instability or secondary displacement. Varus malalignment and tuberosity malposition can negatively affect shoulder biomechanics and lead to reduced range of motion or strength. Especially in physically active individuals this may lead to impaired shoulder function (1,8).

Secondary displacement during conservative care is of particular concern. Especially in patients with osteoporotic bone it is therefore recommended to do radiographic follow-ups during the early phases of healing to identify those cases where patients require delayed surgical intervention (8).

The Role of Conservative Treatment in recent practice

Conservative treatment remains the preferred option for most elderly patients suffering from PHFs. High-level evidence has not yet succeeded to demonstrate significantly superior outcomes of surgical interventions over non-operative treatment. This applies for many fracture patterns in elderly individuals. Conservative treatment therefore remains a safe, effective, and evidence-based approach if indicated adequately by the circumstances of the specific case (3,5).

It continues playing a central role in the treatment algorithm for elderly patients with PHFs, but success depends upon careful patient selection, early mobilization, structured rehabilitation, and close clinical monitoring. Those principles are vital for optimizing functional outcomes while minimizing treatment-related risks in this vulnerable population.

5.5 Surgical Treatment Options for Proximal Humerus Fractures in the Elderly

Surgical treatment of PHFs in elderly patients is considered mainly in cases where significant displacement, fracture instability, compromised vascularity, or failure of conservative management are present. It is important to balance the potential benefits of an operation such as anatomical restoration and early mobilization against the increased risk of complications that are associated with osteoporotic bone, advanced age, and comorbidities. Therefore, clinicians are required to assess the most appropriate individualized approach for each patient (1,2).

The main surgical strategies that are utilized in the treatment of elderly individuals include open reduction and internal fixation (ORIF) with locking plates, intramedullary nailing, hemiarthroplasty, and reverse shoulder arthroplasty (RSA). For each approach, there are specific indications,

advantages, and limitations that must be considered in the context of fracture pattern, bone quality, and patient-related factors.

Open Reduction and Internal Fixation (ORIF)

The aim of ORIF is to preserve the native humeral head while restoring the anatomical alignment and tuberosity position using angular-stable locking plates. It is the technique most applied in displaced two-part and selected three-part fractures in patients demonstrating sufficient bone quality and preserved medial calcar support (1,15).

Unfortunately, the outcomes of ORIF in the elderly population are inconsistent. Especially osteoporotic bone, which compromises screw and plate fixation, can lead to a high incidence of complications such as varus collapse, screw cut-out, secondary displacement, and loss of reduction. Large cohort studies and randomized controlled trials have shown complication rates ranging from 20% to over 40% in elderly individuals, that often require revision surgery (8,16). Loss of medial column support has been identified as a major predictor of fixation failure and poor functional outcome (8).

This stresses the need for careful patient selection and good surgical technique when applying ORIF in this population. ORIF is increasingly limited to fracture patterns where stable fixation and biological healing potential can reasonably be expected.

Intramedullary Nailing

Intramedullary nailing represents a less invasive alternative to plate fixation with reduced soft tissue disruption and a shorter operative time. This procedure is mainly indicated in simple two-part surgical neck fractures and selected three-part fractures without significant tuberosity comminution (15).

Despite the theoretical advantages, clinical outcomes remain mixed in elderly patients. The fixation with a nail may be associated with shoulder impingement, rotator cuff irritation, and insufficient control of tuberosity fragments. In osteoporotic bone it is possible that insufficient stability may lead to secondary displacement, particularly in varus fracture patterns. The combination of these factors has led to intramedullary nailing playing a relatively limited role in the management of PHFs compared to other surgical options (15,16).

Hemiarthroplasty

Hemiarthroplasty was historically considered to be the gold standard for complex three- and four-part fractures in elderly individuals. It was favoured especially when humeral head viability was questionable. One of the benchmarks of this procedure is the reliable relief of pain. Problematic is the

need for good anatomical tuberosity healing and the proper positioning of the implant in order to achieve satisfactory functional outcomes (1,15).

It has been demonstrated through several studies that hemiarthroplasty provides reliable pain reduction that unfortunately often comes at the cost of disappointing functional results. It is not uncommon for range of motion and strength to be limited after the procedure. Major causes for poor outcomes include tuberosity non-union or malposition that are observed frequently in osteoporotic bone. As a result, the use of hemiarthroplasty for PHFs in elderly patients has declined substantially in recent years (17).

Reverse Shoulder Arthroplasty (RSA)

In recent years, RSA has emerged as the main surgical option for many complex PHFs in elderly patients. RSA reduces the dependence on tuberosity healing and provides more predictable functional outcomes in osteoporotic bone by relying on the deltoid muscle rather than the rotator cuff for shoulder elevation (5,17).

In elderly patients with displaced comminute fractures, randomized controlled trials and systematic reviews demonstrate that RSA produces superior functional scores, improved range of motion, and lower revision rates when compared to hemiarthroplasty. Even though RSA is associated with specific complications such as dislocation, scapular notching, and infection, the overall complication and reoperation rates are comparable or lower than those of head-preserving fixation strategies in this patient population (5,17).

It should be noted that RSA is a technically demanding procedure with higher initial costs and limited long-term data in fracture indications. Despite encouraging short- and mid-term outcomes, careful patient selection and surgeon experience remain critical determinants of success.

Summary of Surgical Strategies

Surgical treatment options for PHFs in elderly patients are diverse and have distinct advantages and limitations. Head-preserving operations like ORIF and intramedullary nailing are appropriate in selected cases with favourable fracture patterns and bone quality. In osteoporotic bone, these are associated with high rates of complications. Hemiarthroplasty has largely been replaced by RSA due to inferior functional outcomes. As of now, RSA does offer the most consistent results for complex displaced fractures in elderly patients. The evaluation of cost-effectiveness and long-term outcomes for RSA is still ongoing (1,5,15).

5.6 Outcomes and Complications

When evaluating treatment strategies for PHFs in elderly patients it is not only radiographic healing, but also functional outcomes, complication rates, reintervention frequency, and overall impact on quality of life and independence that must be considered. Age-related physiological limitations, osteoporotic bone quality and frequent comorbidities lead to elderly individuals exhibiting distinct outcome profiles compared to younger populations. That is why direct comparison of results is inappropriate.

Functional outcomes

The most common way of assessing functional outcomes following PHFs is by using validated, shoulder-specific scoring systems like the Constant-Murley score, DASH, ASES, and range-of-motion measurements. Across multiple randomized controlled trials and systematic reviews there has been no clear indication for clinically relevant superiority of surgical over conservative treatment for most fracture patterns. Especially those that are minimally displaced or impacted (3,5).

In a large proportion of elderly individuals the functional outcomes achieved with conservative management following PHFs are satisfactory and provide acceptable pain control and the ability to perform activities of daily living despite radiographic malunion or deformity (1,3). It appears to be true that baseline functional status, rehabilitation adherence, and comorbidity burden are better indicators for functional recovery than anatomical perfection on imaging.

In displaced fractures with many fragments where functional outcomes vary depending on the surgical modality used for treatment this is true. Head-preserving fixation techniques such as ORIF often yield unpredictable results in osteoporotic bone, with functional scores frequently compromised by fixation failure or secondary displacement (8). RSA has demonstrated more consistent improvements in shoulder function and forward elevation in elderly patients with complex fractures (5,17).

Complications

Patient age, bone quality, fracture complexity, and treatment modality are substantial factors that influence complication rates. Non-operative treatment avoids surgery-related complications but is not free of adverse outcomes. Common complications include shoulder stiffness, malunion, persistent pain, and secondary displacement. Particularly in cases with unrecognized instability or poor medial support (1,8).

Being invasive, operative treatment is associated with higher overall complication rates in elderly patients. ORIF using locking plates carries a significant risk of mechanical failure linked to screw

cut-out, varus collapse, and loss of reduction. Complication rates of over 30% are reported in some cohorts in this population (8). Following the development of any of these complications it is likely that revision surgery is often required, although it is associated with inferior functional outcomes and increased morbidity.

Hemiarthroplasty does reliably reduce pain but is associated with tuberosity non-union or malposition that may lead to limited shoulder function. It is the reason for a significant number of patients experiencing dissatisfaction related to complications, although the implant is surviving adequately (1,15).

RSA has its own group of distinct complications that may occur with dislocation, infection, scapular notching, and acromial stress fractures being the most prominent ones. Comparative studies however show that overall complication and revision rates are comparable or lower than those observed after ORIF or hemiarthroplasty in elderly patients with complex PHFs (5,17). It is due to those findings that RSA is steadily becoming one of the mainstay treatment options for complex cases.

Reintervention and Revision Surgery

Reintervention rates are clinically meaningful in the elderly population due to the increased risk associated with secondary surgery. For conservative treatment, the reintervention rates are low although in some cases delayed surgery might be necessary due to secondary displacement or persistent functional impairment (3,8).

ORIF is associated with the highest revision rates amongst all surgical options for treating PHFs in elderly patients. This can be explained primarily by mechanical failure or avascular necrosis of the humeral head (8,16). Often revision involves conversion to RSA, which is associated with inferior outcomes when compared to primary RSA as the initial treatment.

Elderly cohorts demonstrate relatively low revision rates for primary RSA, supporting its role as the definitive solution for complex fracture patterns where head-preserving strategies are unlikely to succeed (5,17).

Mortality and Global Outcomes

Rather than being an isolated injury, PHFs in elderly patients are increasingly recognized as markers of systemic frailty. Large registry studies indicate elevated mortality rates within the first year following PHFs, particularly among surgically treated multimorbid patients (2,4). It is however still generally accepted that mortality is more strongly associated with patient-related factors such as age, comorbidities, and frailty status compared to the choice of treatment.

Clinical Implications

Outcome data indicates that treatment success in elderly patients with PHFs should be evaluated according to pain relief, preservation of independence, and the absence of complications rather than radiographic perfection alone. Especially in simple non-displaced cases, conservative management remains appropriate for many fractures. RSA represents the most reliable treatment modality when it comes to producing adequate functional outcomes for complex displaced fractures.

To optimize outcomes and minimize harm it is important for clinicians to take fracture morphology, healing potential, patient expectations, and overall health into account when making treatment decisions.

6. DISCUSSION

6.1 Summary and Interpretation of Key Findings

The Findings of this literature review demonstrate that it remains complex to manage proximal humerus fractures (PHFs) in elderly patients. No single treatment modality can be universally recommended for all elderly individuals since patient-related and fracture-specific factors are important to consider. Outcomes are influenced by fracture morphology, bone quality, baseline functional status, and the patient's ability to engage in rehabilitation measures.

One of the consistent findings throughout the literature is that satisfactory outcomes are achievable for many minimally displaced fractures through conservative treatment. Multiple randomized controlled trials and systematic reviews indicate that non-operative management is able to produce comparable functional results to surgical interventions while sparing the patient from the risks associated with anaesthesia and surgery (1,3,14). Acceptable pain relief and functional independence are frequently achieved despite radiographic malunion. This shows that anatomical perfection is not a necessity for functional success in low-demand elderly individuals.

Another finding that has become evident over the course of analysing the literature is that surgical treatment becomes increasingly relevant as fracture complexity increases. Fractures that are fragmented into three or more parts, displaced, dislocated, or show compromised medial calcar support require intervention to prevent inferior outcomes compared to conservatively treated cases. The main reasons are instability, secondary displacement, and impaired healing potential (1,8,15). Importantly, in osteoporotic bone, head-preserving strategies such as ORIF and intramedullary nailing show inconsistent results. The complication and revision rates reported for these techniques

may be explained by the biomechanical limitations that come with reduced bone quality and comminution, typical of geriatric fractures (8,16).

The recent evidence about reverse shoulder arthroplasty (RSA) indicates a fundamental change in the way complex PHFs are treated surgically. It demonstrates superior functional outcomes and lower revision rates for RSA compared to hemiarthroplasty and plate fixation in displaced fractures (5,16,17). By relying less on tuberosity healing and rotator cuff integrity, RSA can produce more predictable functional outcomes in patients suffering with compromised bone and soft tissue quality. Those advantages outweigh the procedure-specific risks that RSA presents. Continuously it is emerging as the mainstay treatment for those cases, especially if performed as a primary intervention and not as a salvage procedure.

Despite these advances, surgical superiority is not absolute. Meta-analyses comparing arthroplasty to non-operative treatment fail to indicate consistent overall functional advantages across all elderly patients, which stresses the need for careful patient selection (5). This may explain the controversy surrounding treatment guidelines and underscores that aggressive surgical intervention does not automatically translate into improved outcomes in this frail population.

All things considered, the evidence suggests that the selection of the best treatment modality for each PHF in an elderly individual should focus on functional goals, the avoidance of complications, and the preservation of independence in addition to fracture classification. The increasing use for RSA in complex cases indicates a shift towards reliability and predictable outcomes. At the same time, conservative management remains a viable option for most elderly patients, particularly those with limited functional demands or at increased risk of surgery-related complications.

6.2 Comparison of Treatment Strategies and Conflicting Evidence

One of the challenges of interpreting the literature on PHFs in elderly patients is the variety between studies when it comes to comparing treatment strategies. Differences in study design, inclusion criteria, fracture classification, outcome measurements, rehabilitation protocols, and surgeon expertise are significant factors that are responsible for the differences in conclusions seen across randomized controlled trials, cohort studies, and meta-analyses (3,18,19). Next to the complexity of fracture types and their differentiating demands, the methodological variations may explain why no universally accepted treatment algorithm has emerged up until now.

Another source of inconsistency is the definition of the elderly population. Many studies use different age ranges and do not classify outcomes by patient factors like frailty, comorbidity burden, and baseline functional status. This leads to surgical cohorts being composed of fitter patients who have higher functional demands. Since many frail individuals are managed conservatively this introduces

selection bias (18,19). This imbalance limits the validity of certain studies and may overestimate the benefit of surgical treatment modalities in some analyses.

Fracture classifications can also contribute to different results. Although the NEER and AO/OTA classification are used numerous times they remain subjective to examiner interpretation and application. This applies certainly to cases where osteoporotic bone and comminuted fractures are present (7,11,12). Additional morphological features that influence treatment decisions but are not fully integrated into these classification systems are medial calcar integrity, tuberosity displacement, and fracture dislocation patterns. Therefore fractures of the same category may differ substantially in their biomechanical stability and healing potential (1,15).

The influence of rehabilitation protocols on the functional outcome cannot be understated and differences in their application represent another key factor that can explain conflicting evidence. Early mobilization has been shown to improve functional recovery after both conservative treatment and RSA. Unfortunately rehabilitation strategies are inconsistent and poorly standardized across studies (3,19). The adherence to physiotherapy in the elderly population is strongly influenced by cognitive status, social support, and pre-injury mobility. All of these variables are rarely controlled for but can substantially affect functional outcomes (2,4).

Factors related to surgeon expertise are also very influential. Especially in head-preserving procedures such as ORIF and intramedullary nailing, the technical demand is high in cases of osteoporotic bone. Outcomes depend heavily on implant positioning, and restoration of medial column support. Multicentre studies paint a picture of wide variability in complication and revision rates, which suggests that surgeon skill and case volume significantly influence outcomes (8,16,20).

In contrast, RSA appears to produce more comparable results across institutions. This might be explained by its increasing utilization for complex fractures in elderly individuals and lower dependence on bone quality (5,16,21).

Overall, the conflicting evidence regarding optimal treatment of PHFs in elderly patients reflects differences between treatment modalities in combination with methodological limitations the existing literature includes. The data that is available supports an individualized approach for each patient that integrates fracture morphology, biological healing potential, patient-related factors, rehabilitation capacity, and healthcare resources rather than reliance on fracture classification alone (1,3,19).

6.3 Patient-Centred Outcomes and Unaddressed Clinical Priorities

While the bulk of the literature is comparing functional outcomes and complication rates of different treatment strategies for PHFs, there is a lack of attention given to outcomes, which directly matter to elderly patients. In geriatric populations, treatment success is often defined less by restoration of

maximal shoulder function and more by pain control, preservation of independence, and the ability to perform activities of daily living. These priorities are closer to the patients, compared to the physician's perspective and lack reflection in today's literature(3,22).

It is common for studies to rely mostly on clinician-reported functional scores such as the Constant-Murley score or DASH. Although these are valuable tools for standardized comparison, they may insufficiently capture meaningful differences in elderly individuals with low functional demands, where modest functional improvements do not represent meaningful benefits in daily life. Patient-reported outcome measures, quality of life measures, and return to independence assessments remain underrepresented, despite their relevance for this population group (22,23).

Another major gap concerns the insufficient integration of frailty into treatment evaluation. Most often age is used to define the elderly in cohorts, although there are many characteristics which may vary in individuals of same chronological age such as frailty status, biological age, and the physiological reserve of the organism. It has been shown that there is a clear connection between frailty and complication rates, mortality, rehabilitation potential, and long-term dependency following fragility fractures. Such parameters are rarely integrated into treatment algorithms raising the need for better assessments of vulnerable patients beyond chronological age (23).

Another underexplored area is decision-making and patient preferences. Elderly patients may tend to avoid surgery, prioritize rapid pain relief and focus on maintaining autonomy over maximal shoulder strength. It is however shared decision-making models and preference-sensitive outcomes that are rarely addressed in comparative studies on PHF management (24). Even in cases of radiographic and functional satisfaction this disconnect may contribute to treatment dissatisfaction.

Long-term functional trajectories of certain interventions are also frequently overlooked. While short- and mid-term outcomes are commonly reported, data on sustained independence and late functional decline is rare. This is especially relevant in the case of RSA, where long-term functional durability and survivorship in fracture indications are still evolving (5,17,21).

In summary, current PHF literature remains mostly procedure-oriented and not sufficiently aligned with the priorities of geriatric patients. It will be important for future research to place greater emphasis on patient-centred outcomes, frailty-based assessments, shared decision-making, and long-term functional independence. By addressing these gaps and developing treatment strategies according to emerging evidence meaningful improvements and appropriate modalities for each patient may be achieved.

6.4 Clinical Decision-Making in Elderly Patients with Proximal Humerus Fractures

The previously addressed need for taking patient-centred outcomes and frailty into account has highlighted one of the challenges in the management of PHFs in this population. In this vulnerable group, treatment decisions cannot rely on fracture characteristics alone. Outcomes reflect the interaction between fracture morphology, biological aging, functional demand, and the patient's capacity to participate in rehabilitation (1,3,10,23). The need for treatment selection to move beyond fracture-centred algorithms towards an integrated and individualized approach is evident.

One of the key insights that has emerged from the literature is that radiographic severity does not translate directly into functional impairment in older adults. Patients in this age group tolerate residual deformity, malunion, or restricted range of motion surprisingly well although, adequate pain control and independence in the activities of daily living have to be ensured (1,3,22). It is one of the major explanations for conservative treatment producing satisfactory functional outcomes despite imperfect radiographic healing. This is reinforced by anatomical reconstruction not consistently achieving superior results in low-demand patients (3,14,18). In this context, the ultimate treatment success is less defined by anatomical restoration and more by preservation of autonomy and quality of life (22,23).

Integrating Fracture Morphology with Biological and Functional Context

Fracture classification remains a cornerstone of treatment planning. It is important to analyse displacement, comminution, and medial calcar integrity since they influence stability and healing potential (7). In elderly patients, these features must be evaluated in the context of comorbidities such as osteoporosis, impaired vascularity, sarcopenia, and reduced physiological reserve (1,6,8). Regardless of surgical technique, these age-related factors limit the mechanical reliability of fixation and the capacity for postoperative recovery.

Especially head-preserving fixation strategies like ORIF are particularly sensitive to these biological limitations. Predictable failure mechanisms in osteoporotic bone are loss of medial column support, metaphyseal comminution, and poor screw fixation. These explain the high rates of secondary displacement, fixation failure, and revision surgery reported in elderly cohorts (8,16). In such cases, it is possible for technically successful surgeries to fail in delivering meaningful functional benefit. In these cases patients get exposed to operative risk without proportional gain (16,18). Consequently, the decision to pursue fixation should be guided not only by fracture pattern but also by the ability to achieve stable biological healing and effective rehabilitation.

One intervention that addresses many of these limitations by design is RSA. It can provide a mechanically stable construct by reducing the dependence on tuberosity healing and rotator cuff

integrity since it relies mainly on deltoid function. Importantly the ability of this muscle is preserved even in individuals of advanced age (5,16,17). This conceptual advantage is responsible for the more predictable functional outcomes observed in elderly patients with displaced or multi-fragmentary fractures (5,16). It is important to note that this does not imply general superiority of RSA but rather that its biomechanical principles align more closely with the biological realities of aging bone and soft tissue.

Functional Demand, Rehabilitation Capacity, and Real-World Outcomes

Across all treatment modalities it is evident that baseline functional status and rehabilitation capacity are important determinants of the outcomes. Elderly patients with limited mobility, cognitive impairment, or lack of social support may not benefit from successful surgical reconstruction. The reason is that postoperative care cannot be implemented adequately in such cases, which may lead to failure of the theoretical advantages of surgery being translated into meaningful improvements in daily function (2,10,23).

Early mobilization, regardless of invasive or conservative treatment choice, is consistently associated with better recovery of function (3,19). The ability to engage in early and sustained rehabilitation however, fluctuates between elderly individuals and is influenced strongly by frailty, comorbidity burden, and access to physiotherapy (2,4,23). Even though these are real-world outcome influencing factors they are rarely incorporated into formal treatment algorithms.

Conservative Management as a Deliberate Treatment Strategy

Within this framework, conservative treatment should be considered as an active and intentional management strategy rather than a default option for patients who seem unsuitable for surgical intervention. For minimally displaced fractures, stable varus-impacted patterns, or patients with low functional demands, it is the treatment modality which offers a favourable balance between risk and benefit (1,3,14). The benefit of this approach lies in avoiding surgical complications while providing acceptable pain relief and preserving independence that frequently aligns more closely with patient priorities than aggressive anatomical reconstruction (22,23).

Reestablishing conservative management as a valid therapeutic endpoint helps resolve supposed contradictions in the literature which compares operative and non-operative outcomes. Similar functional results across treatment groups often follow appropriate matching of treatment intensity to patient capacity instead of assuming that a treatment works the same for everyone (3,18).

Toward Individualized Decision-Making

In summary, the evidence supports an approach where individualized clinical decision making integrates fracture morphology informing but not dictating treatment selection. Optimal management of PHFs in the elderly requires a balance of mechanical utility, biological healing potential, functional goals, and rehabilitation capacity (1,3,23). This approach acknowledges that different treatment strategies may be equally appropriate for different patients suffering from similar fracture patterns. It also takes into account that overtreatment carries risks which may outweigh potential benefits (2,24). By moving beyond solely fracture-centred algorithms to patient-centred reasoning, it will be possible for clinicians to surpass polarized debates about operative vs non-operative management and instead select interventions that are most feasible, realistic, and aligned with patient priorities. This perspective provides the foundation for the broader clinical implications and future directions discussed in the following section.

6.5 Clinical Implications, Treatment Pathways, and Future Directions

The previous discussion has established that the management of PHFs in elderly patients is not a simple choice between operative and non-operative treatment modalities. Optimal care emerges from an approach that combines fracture characteristics with patient-related factors such as frailty, baseline function, rehabilitation capacity, and the outcome goals of the specific patient. When clinically integrated this perspective goes beyond individual treatment decisions and challenges routine management of PHFs in elderly patients.

Implications for Clinical Decision-Making

The findings of this review support a shift from fracture-centred treatment algorithms toward patient-centred decision-making pathways, relevant for clinicians involved in treatment selection. While fracture classification remains vital for the assessment of mechanical stability and viability of fixation, it should not be considered the determinant of treatment but rather as a starting point. Similar fracture patterns may require fundamentally different management strategies. This depends on biological reserve, functional expectations, and the likelihood of successful rehabilitation.

The inconsistencies emerging from the comparison of conservative treatment, fixation, and arthroplasty may be resolved by this perspective on treatment selection. The ability to produce similar functional outcomes across treatment modalities does not necessarily indicate the interventions effectiveness but rather reflects the right balance between treatment intensity and patient capacity. When treatment selection is guided by patient-centred reasoning, conservative management, fixation, and RSA each hold a legitimate and complementary role in the overall therapeutic spectrum (1,3,16,22).

This approach also stresses the need for appropriate intensity of intervention in surgical decision making. Especially in elderly patients, the potential functional gains of surgery must be weighed against perioperative risk, complication burden, and the demands on the patient to participate adequately in postoperative rehabilitation. When these requirements exceed the patients physiological or social capacity, choosing a more conservative over an invasive treatment approach may reflect better clinical judgement.

Towards Individualized Treatment Pathways

The combination of fracture morphology with patient-specific factors moves clinicians towards developing individualized treatment pathways rather than rigid algorithms. Such pathways would naturally incorporate radiographic assessment together with structured evaluation of frailty, cognitive function, baseline mobility, and access to rehabilitation services. Since these parameters are not routinely quantified they are inconsistently reported in clinical trials, although they repeatedly emerge as decisive determinants of outcome in elderly cohorts (2,23).

Within this framework, conservative treatment can be considered the default strategy for stable or minimally displaced fractures or for patients with low functional demands. It represents a rational choice aligned with patient priorities rather than a compromise. Head-preserving fixation is indicated in selected elderly patients with sufficient bone quality and rehabilitation potential. RSA is emerging as the reliable solution for complex, unstable fractures in patients who strive for predictable pain relief and functional independence (5,16,17). These pathways are dynamic and not rigid since there is a need for individualization depending on the patient's characteristics. The choice of treatment needs to remain adaptable and incorporate patient preferences with the evolving clinical circumstances. Shared decision-making represents a central part of it. Particularly in cases where multiple treatment modalities offer comparable functional outcomes but different risk profiles and recovery trajectories.

Multidisciplinary Care and System-Level Considerations

The successful implementation of patient-centred pathways requires multidisciplinary collaboration. Team meetings, already established in oncology care, will make it possible to address the complexity of frailty, comorbidity, and rehabilitation. This is important for the outcomes in elderly patients with PHFs. Cooperation between internal medicine, orthopaedic surgery, geriatrics, physiotherapy, and social services is essential to ensure that chosen treatment strategies are supported by adequate postoperative care.

Major determinants on outcomes regardless of the chosen treatment modality are early mobilization, continuity of rehabilitation, and appropriate planning of the discharge (3,19). Insufficient rehabilitation infrastructure can undermine the benefits that technically successful surgical interventions may provide. Well-coordinated multidisciplinary care can enhance recovery following both operative and non-operative management. Since orthopaedic surgeons only take care of their patients in the vital beginning of the treatment and rehabilitation process, it is very important to provide a protocol, the rehabilitation tools and services required to pass through the healing period successfully after an intervention.

Directions for Future Research

The findings of this review identify several directions for future research. There is a need for studies that integrate frailty, baseline functional status, and the ability of elderly patients to participate in rehabilitation measures into the study design. Current research often categorizes patients by age and fracture type while underrepresenting individual specific factors that strongly influence outcomes.

Also undervalued are patient-centred outcomes in pain control, independence, and quality of life. These oppose isolated measures of shoulder function, which may not reflect meaningful patient benefit. These outcomes reflect the priorities of elderly patients better and may provide a more meaningful basis for comparing treatment strategies (22,23).

Finally, the goal of future research should shift from identifying a universally superior treatment modality to refining selection criteria that guide individualized treatment. This approach aligns better with clinical reality that optimal management of PHFs in elderly individuals is very context dependent.

Integrative Perspective

Taken together, the clinical conclusions of this review support a paradigm shift in the management of proximal humerus fractures in elderly patients. Moving beyond fracture-centred algorithms toward patient-centred ones with integrated biologically informed decision-making should improve level of care. Clinicians will be empowered to resolve conflicting evidence, avoid overtreatment, and align treatment modalities more closely with patient priorities. This perspective guides the conclusions and recommendations that follow.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

This literature review examined current evidence on the treatment of proximal humerus fractures in elderly patients, with particular focus on functional outcomes, complications, and clinical decision-making. Treatment choice in this population must be guided by a combination of fracture-related and patient-specific factors. Outcomes are strongly influenced by patient specific circumstances.

Conservative treatment remains a reliable option for a large proportion of elderly patients. Acceptable pain relief and preservation of independence can often be achieved despite radiographic imperfections. This shows that anatomical restoration is not always required for a satisfactory clinical outcome in this population. Surgical treatment has an important but selective role. Head-preserving fixation may be appropriate in selected patients with sufficient bone quality and non-displaced fracture patterns, although its reliance can be limited in osteoporosis.

Reverse shoulder arthroplasty offers more predictable results in complex or unstable fractures, which cannot be reconstructed. This is possible due to decreased reliance on tuberosity healing and rotator cuff integrity. Adequate deltoid function remains essential, since it becomes the main driver of shoulder elevation after the procedure. Overall, the available evidence does not support a universal treatment strategy for proximal humerus fractures in elderly patients. Similar functional outcomes between treatment modalities should not be interpreted as proof that all approaches are interchangeable. They indicate that different treatments may be appropriate when matched correctly to the individual patient.

7.2 Recommendations

Treatment decisions should integrate fracture-related and patient-related factors equally. Conservative management should be preferred in cases where the expected benefit of surgery does not clearly outweigh perioperative risk and postoperative burden. Successful non-operative care requires structured physiotherapy alongside early mobilization. Head-preserving fixation should be reserved for selected elderly patients with realistic rehabilitation capacity. In cases with severe osteoporosis, medial column impairment, or fracture patterns with more than two or three fragments, the risk of fixation failure must be considered carefully. Reverse shoulder arthroplasty should be considered in elderly patients with complex or unstable fractures when predictable pain relief and functional independence are realistic goals. Here success depends on correct indication, preserved deltoid function, surgical experience, and access to postoperative rehabilitation. From a future

surgical perspective, further development of prosthetic implants that allow functional integration of rotator cuff elements could represent an important step forward. At present it remains technically challenging to do so after resection of the humeral head and is not part of standard clinical practice. The management of proximal humerus fractures in elderly patients should not end with the chosen implant or treatment modality. Post-interventional care should be regarded as an important part of treatment.

Future research should address the limited comparability of current evidence. Studies should more consistently include frailty, baseline functional status, cognitive function, comorbidity burden, and rehabilitation capacity in their design and analysis. These factors strongly influence outcomes but are still underrepresented in many studies. Greater emphasis should also be placed on patient-centred outcomes. Future investigations must focus less on identifying one universally superior treatment and more on defining which patients benefit most from conservative treatment, fixation, or reverse shoulder arthroplasty. This would support more precise, realistic, and clinically useful decision-making in geriatric fracture care.

8. REFERENCES

1. Launonen AP, Lepola V, Flinkkilä T, Laitinen M, Paavola M, Malmivaara A. Treatment of proximal humerus fractures in the elderly. Acta Orthop. 2015 Jun;86(3):280–5. doi:10.3109/17453674.2014.999299 PubMed PMID: 25574643; PubMed Central PMCID: PMC4443467.

2. Walter N, Szymski D, Kurtz SM, Lowenberg DW, Alt V, Lau E, et al. Proximal humerus fractures – epidemiology, comparison of mortality rates after surgical versus non-surgical treatment, and analysis of risk factors based on Medicare registry data. Bone Jt Res. 2023 Feb 1;12(2):103–12. doi:10.1302/2046-3758.122.BJR-2022-0275.R1

3. Handoll HHG, Brorson S. Interventions for treating proximal humeral fractures in adults. Cochrane Database Syst Rev. 2015 Nov 11;(11):CD000434. doi:10.1002/14651858.CD000434.pub4 PubMed PMID: 26560014.

4. Borgström F, Karlsson L, Ortsäter G, Norton N, Halbout P, Cooper C, et al. Fragility fractures in Europe: burden, management and opportunities. Arch Osteoporos. 2020 Apr 19;15(1):59.

doi:10.1007/s11657-020-0706-y PubMed PMID: 32306163; PubMed Central PMCID: PMC7166207.

5. Lai B, Zhang S, Pan J, Li A, Guo D, Peng Z, et al. Comparison between arthroplasty and non-operative treatment for proximal humeral fractures: a systematic review and meta-analysis. Front Med. 2024 Sep 6;11. doi:10.3389/fmed.2024.1436000

6. Hettrich CM, Boraiah S, Dyke JP, Neviaser A, Helfet DL, Lorich DG. Quantitative Assessment of the Vascularity of the Proximal Part of the Humerus: J Bone Jt Surg-Am Vol. 2010 Apr;92(4):943–8. doi:10.2106/JBJS.H.01144

7. Carofino BC, Leopold SS. Classifications in Brief: The Neer Classification for Proximal Humerus Fractures. Clin Orthop. 2013 Jan;471(1):39–43. doi:10.1007/s11999-012-2454-9 PubMed PMID: 22752734; PubMed Central PMCID: PMC3528923.

8. Haws BE, Samborski SA, Karnyski S, Soles G, Gorczyca JT, Nicandri GT, et al. Risk factors for loss of reduction following locked plate fixation of proximal humerus fractures in older adults. Injury. 2023 Feb;54(2):567–72. doi:10.1016/j.injury.2022.11.043 PubMed PMID: 36424218.

9. Brorson S, Viberg B, Gundtoft P, Jalal B, Ohrt-Nissen S. Epidemiology and trends in management of acute proximal humeral fractures in adults: an observational study of 137,436 cases from the Danish National Patient Register, 1996-2018. Acta Orthop. 2022 Sep 20;93:750–5. doi:10.2340/17453674.2022.4578 PubMed PMID: 36148615; PubMed Central PMCID: PMC9500535.

10. Dent E, Kowal P, Hoogendijk EO. Frailty measurement in research and clinical practice: A review. Eur J Intern Med. 2016 Jun;31:3–10. doi:10.1016/j.ejim.2016.03.007 PubMed PMID: 27039014.

11. 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 Oct;27(10):1756–61. doi:10.1016/j.jse.2018.03.024 PubMed PMID: 29866397.

12. Brorson S, Olsen BS, Frich LH, Jensen SL, Sørensen AK, Krogsgaard M, et al. Surgeons agree more on treatment recommendations than on classification of proximal humeral fractures. BMC

Musculoskelet Disord. 2012 Jun 27;13:114. doi:10.1186/1471-2474-13-114 PubMed PMID: 22738149; PubMed Central PMCID: PMC3495208.

13. Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. Fracture and Dislocation Classification Compendium-2018. J Orthop Trauma. 2018 Jan;32 Suppl 1:S1–170. doi:10.1097/BOT.0000000000001063 PubMed PMID: 29256945.

14. 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 Jul;20(5):747–55. doi:10.1016/j.jse.2010.12.018 PubMed PMID: 21435907.

15. Baker HP, Gutbrod J, Strelzow JA, Maassen NH, Shi L. Management of Proximal Humerus Fractures in Adults-A Scoping Review. J Clin Med. 2022 Oct 18;11(20):6140. doi:10.3390/jcm11206140 PubMed PMID: 36294459; PubMed Central PMCID: PMC9604576.

16. Fraser AN, Bjørdal J, Wagle TM, Karlberg AC, Lien OA, Eilertsen L, 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. JBJS. 2020 Mar 18;102(6):477. doi:10.2106/JBJS.19.01071

17. Gallinet D, Ohl X, Decroocq L, Dib C, Valenti P, Boileau P, et al. Is reverse total shoulder arthroplasty more effective than hemiarthroplasty for treating displaced proximal humerus fractures in older adults? A systematic review and meta-analysis. Orthop Traumatol Surg Res OTSR. 2018 Oct;104(6):759–66. doi:10.1016/j.otsr.2018.04.025 PubMed PMID: 29969722.

18. Rangan A, Handoll H, Brealey S, Jefferson L, Keding A, Martin BC, et al. Surgical vs nonsurgical treatment of adults with displaced fractures of the proximal humerus: the PROFHER randomized clinical trial. JAMA. 2015 Mar 10;313(10):1037–47. doi:10.1001/jama.2015.1629 PubMed PMID: 25756440.

19. Resch H. Proximal humeral fractures: current controversies. J Shoulder Elbow Surg. 2011 Jul;20(5):827–32. doi:10.1016/j.jse.2011.01.009 PubMed PMID: 21454104.

20. Spross C, Kaestle N, Benninger E, Fornaro J, Erhardt J, Zdravkovic V, et al. Deltoid Tuberosity Index: A Simple Radiographic Tool to Assess Local Bone Quality in Proximal Humerus Fractures. Clin Orthop. 2015 Sep;473(9):3038–45. doi:10.1007/s11999-015-4322-x PubMed PMID: 25910780; PubMed Central PMCID: PMC4523505.

21. Ferrel JR, Trinh TQ, Fischer RA. Reverse total shoulder arthroplasty versus hemiarthroplasty for proximal humeral fractures: a systematic review. J Orthop Trauma. 2015 Jan;29(1):60–8. doi:10.1097/BOT.0000000000000224 PubMed PMID: 25186842.

22. Bell JE, Leung BC, Spratt KF, Koval KJ, Weinstein JD, Goodman DC, et al. Trends and variation in incidence, surgical treatment, and repeat surgery of proximal humeral fractures in the elderly. J Bone Joint Surg Am. 2011 Jan 19;93(2):121–31. doi:10.2106/JBJS.I.01505 PubMed PMID: 21248210; PubMed Central PMCID: PMC3016042.

23. Clement ND, Duckworth AD, McQueen MM, Court-Brown CM. The outcome of proximal humeral fractures in the elderly: predictors of mortality and function. Bone Jt J. 2014 Jul;96-B(7):970–7. doi:10.1302/0301-620X.96B7.32894 PubMed PMID: 24986953.

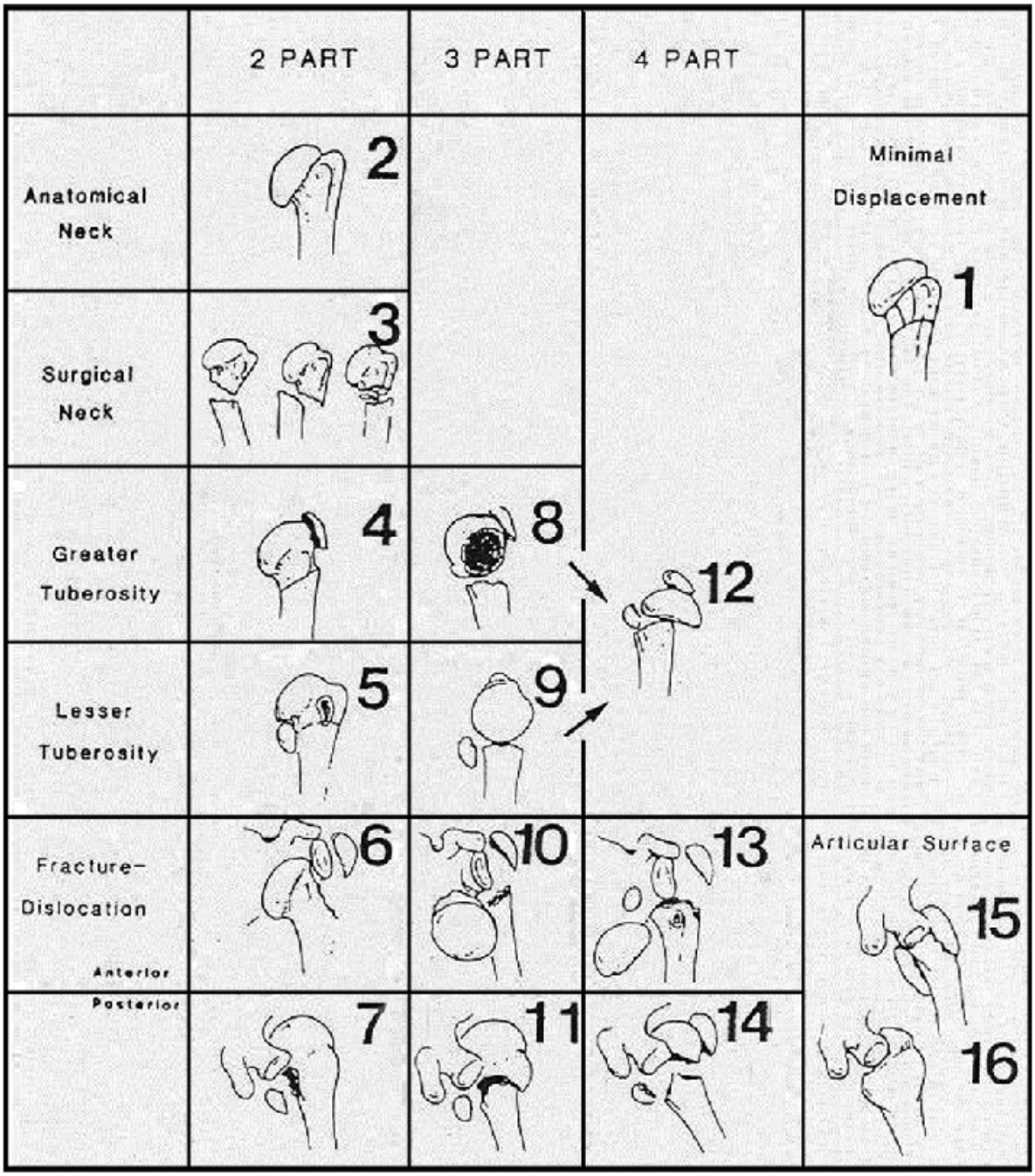
24. Neuhaus V, Bot AGJ, Swellengrebel CHJ, Jain NB, Warner JJP, Ring DC. Treatment choice affects inpatient adverse events and mortality in older aged inpatients with an isolated fracture of the proximal humerus. J Shoulder Elbow Surg. 2014 Jun;23(6):800–6. doi:10.1016/j.jse.2013.09.006 PubMed PMID: 24135421; PubMed Central PMCID: PMC4239693.

9. ANNEXES

Annex A. Core Evidence Table

Study	Design	Population (Age)	Comparison	Key Outcomes
Rangan et al. 2015 (PROFHER)	RCT	Adults with PHF (majority elderly)	Surgery vs non-operative	QoL similar in both patient groups
Launonen et al. 2015	Systematic review	Elderly patients with PHF	Conservative vs surgical	Outcome of conservative approach similar to surgery
Fraser et al. 2020	RCT	Elderly patients with displaced PHF	RSA vs ORIF	RSA produces superior outcomes in complicated cases
Gallinet et al. 2018	Meta-analysis	Elderly with complex PHF	RSA vs hemiarthroplasty	RSA can produce better ROM and functional ability
Lai et al. 2024	Meta-analysis	Elderly PHF patients	Arthroplasty vs non-operative	RSA can improve outcomes in complicated cases
Handoll et al. (Cochrane)	Systematic review	Adults (incl. elderly)	Various interventions	Surgical outcomes not clearly superior to conservative approach
Brorson et al. 2022	Registry study	National cohort (elderly majority)	Treatment trends	RSA numbers are growing compared to fixation - Trend
Sumrein et al. 2018	Cohort study	Elderly PHF patients	Operative vs non-operative	Surgical groups have higher complication rates compared to conservative ones

Annex B. Neer Classification of Proximal Humerus Fractures Figure



Source: adapted from Rangan A, Handoll H, Brealey S, et al. Defining the fracture population in the PROFHER trial and the Neer classification of proximal humeral fractures. Bone Joint J. 2016.

Annex C. Vilnius University AI - Declaration

In the preparation of this Integrated Study Master's Thesis in Medicine, AI-based language tools (e.g.ChatGPT, OpenAI; Claude, Anthropic) were used in a limited and supportive manner. Their use was strictly restricted to linguistic editing, improvement of academic phrasing, grammar correction, formatting, and translation of the Lithuanian abstract. No AI-generated text was adopted without critical review and revision by the author.

AI tools were not used to generate scientific content, select or interpret literature, draw methodological conclusions, or formulate clinical recommendations. All scientific content, critical analysis, literature search, study selection, synthesis of evidence, and final conclusions were independently developed by the author.

Reference management and citation formatting were performed using Zotero (Corporation for Digital Scholarship, USA).

The author bears sole responsibility for the content, quality, and authenticity of this thesis.

In accordance with the Guidelines on Artificial Intelligence Usage at Vilnius University (Senate Resolution No. SPN-54, 18 June 2024), the use of these tools is hereby disclosed.

References:

Anthropic. (2026). Claude [Large Language Model]. https://claude.ai

OpenAI. (2026). ChatGPT [Large Language Model]. https://chat.openai.com

Annex D Vilnius University Declaration of Warranty

Vilniaus universiteto studijuojančiojo, teikiančio baigiamąjį darbą, GARANTIJA

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Padalinys: Faculty of Medicine
Studijų programa: Medicine
Darbo pavadinimas: Treatment of proximal humerus fractures in the elderly
Darbo tipas: Narrative literature review

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Study programme: Medicine (Integrated studies)
Thesis topic: Treatment of proximal humerus fractures in the elderly
Thesis type: Narrative literature review

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