1 Displaced Proximal Humeral Fractures in the Elderly: Conservative Treatment Versus Open Reduction and Internal Fixation Versus Hemiarthroplasty Versus Reverse Shoulder Arthroplasty

Sarah Mills and Juan C. Rubio-Suárez

1.1 Introduction

Proximal humeral fractures (PHF) in the elderly are nowadays among the most frequent fractures. Their incidence is increasing fast associated with population aging. These fractures are related to osteoporosis or poor bone quality [1].

These fractures impair quality of life as they affect patients' independence, just after the event and even in the long term, when some patients still report some degree of disability [2].

Treatment for these fractures has been a matter of discussion in the last few years as it supposes a challenge. That is why many studies evaluating different techniques have been published. Surgical treatment is complex, but it was the preferred option some years ago. Due to the moderate-high rate of complications and unpredictable outcomes, numerous studies tried to evaluate clinical results and cost-effectiveness of the different therapeutic options available.

Although surgery has not proven superior clinical results (and it is, obviously, more expensive) when compared to conservative treatment in PHF in the elderly, in this chapter we will discuss the different surgical techniques that can be chosen.

1.2 Epidemiology, Pathoanatomy, and Fracture Classification

1.2.1 Epidemiology

PHF constitute 5–6% of all fractures in adults and are more frequent in women (2:1) [1]. In the last few years, their incidence increased simultaneously with osteoporosis' prevalence due to population aging. They are usually due to ground-level falls on an outstretched arm. Very often, these fractures are the first evidence of bone fragility. When present, secondary prevention of future fractures is mandatory. Risk factors for suffering a PHF, in addition to osteoporosis, are diabetes, epilepsy, or female gender.

The most common associated lesion is axillary nerve injury. Vascular injury is uncommon (<5%) and occurs more frequently in the elderly, associated with surgical neck fractures or subcoracoid dislocation of the humeral head. PHF

S. Mills (✉) · J. C. Rubio-Suárez
Department of Orthopedic Surgery, La Paz University Hospital, Madrid, Spain
e-mail: sarah.mills@salud.madrid.org

E. C. Rodríguez-Merchán, A. Moreno-Garcìa (eds.), *Controversies in Orthopedic Surgery of The Upper Limb*, https://doi.org/10.1007/978-3-031-04907-1_1

can present with concomitant chest wall injuries or other fractures due to the fall.

1.2.2 Pathoanatomy

Depending on fracture pattern and location, humeral head vascularization can be compromised. The principal blood supply depends on the posterior humeral circumflex artery. Vascularity of the humeral head is more likely to be intact if more than 8 mm of calcar is attached to the articular fragment.

Hertel described some criteria to predict ischemia in the humeral head (Table 1.1) [3]. It is very important to highlight that the presence of those factors does not predict avascular necrosis of the humeral head.

PHF can be displaced or not; when displaced, deforming forces are determined by:

- Pectoralis major that displaces shaft anteriorly and medially.
- Supraspinatus, infraspinatus, and teres minor that externally rotates greater tuberosity.
- Subscapularis internally rotates articular segment or lesser tuberosity.

1.2.3 Classification

AO/OTA classification can be used, but Neer classification is the most extended one. According to the later, fractures can occur at the surgical neck, anatomic neck, greater tuberosity (GT), and lesser tuberosity (LT), determining four principal fragments: GT, LT, articular fragment, and shaft. Neer classification is based on the anatomic relationship of the four parts [4].

Table 1.1 Hertel criteria for prediction of humeral head ischemia [3]

<8 mm of calcar attached to articular segment
Disrupted medial hinge
Increased fracture complexity
Displacement >10 mm
Angulation >45°

"A part" is considered only if one of the following:

- It is displaced more than 1 cm.
- It is angulated more than 45°.

Two parts surgical neck fractures are the most common. More complex fracture patterns are seen with increasing age.

1.3 Diagnosis: Clinical Presentation and Imaging

1.3.1 Clinical Presentation

Like other fractures, PHF I presents with pain, swelling, and decreased range of motion. On physical exam, we will typically find an extensive hematoma over the chest, arm, and forearm, known as Hennequin hematoma.

A comprehensive neurovascular exam must be performed, and axillary nerve examination should not be overlooked, by determining deltoid muscle function and lateral shoulder sensation. Arterial injuries are often masked by extensive collateral circulation that can preserve distal pulses, so a high grade of suspicion is needed.

1.3.2 Imaging

When a PHF is suspected, the following radiographs should be ordered:

- True AP radiograph – Grashey projection
- Scapular Y projection
- Axillary projection

CT scan is helpful in preoperative planning and when determining humeral head or GT tuberosity position when they are uncertain. It also serves to determine the presence of head-split fractures. MRI is helpful when a rotator cuff injury is suspected, but its use is not standardized.

1.4 Treatment

Treatment options for PHF in the elderly have been under debate in the last few years. Nonsurgical treatment was the preferred option before the arrival of new implants and techniques. Many recent studies investigate if this interest in surgical intervention is supported by evidence or it is only a fad due to the appearance of new techniques and implants. Shoulder arthroplasties as a therapeutic option for PHF appeared in the twenty-first century. After that, few studies investigated its effectiveness and outcomes.

Studies analyzing different techniques for PHF treatment show that there is no benefit of surgical intervention in displaced fractures in comparison to nonoperative treatment. In addition, all surgical techniques have more complications and are more expensive than conservative management [5–7]. Summarizing, published results do not support the increasing trend for surgery in elderly patients with PHF [8, 9].

1.4.1 Nonoperative Treatment

Nonoperative treatment consists of sling immobilization for 4–6 weeks, followed by progressive rehabilitation. Immediate physical therapy offers a faster recovery. The vast majority of PHF can be treated conservatively (Fig. 1.1).

- Minimally displaced surgical and anatomic neck fractures.
- GT fracture with <5 mm displacement.
- Patients who are unsuitable for surgery.
- In the last years, age was included as an indication for conservative treatment even in case of displaced and complex fractures.

1.4.2 Operative Treatment

Surgical treatment for displaced PHF in the elderly is a subject under debate. Different techniques and implants are available: angular-stable plates, nails, or arthroplasties. Their indications and characteristics are described in the following sections. However, to date, little evidence supports one technique over another. All of these techniques had been evaluated in randomized control trials (RCT) versus the nonoperative treatment, and no relevant differences were found in terms of clinical or functional outcomes [5, 8, 10].

1.4.2.1 Open Reduction and Internal Fixation (ORIF)

Angular stable plate with locking screws is a widely used treatment for PHF, and before the development of nails or arthroplasties, it was the gold-standard technique. Later studies showed a 30% rate of reinterventions due to complications [10].

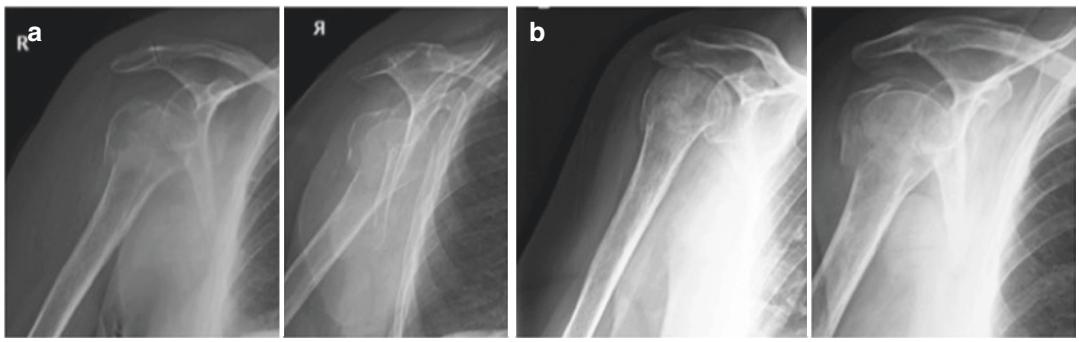

Fig. 1.1 84-year-old female with displaced proximal humeral fracture: (**a**) First X-ray evaluation after the fall. (**b**) Radiographical outcome: fracture healed after conservative treatment. Eight weeks follow-up

This technique is indicated if:

- GT is displaced >5 mm.
- Displaced 2-part fractures.
- 3- and 4-part fractures in younger patients.
- Head-splitting fractures in younger patients.

Better outcomes depend on some mechanical details, like the presence of medial support, which is necessary for fractures with posteromedial comminution, and calcar screw placement, which is critical to decreasing the risk of varus collapse of the articular fragment.

Technique

ORIF can be performed either by deltopectoral or lateral approach; this one has an increased risk for axillary nerve injury (Figs. 1.2 and 1.3).

- Nonabsorbable sutures are needed to isolate tuberosities and use them to reduce the fragments.
- The most common hardware used is a locking plate to fix the fracture once fragments are reduced.
  - The most frequent complication of this technique is screw cutout (14%). In osteoporotic bone, varus collapse is often seen, and it can be prevented with a screw placed inferomedial at calcar.
  - The plate must be placed lateral to the bicipital groove to avoid vascular injury (ascending branch of the anterior humeral circumflex artery).

Minimally invasive approaches were described to avoid soft tissue damage and healing problems due to periosteal stripping. These techniques present with two main disadvantages: a higher risk of axillary nerve injury and a more difficult fracture reduction maneuver [11].

Recent studies evaluate results for cemented augmentation locking screws. Results are promising, and hardware-related complications can be

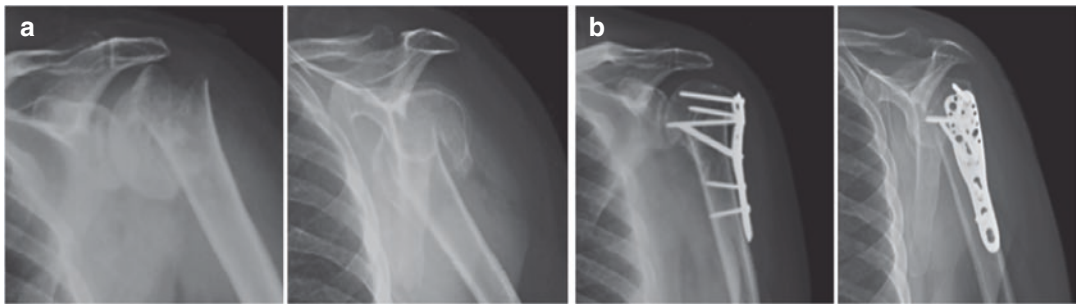

Fig. 1.2 (**a**) Displaced proximal humeral fracture in a 73-year-old female. (**b**) Radiographical outcome after treatment with open reduction and internal fixation with locking plate

Fig. 1.3 Patient from Fig. 1.2, clinical outcome with full active range of motion after 15 months of follow-up and rehabilitation program

reduced drastically if this technique is employed. Neither clinical outcomes nor the need for revision surgery is modified; only the rate of implant-related failure and the global rate of complications were diminished. This technique also appears to help reduce the rate of avascular necrosis [12]. However, further studies are needed to achieve stronger evidence.

1.4.2.2 Intramedullary Nailing (IMN)

Intramedullary nailing can be used in surgical neck fractures or 3-part GT fractures in younger patients or patterns combined with shaft fractures. IMN can be performed in shorter surgical time, and there are no differences in complication rates when compared to ORIF with plates [13]. It offers less stability in torsion compared with plates, but no differences were found in fracture healing, nor ROM recovery compared to plating [14].

- The superior deltoid-splitting approach is used to insert the nail.
- The most common complications are rod migration and shoulder pain secondary to rotator cuff injury.
- Care should be taken when placing locking screws, as radial and musculocutaneous nerves can be injured.

1.4.2.3 Arthroplasty

Complex 3-part and 4-part fractures in the elderly are frequently impossible to fix due to comminution, poor bone quality, and high risk of mechanical and biological complications. For these cases, articular replacement seems to be a good solution.

Hemiarthroplasty (HA) was first employed in treating these fractures, but this technique is highly demandant, and good results are influenced by tuberosity healing, accurate size selection of the stem, and its final position. A functional rotator cuff is also needed for the proper functioning of a HA.

As results with plates and HA were inconsistent, reverse shoulder arthroplasty (RSA) emerged as an option to treat these complex fractures. Outcomes for RSA are less dependent on tuberosity healing and rotator cuff function/integrity compared to HA.

Age is a demonstrated predictor of outcome, so when choosing arthroplasty for treating a PHF, RSA is advisable over 70-year-old patients [15].

Hemiarthroplasty (HA)

The performance of a hemiarthroplasty is indicated in 4-part fractures, 3-part fractures with osteopenia, head-splitting, and severe articular fractures. HA is used in younger patients (40–65 y.o.) with complex fracture-dislocations or head-splitting component that may fail fixation.

- Recommended use of convertible stems in case reverse shoulder arthroplasty is needed.
- The deltopectoral approach is the most extended.
- Tuberosities must be sutured and passed through the prostheses' holes to improve stability.
- The height of the prosthesis is determined with the superior border of the pectoralis major tendon.
- Head to tuberosity distance (HTD) must be maintained (GT 8 mm below the articular surface) to respect external rotation kinematics.

Individualized assessment and preoperative planning are essential to succeed. Outcomes are better for younger patients and fractures treated acutely. It is very important to accurately choose the size of the prosthesis and to ensure the reattachment of the tuberosities to the stem/shaft [16].

Risk factors for a poor postoperative result are rotator cuff injuries, tuberosities malunion or nonunion, and age. Outcomes for this technique are not always satisfactory, and complications like significant postoperative pain, tuberosities' detachment, component malposition, instability, or rotator cuff tears are not uncommon (overall rate 35%) [16]. Healing of the tuberosities determines the success of this technique, and, when healing properly, better score punctuations and better ROM (in forward elevation and external rotation) are achieved [17]. Prosthesis has a mean survival time of 6.3 years [15].

When comparing HA with plating, better functional outcomes were registered with the use of

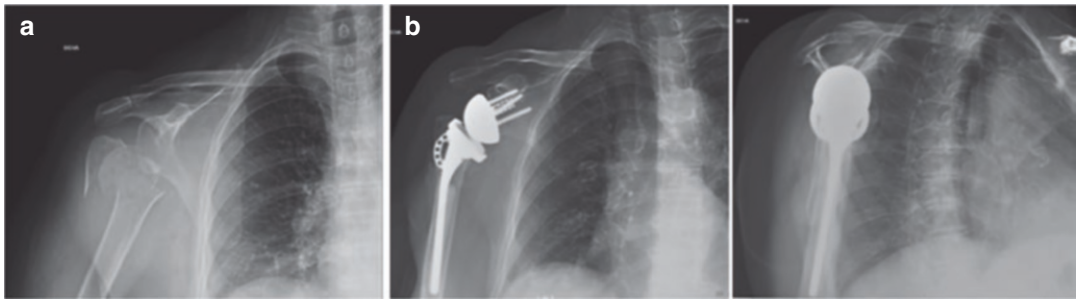

Fig. 1.4 (**a**) Female, 81-year-old, displaced proximal humeral 4-part fracture. (**b**) She was treated with reverse total shoulder arthroplasty

plates; however, HA had a lower rate of revision surgery and fewer surgical complications [18].

Due to poor results with HA, surgeons started using RSA to treat these complex fractures, which yielded better functional and patient-reported satisfaction scores when compared to HA. ROM in flexion after rehabilitation program was also better in RSA group, without differences for ROM in rotation. Both techniques have similar complication rates [17].

When analyzing the clinical and functional outcomes and comparing them with the nonoperative treatment, no differences were found, although the number of studies is scarce and evidence is low [5].

Reverse Shoulder Arthroplasty (RSA)

Reverse shoulder arthroplasty relies on deltoid muscle function instead of rotator cuff integrity or tuberosities position and healing. It is useful in low-demand elderly individuals with non-reconstructible tuberosities and poor bone stock or fracture-dislocations. Despite RSA can compensate for nonfunctioning rotator cuff, repairing tuberosities is recommended for an improved ROM.

Better outcomes if:

- Good glenoid bone stock is ensured.
- Restoration of humeral height and version. Poor results when retroversion of the humeral component is >40°.

The deltopectoral approach or the anterolateral deltoid splitting approach is the most frequently used.

Outcomes

The most reasonable options for treating PHF nowadays are RSA or nonoperative treatment. A randomized control trial (RCT) revealed that RSA has minimal benefits over conservative treatment in terms of pain perception [19]. RSA has been compared to ORIF too. Patient satisfaction and clinical outcomes resulted higher in the RSA group after two years of follow-up. Reverse total shoulder arthroplasty showed better ROM (except for internal rotation) and strength [10]. The complication rate for RSA is 8–11% [10, 17], with a 6% needing another surgery [10].

When compared to HA, RSA showed better results regarding patient satisfaction, outcome scores, and a higher range of motion (forward elevation). Healing of the tuberosities in RSA is irrelevant for score punctuation, and it is only relevant for recovery of external rotation (Fig. 1.4) [17].

1.5 Postoperative Rehabilitation

Rehabilitation is a very important part of the treatment of these fractures, and the best results are achieved when well established physical therapy protocols are followed. Stiffness is directly related to a long immobilization period.

- **Early passive range of motion.** As soon as the patient tolerates it
- **Active range of motion and progressive resistance**
- **Advance stretching and strengthening**

In minimally displaced fractures, an immediate rehabilitation program is an option, but. in displaced fractures, as is often the case in the elderly, immobilization for a small period is needed until the pain is relieved. It has been shown that stiffness related to immobilization, when it extends over 3 weeks, remains even after 2 years in the follow-up. The relevance of early rehabilitation has been widely proved, and it gains even more importance in the elderly. Adequate rehabilitation improves function and quality of life, and that is especially important in people that have poor neuromuscular status with bone fragility. Everything that compromises their independence can dramatically worsen their general health [2].

1.6 Outcomes Evaluation

Outcomes are generally evaluated with health questionnaires and functional scales, specifically conceived for upper limb affections.

1.6.1 Health Questionnaires

Scales as EQ-5D or 15D are the most frequently applied.

1.6.2 Functional Scales

Some examples are DASH score, Constant score, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES), or Oxford shoulder score (OSS).

1.7 Overall Complications

- **Screw cutout:** The most frequent complication when locking plate fixation is used.
- **Avascular necrosis:** Better tolerated than in lower extremities. This complication is not related to risk factors for humeral head ischemia, nor type of fixation.
- **Nerve injury:**
  - **Axillary nerve:** Most common nerve injury (up to 60%)
    Deltoid-splitting approach
  - **Suprascapular nerve**
  - **Musculocutaneous nerve**
- **Malunion.**
- **Nonunion:** Risk increased with age and smoking. Nonunion of the tuberosities results in misfunctioning rotator cuff.
- **Rotator cuff injuries and dysfunction. Long head of biceps (LHB) tendon injuries.**
- **Missed posterior dislocation.** Maintain high suspicion in lesser tuberosity fractures.
- **Adhesive capsulitis.**
- **Posttraumatic arthritis.**
- **Infection.**

1.8 Mortality

Increased mortality has been related to different types of fractures: hip or periprosthetic fractures, vertebral fractures, distal femoral fracture, etc. [20]. All of them are often related somehow to a variable degree of frailness or comorbidities. Proximal humeral fractures are frequently associated with factors related to poor general health and morbidity, and also an increased mortality rate during the first year after the fracture has been described, especially in males and in those fractures treated surgically [21].

Registered one-year mortality rate after a PHF in people aged over 80 years old is 19.8%; the relative risk of dying after suffering a proximal humeral fracture was higher during the first 30 days after the incident (5 times higher) compared to the general population. Independent factors related to death were increased age, male sex (7 times higher), low bone mineral density, or concomitant fractures [21].

It is proposed that multidisciplinary teams (like in hip fractures in the elderly) may be advisable to treat these frail patients in order to reduce morbidity and mortality.

1.9 Conclusions

- Proximal humeral fractures represent 5% of all adult fractures and the second in frequency at the upper limb. They are related to osteoporosis, and almost 75% appear in people over 60 years of age. Its overall incidence is 40 in 100,000 patients, and, because of population aging and the increase of life expectancy, its incidence is predicted to triple in the next 10 years [19].
- These fractures impair quality of life and decrease patients' independence, so they have become a public health concern. Many studies have tried to establish protocols to improve their management.
- All therapeutic options available achieve pain relief (except in case of complications), but results are less predictable in terms of functional outcomes and range of motion. New implants and techniques were approved trying to fill this gap. Nevertheless, the gold-standard technique for treating PHF is still under debate. The implementation of different techniques and implants made necessary the development of studies, trying to determine whether to choose one over another, but the evidence is still scarce, and high-quality studies are still needed to establish more solid conclusions.
- Based on the evidence available, the trend is nonoperative treatment for PHF in the elderly, supported by moderate to high evidence. Current evidence shows that surgical treatment of displaced PHF in the elderly has no benefit compared to nonsurgical treatment. On these bases, surgical treatment must be very restrictive, and every case has to be individualized [9].
- In those cases in which surgery is needed, RSA seems to be the most adequate option. Elderly patients present with poor bone quality: it produces complex fracture patterns and also increases the risk of complications with ORIF. RSA showed better outcomes over the other surgical techniques (plates, nails, or hemiarthroplasty) in the elderly. All of them relieve pain, but RSA offers better results in terms of ROM and strength.
- RSA could be recommended in those cases of complex fractures with head split, head dislocation, or associated complex rotator cuff tears.
- The question now is "What do I choose? RSA or nonoperative treatment?" It is very important to individualize and study each patient's comorbidities and functional status. If surgery is chosen, we should remember that RSA offers a minimal advantage over conservative treatment and only in pain perception [19].

References

1. Palvanen M, Kannus P, Niemi S, Parkkari J. Update in the epidemiology of proximal humeral fractures. Clin Orthop Relat Res. 2006;442:87–92.
2. Hodgson SA, Mawson SJ, Saxton JM, Stanley D. Rehabilitation of two-part fractures of the neck of the humerus (two-year follow-up). J Shoulder Elb Surg. 2007;16:143–5.
3. Hertel R, Hempfing A, Stiehler M, Leunig M. Predictors of humeral head ischemia after intracapsular fracture of the proximal humerus. J Shoulder Elb Surg. 2004;13:427–33.
4. Neer CS. Four-segment classification of proximal humeral fractures: purpose and reliable use. J Shoulder Elb Surg. 2002;1:389–400.
5. Navarro CM, Brolund A, Ekholm C, et al. Treatment of humerus fractures in the elderly: a systematic review covering effectiveness, safety, economic aspects and current practice. PLoS One. 2018;13(12):e0207815.
6. Beks RB, Ochen Y, Frima H, et al. Operative versus nonoperative treatment of proximal humeral fractures: a systematic review, meta-analysis, and comparison of observational studies and randomized controlled trials. J Shoulder Elb Surg. 2018;27:1526–34.
7. Launonen AP, Lepola V, Flinkkilä T, Laitinen M, Paavola M, Malmivaara A. Treatment of proximal humerus fractures in the elderly. Acta Orthop. 2015;86:280–5.
8. Rangan A, Handoll H, Brealey S, et al. Surgical vs nonsurgical treatment of adults with displaced fractures of the proximal humerus the PROFHER randomized clinical trial. JAMA. 2015;313:1037–47.
9. Handoll H, Brealey S, Rangan A, et al. The ProFHer (PROximal fracture of the humerus: evaluation by randomisation) trial—a pragmatic multicentre randomized controlled trial evaluating the clinical effectiveness and cost-effectiveness of surgical compared with non-surgical treatment for proxi. Health Technol Assess (Rockv). 2015; https://doi.org/10.3310/hta19240.
10. Fraser AN, Bjørdal J, Wagle TM, et al. Reverse shoulder arthroplasty is superior to plate fixation at 2

years for displaced proximal humeral fractures in the elderly: a multicenter randomized controlled trial. J Bone Joint Surg Am. 2020;102:477–85.
11. Barco R, Barrientos I, Encinas C, Antuña SA. Minimally invasive poly-axial screw plating for three-part fractures of the proximal humerus. Injury. 2012;43(Suppl 2):7–11.
12. Foruria AM, Martinez-Catalan N, Valencia M, Morcillo D, Calvo E. Proximal humeral fracture locking plate fixation with anatomic reduction, and a short-and-cemented-screws configuration, dramatically reduces the implant related failure rate in elderly patients. JSES Int. 2021; https://doi.org/10.1016/j.jseint.2021.06.004.
13. Lekic N, Montero NM, Takemoto RC, Davidovitch RI, Egol KA. Treatment of two-part proximal humerus fractures: intramedullary nail compared to locked plating. HSS J. 2012;8:86–91.
14. Lee W, Park JY, Chun YM. Operative treatment of 2-part surgical neck fracture of the humerus: intramedullary nail versus locking compression plate with technical consideration. J Orthop Trauma. 2017;31:e270–4.
15. Robinson CM, Page RS, Hill RMF, Sanders DL, Court-Brown CM, Wakefield AE. Primary hemiarthroplasty for treatment of proximal humeral fractures. J Bone Joint Surg Am. 2003;85:1215–23.
16. Hartsock LA, Estes WJ, Murray CA, Friedman RJ. Shoulder hemiarthroplasty for proximal humeral fractures. Orthop Clin North Am. 1998;29:467–75.
17. Cuff DJ, Pupello DR. Comparison of hemiarthroplasty and reverse shoulder arthroplasty for the treatment of proximal humeral fractures in elderly patients. J Bone Joint Surg Am. 2013;95:2050–5.
18. Dai J, Chai Y, Wang C, Wen G. Meta-analysis comparing locking plate fixation with hemiarthroplasty for complex proximal humeral fractures. Eur J Orthop Surg Traumatol. 2014;24:305–13.
19. Lopiz Y, Alcobía-Díaz B, Galán-Olleros M, García-Fernández C, Picado AL, Marco F. Reverse shoulder arthroplasty versus nonoperative treatment for 3- or 4-part proximal humeral fractures in elderly patients: a prospective randomized controlled trial. J Shoulder Elb Surg. 2019;28:2259–71.
20. Merino-Rueda LR, Rubio-Sáez I, Mills S, Rubio-Suárez JC. Mortality of distal femur fractures in the elderly. Injury. 2021;52(Suppl 4):S71–5.
21. Bergdahl C, Wennergren D, Ekelund J, Möller M. Mortality after a proximal humeral fracture. Bone Joint J. 2020;102-B:1484–90.