USE OF UNCEMENTED HUMERAL STEM IN REVERSE ARTHROPLASTIES FOR FRACTURES OF THE PROXIMAL END OF THE HUMERUS: RADIOGRAPHIC AND FUNCTIONAL EVALUATION

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ABSTRACT

Reverse shoulder arthroplasty (RSA) utilizing uncemented humeral stems has emerged as a preferred approach for treating proximal humeral fractures (PHFs) at our institution. This retrospective study evaluated the functional and radiographic outcomes of 23 patients who underwent RSA with uncemented humeral stems for acute PHFs. Surgery was performed between January 2020 and February 2022 by two surgeons. Functional outcomes were assessed using the Constant Shoulder Score (CSS), while radiographic evaluation included assessment of tuberosity healing, notching, and humeral stem migration. Results showed satisfactory outcomes, with no instances of early loosening

observed in the humeral stems. Patients demonstrated high levels of satisfaction and functional improvement postoperatively. The employment of uncemented humeral stems allows for precise insertion, contributing to favorable outcomes in acute PHFs treated with RSA.

Keywords: Proximal humeral fractures; Reverse shoulder arthroplasty (RSA); Uncemented humeral stems; Functional outcomes; Surgical intervention

1. INTRODUCTION

The current projection indicates a threefold increase in the prevalence of proximal humeral fractures by 2030[1,2]. Factors such as patient age, osteopenia, and osteoporosis will undoubtedly influence the successful management of these fractures[2]. Proximal humeral fractures (PHFs) in the elderly can often be managed conservatively if good alignment is maintained[3,4]. However, when surgery is necessary, options range from open reduction with internal fixation to arthroplasty, depending on factors like fracture pattern, bone quality, and surgeon preference. A study conducted in 2015 across 32 British hospitals (PROFHER - Proximal Fracture of the Humerus: Evaluation by Randomisation)[5] influenced surgeons to opt for conservative treatment in severely displaced PHFs, but this approach yielded poor outcomes and severe sequelae in many cases[6].

The limited success of conservative treatment for displaced fractures, complications associated with osteosynthesis of PHFs, and the variable outcomes of hemiarthroplasty have prompted many shoulder surgeons to endorse reverse shoulder arthroplasty (RSA) as the primary option for complex PHFs in the elderly[7,8]. The use of RSA for such fractures in elderly patients is increasingly favored[9,10,11].

In RSA for PHFs, the use of cementation for the humeral stem may vary. An uncemented humeral prosthesis offers several advantages over a cemented one, including shorter operating time, avoidance of cement-related morbidity, and intraoperative alignment adjustments[12].

RSA employs a semi-constrained prosthesis, but increased stress on the humeral component and comminuted fractures may compromise the fixation of an uncemented humeral stem, leading to early mechanical loosening[13], related to the stem design[14,15]. Advocates for cemented humeral stems argue that metaphyseal comminution and varying degrees of bone loss in PHFs justify their use. Conversely, proponents of cementless fixation cite faster technique, lower costs, reduced complication rates (such as

thromboembolism, infection, and neurological damage), and easier revision when necessary[16,17].

At the institution where this study was conducted, RSA procedures for PHFs, when indicated, utilized uncemented humeral stems, which became the preferred approach. Consequently, this study aimed to showcase functional and radiographic outcomes, emphasizing a surgical technique ensuring safe determination of the ideal humeral stem position before definitive placement.

2. METHODOLOGY

Between January 2020 and February 2022, 32 patients underwent RSA using uncemented humeral stems for the treatment of PHFs by two surgeons from the same institution. Among the 32 patients, 23 were operated on in the acute phase, while 9 had sequelae of fractures, and these nine patients were excluded from the study.

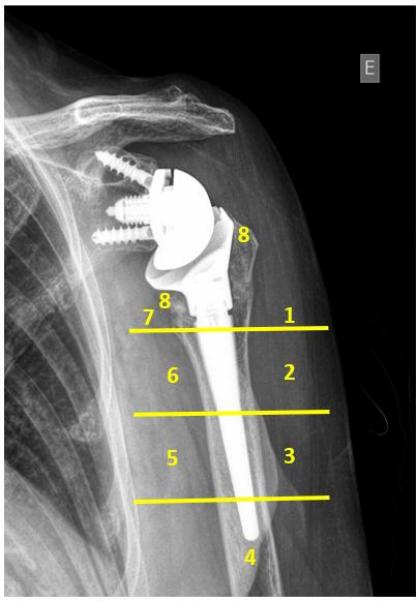
Our inclusion criteria comprised all RSAs for acute PHFs performed with uncemented humeral stems. Exclusion criteria included RSAs performed for sequelae of PHFs. This was a retrospective study approved by the ethics committee under protocol number CAAE 59899622.70000.0035. All patients who underwent reverse shoulder arthroplasty for acute PHFs during the period were screened for inclusion.

Preoperative radiographs and computed tomography scans were reviewed to classify fracture patterns according to the Neer classification. Surgery was performed between the second- and twenty-first-days post-injury by two shoulder surgeons, using the SMR® reverse shoulder modular replacement prosthesis (Lima Corporate, San Daniele del Friuli, Italy), figure 1.

Figure 1: SMR (Shoulder Modular Replacement, San Daniele del Friuli, Italy)

All patients were clinically examined and evaluated using the Constant Shoulder Score (CSS) system, widely used in the literature to assess functional outcomes of shoulder arthroplasties. Radiographic evaluation of all patients was conducted using Grashey anteroposterior and axillary lateral views to assess tuberosity healing, presence of notching, and loosening of the humeral stem. Radiographic loosening of the humeral stem was specifically assessed using modified Gruen radiolucency zones for the shoulder, figure 2.

Figure 2: Gruen radiolucency zones adapted for the shoulder.



Legend: The radiolucency zones are assessed in eight zones and classified according to width (<2 mm or >2 mm). The presence of radiolucency in 3 or more zones >2 mm is considered "at risk" for clinical loosening. Loosening is defined as displacement of the humeral component between the initial postoperative radiograph and the most recent follow-up, or if radiolucency >2 mm is present in 3 or more zones.

Patients were clinically and radiographically followed up at 1, 3, and 6 months postoperatively, then at 12 months, and every 6 months thereafter.

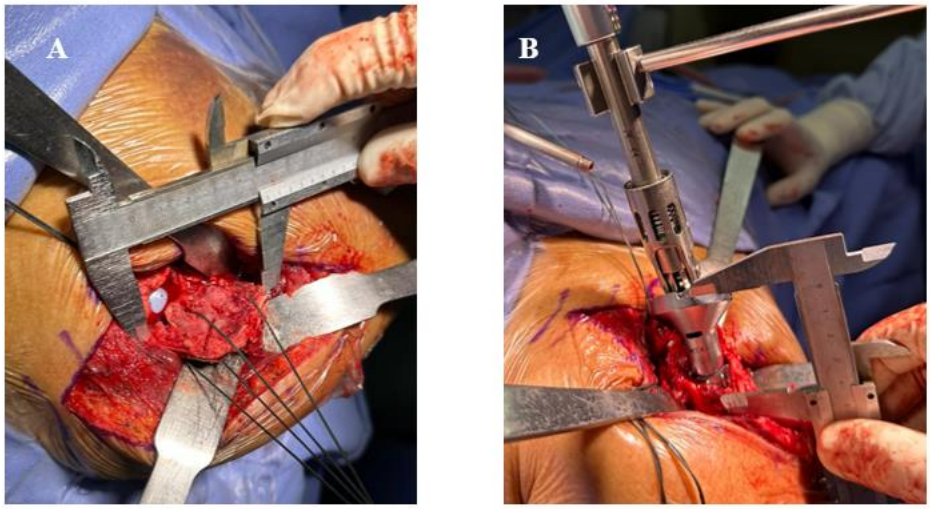
2.1.Intervention and Surgical Technique

All patients were positioned in a beach chair with the head elevated between 20° and 30° and the ipsilateral scapula supported on a small bolster. The SMR® reverse shoulder prosthesis was used in all cases. The biceps tendon was tenodesed to the upper border of the pectoralis major in all cases. The greater and lesser tuberosities were repaired at the

tendon-bone junction with two non-absorbable No. 5 sutures each. Subsequently, the fractured fragment of the humeral head was removed.

The glenoid baseplate was placed in a neutral position or with a 10-degree inferior tilt. The choice of glenosphere size was based on the size of the native humeral head. The 36mm glenosphere used was made of chrome-cobalt with a polyethylene liner, while the 40mm and 44mm glenospheres were polyethylene with a chrome-cobalt liner (emphasis added) (Figure 3).

Figure3: Intraoperative measurements at the shoulder



Legend: A: Intraoperative measurement of the height of the greater tuberosity; B: Measurement of the height of the humeral stem, according to the height of the greater tuberosity.

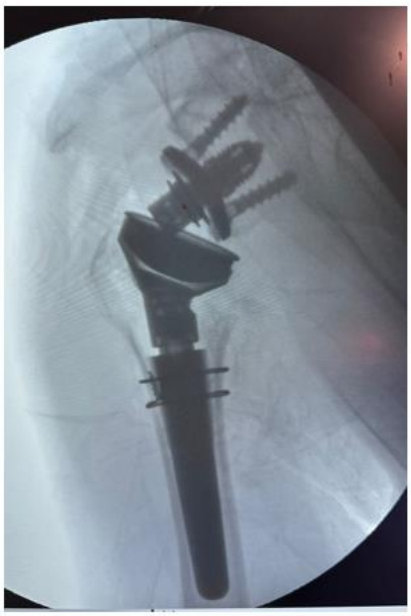
The humeral shaft was prepared with manual reamers until smooth cortical resistance was felt. Humeral implantation was performed using a press-fit uncemented stem.

The height of the humeral stem was determined using the greater tuberosity height as a reference, which corresponds to the distance from the tip of the fractured greater tuberosity to the insertion of the articular side of the rotator cuff. This determines the lateral height of the humeral head (Figure 3-A). The medial height extends from the cartilage-free zone of the humeral head to the calcar.

The humeral stem was press-fit, allowing its height to be determined by the greater tuberosity height (Figure 3-B) and confirmed by intraoperative fluoroscopy (Figure 4). Humeral version was adjusted to 20° of retroversion towards the glenosphere. Tuberosity fixation was performed with horizontal sutures using three high-strength sutures in each tuberosity and vertical sutures with two high-strength sutures. Before the final tuberosity sutures, compacted cancellous graft was placed in the humeral metaphysis and between

the stem and tuberosities, harvested from the removed humeral head. In cases where the cortical thickness of the humerus was thin with a risk of fracture, or if there was a fracture in the metaphyseal-diaphyseal region, cerclage with metal wires was performed before humeral stem placement (Figure 4).

Figure 4: Intraoperative fluoroscopy to confirm the relationship between the humeral stem and the greater tuberosity. In this case, prior cerclage was necessary to prevent cortical opening.



Postoperatively, immobilization was used for 6 weeks. Pendulum exercises were initiated in the second week, followed by passive and active elevation after 6 weeks.

2.2.Statistical Analysis:

Data were tabulated using Microsoft Excel and analyzed with the Minitab statistical software. Descriptive statistics were performed to assess demographic variables, fracture configuration, radiographic findings, functional evaluation, and Constant Shoulder Score, presented as mean values, standard deviation, percentage, and quantity.

3. RESULTS

The study involved 23 patients who underwent the surgical procedure, with 15 females and 8 males. They had an average age of 75.21 years at the time of surgery and 76.65 years at the postoperative evaluation. Twenty-two patients did not experience any complications, while one patient had an acromion fracture, which was resolved with

immobilization in abduction for 6 weeks. All patients reported no pain and were satisfied with the surgical procedure, as shown in Table 1.

Table 1: Demographic data of participants

Variable	Number of Shoulders or Mean Value (± Standard Deviation)	Percentage (%)
Sex		
Male	8	34.78
Female	15	65.22
Age on the Day of Surgery (years)	75.21 (±7.07)	-
Age on the Day of Evaluation (years)	76.65 (±6.75)	-
Follow-Up Between Surgery and Evaluation (months)	15 months and 6 days (±0.66)	-
Complication		
Without Complication	22	95.65
Acromion Fracture	1	4.35
Pain		
Presence of Pain	0	0
Absence of Pain	23	100
Satisfaction		
Yes	23	100
No	0	0

Regarding the fracture configuration, 18 patients had four-part fractures, 4 had three-part fractures, and 1 had a "Head Split" fracture, as shown in Table 2.

Table 2: Fracture Configuration

Fracture Configuration (Parts)	Number of Shoulders	Percentage (%)
Head Split	1	4.35
Two Parts	-	-
Three Parts	4	17.39
Four Parts	18	78.26

Regarding the radiographic assessment, all patients showed tuberosity union, with no evidence of notching or humeral stem migration figure 5. However, when evaluating the Gruen zones, 16 patients showed no radiolucency, 4 showed one zone, and 3 showed two zones, all equal to or less than 2mm, as shown in Table 3.

Table 3: Radiographic Findings

Consolidated Findings	Shoulder Quantity	Percentage (%)
Consolidated Tuberosities	23	-
No Notching	23	-
No Changes in Humeral Stem	23	-

Gruen Zones		
- No Radiolucency	16	69.56
- 1 Zone*	4	17.39
- 2 Zones*	3	13.05

Legend: *Equal to or less than 2mm

Figure 5: Recovery from pre- or post-operative humerus fracture

Legend: A: Female, 75 years old, with a defect in the humerus due to an old fracture. Cobalt-chromium glenosphere size 36 and polyethylene liner. Consolidated tuberosities, no notching, and no signs of loosening of the humeral stem; B: Female, 77 years old. Polyethylene glenosphere size 40 and cobalt-chromium liner. Consolidated tuberosities, no notching, and no signs of loosening of the humeral stem.

Finally, postoperative functional evaluation was performed, and the patients showed 139.56 degrees of anterior elevation and 31.08 degrees of external rotation. As for internal rotation, 13 patients presented near the lumbar spine, 9 near the sacral spine, and 1 in the gluteal region, as shown in Table 4.

Table 4: Functional Evaluation

Variable	Shoulder Quantity or Mean Value (± Standard Deviation)	Percentage (%)
Anterior Elevation (Degrees)	139.56 (± 17.44)	-
External Rotation (Degrees)	31.04 (± 10.07)	-

Internal Rotation		
- Lumbar Spine	13	56.53
- Sacral Spine	9	39.13
- Gluteal Region	1	4.33
Constant Score	80.00 (± 22.89)	-

The Constant Score functional assessment scale, which is one of the most widely used instruments for shoulder functional evaluation, showed that the patients achieved a score of 80 points. Therefore, they exhibit satisfactory shoulder functionality, as indicated in Table 4.

4. DISCUSSION

There is no universally applicable treatment for patients with fractures of the proximal humerus due to the multifaceted nature of each fracture. However, treatment of these fractures with reverse shoulder arthroplasty (RSA) has consistently demonstrated superior functional outcomes and increased consistency[21]. As surgeons become more adept with RSA, its indications appear to broaden, including for the management of proximal humeral fractures.

The conventional surgical technique for RSA involves cemented fixation of the humeral stem in treating proximal humeral fractures, yielding favorable functional results. However, cemented fixation may be associated with intraoperative hypotension, pulmonary embolism, prolonged surgical duration, higher costs, and, importantly, increased complexity in revision surgeries[22]. Early attempts at cementless fixation led to higher rates of radiolucency lines and early implant loosening[13,14]. Modern humeral stem designs incorporate proximal stem coating to promote osseointegration. The uncemented humeral stem used in our study is made of titanium, coated with titanium spray, facilitating osseointegration, and featuring two fins for tuberosity fixation. The distal portion of the humeral stem is also uncemented, with a tapered design and anti-rotation fins providing secure distal fixation.

Numerous studies have reported favorable functional outcomes with cementless RSA for complex proximal humeral fractures[22,13,6,23]. Although most studies reporting favorable outcomes included a small number of acute fractures, they consistently showed comparable functional outcomes to cemented RSA. Complication and revision rates of uncemented RSA for proximal humeral fractures are low[22,24,25]. Specifically, the absence of humeral stem loosening, a significant concern, was observed in all cases, substantiating the continued use of uncemented stems.

Regarding tuberosity consolidation, studies have shown that patients with consolidated tuberosities exhibit significantly better range of motion, particularly postoperative external rotation, compared to those with non-consolidated or resorbed tuberosities[26,18].

A recent meta-analysis revealed that favorable functional outcomes can be achieved with RSA, regardless of whether the humeral component is cemented or uncemented[27]. The tuberosity consolidation rate did not significantly differ between cemented and uncemented humeral stems. Complications associated with uncemented humeral stems, if present, may not necessarily necessitate reoperation or revision.

In our study, placement of the uncemented humeral stem allowed for safe determination of its height by measuring the size of the greater tuberosity before the placement of the definitive implant, confirmed by fluoroscopy. This was facilitated by the stem's various diameters and sequential impaction until a stable metaphyseal and diaphyseal fit was achieved. In cases of thin cortex or metaphyseal-diaphyseal fractures, prior cerclage was used.

All patients in our study were operated on within three weeks and showed significant motion improvement, typically by the fourth month. Early RSA for acute proximal humeral fractures in elderly patients leads to quicker recovery, favorable outcomes, and reduced pain and discomfort[6].

Tuberosity consolidation was observed in all cases, ensuring improved prosthesis stability and restoration of rotational capabilities. One case of acromion fracture in a patient with low BMI consolidated with abduction immobilization for six weeks. No notching was observed, as it was avoided by neutral placement or with a 10° inferior tilt of the baseplate and an eccentric glenosphere design. We did not observe humeral stem loosening in our short-term follow-up, using adapted Gruen zones for the shoulder[19,20]. Youn et al., using the same humeral stem design as in our study, reported a low rate of radiolucency and no failures or loosening during revisions of uncemented stems with a follow-up of 2.5 to 7.8 years. Some observed areas, particularly around the proximal part of the humeral component, showed bone resorption due to stress shielding, a phenomenon well-documented in hip joint prostheses.

A recent study by G.N. Panagopoulos et al. using uncemented humeral stems with an average follow-up of 39.3 months in RSAs for acute proximal humeral fractures found

no signs of loosening[6]. Similarly, Chaudhury et al. did not observe humeral stem loosening in a review with a follow-up range of 24 to 55 months.

5. CONCLUSION

The employment of uncemented humeral stems did not manifest early loosening, exhibiting a high level of patient satisfaction and favorable functional outcomes with a minimum follow-up period of 12 months and an average of 15 months and six days. Our findings suggest that uncemented humeral stems can be inserted with greater precision, as they enable the determination of height and version prior to the definitive placement of the humeral stem.

6. REFERENCES

1. Tsuda T. Epidemiology of fragility fractures and fall prevention in the elderly: a systematic review of the literature. Curr Orthop Pract 2017;28(6):580-585.

2. Court-Brown CM, Garg A, McQueen MM. The epidemiology of proximal humeral fractures. Acta Orthop Scand 2001;72(4):365-371.

3. Launonen AP, Lepola V, Flinkkila T, Laitinen M, Paavola M, Malmivaara A. Treatment of proximal humerus fractures in the elderly: a systemic review of 409 patients. Acta Orthop 2015;86:280-5. https://doi.org/10.3109/17453674.2014.999299

4. Gallinet D, Clappaz P, Garbuio P, Tropet Y, Obert L. Three or four parts complex humerus fractures: hemiarthroplasty versus reverse prosthesis: a comparative study of 40 cases. Orthop Traumatol Surg Res 2009;95:48-55. http://dx.doi.org/10.1016/j.otsr.2008.09.002

5. 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;313:1037-47. https://doi.org/10.1001/jama.2015.1629

6. Panagopoulos GN, Pugliese M, Leonidou A, Butt F, Jaibaji M, Megaloikonomos, PD, Levy O. Acute versus delayed reverse total shoulder arthroplasty for proximal humeral fractures: a consecutive cohort study. Journal of Shoulder and Elbow Surgery, 2022;31(2), 276-285.

7. Pizzo RA, Gianakos AL, Haring RS, et al. Are arthroplasty procedures really better in the treatment of complex proximal humerus fractures? A comprehensive metaanalysis and systematic review. J Orthop Trauma 2021;35(3):111-119.

8. Savin DD, Zamfirova I, Iannotti J, Goldberg BA, Youderian AR. Survey study suggests that reverse total shoulder arthroplasty is becoming the treatment of choice for four-part fractures of the humeral head in the elderly. Int Orthop 2016;40(9):1919-1925.

9. Gigis I, Nenopoulos A, Giannekas D, Heikenfeld R, Beslikas T, Hatzokos I. Reverse shoulder arthroplasty for the treatment of 3 and 4-part fractures of the

humeral head in the elderly. Open Orthop J 2017;11:108-18. https://doi.org/10.2174/1874325001711010108.

10. Holton J, Yousri T, Arealis G, Levy O. The role of reverse shoulder arthroplasty in management of proximal humerus fractures with fracture sequelae: a systematic review of the literature. Orthop Rev(Pavia) 2017;9:6977. https://doi.org/10.4081/or.2017.6977.

11. Mata-Fink A, Meinke M, Jones C, Kim B, Bell JE. Reverse shoulder arthroplasty for treatment of proximal humeral fractures in older adults: a systematic review. J Shoulder Elbow Surg 2013;22:1737-48. https://doi.org/10.1016/j.jse.2013.08.021.

12. Bufquin T, Hersan A, Hubert L, Massin P. Reverse shoulder arthroplasty for the treatment of three- and four-part fractures of the proximal humerus in the elderly: a prospective review of 43 cases with a short-term follow-up. J Bone Joint Surg Br 2007;89(4):516-520.

13. Youn SM, Deo S, Poon PC. Functional and radiologic outcomes of uncemented reverse shoulder arthroplasty in proximal humeral fractures: cementing the humeral component is not necessary. J Shoulder Elbow Surg 2016;25(4):e83-e89.

14. Morwood MP, Johnston PS, Garrigues GE. Proximal ingrowth coating decreases risk of loosening following uncemented shoulder arthroplasty using mini-stem humeral components and lesser tuberosity osteotomy. J Shoulder Elbow Surg 2017;26(7):1246-1252.

15. Szerlip BW, Morris BJ, Laughlin MS, Kilian CM, Edwards TB. Clinical and radiographic outcomes after total shoulder arthroplasty with an anatomic press-fit short stem. J Shoulder Elbow Surg 2018;27(1):10-16.

16. Phadnis J, Huang T, Watts A, Krishnan J, Bain GI. Cemented or cementless humeral fixation in reverse total shoulder arthroplasty? a systematic review. Bone Joint J 2016;98-B(1):65-74.

17. Werthel JD, Lonjon G, Jo S, Cofield R, Sperling JW, Elhassan BT. Long-term outcomes of cemented versus cementless humeral components in arthroplasty of the shoulder: a propensity score-matched analysis [published correction appears in Bone Joint J 2018;100-B(9):1260]. Bone Joint J 2017;99-B(5):666-673.

18. O'Sullivan J, Lädermann A, Parsons BO, et al. A systematic review of tuberosity healing and outcomes following reverse shoulder arthroplasty for fracture according to humeral inclination of the prosthesis. J Shoulder Elbow Surg 2020;29(9):1938-1949.

19. Lenarz C, Shishani Y, McCrum C, Nowinski RJ, Edwards TB, Gobezie R. Is reverse shoulder arthroplasty appropriate for the treatment of fractures in the older patient?: Early observations. Clin Orthop Relat Res 2011;469:3324-31. http://dx.doi.org/10.1007/s11999-011-2055-z.

20. Banaszkiewicz, PA. “Modes of failure” of cemented stem-type femoral components: a radiographic analysis of loosening." Classic Papers in Orthopaedics. London: Springer London, 2013; 35-38.

21. Grey B, Rodseth RN, Roche SJ. Humeral stem loosening following reverse shoulder arthroplasty: A systematic review and meta-analysis. JBJS Rev 2018;6(5):e5.

22. Wright JO, Ho A, Kalma J, et al. Uncemented reverse total shoulder arthroplasty as initial treatment for comminuted proximal humerus fractures. J Orthop Trauma 2019;33(7):e263-e269.

23. Chaudhury S, Myatt R, Aboelmagd T, Hussain M, Malhas A. Two-year clinical and radiographic outcomes following uncemented reverse shoulder replacements for proximal humerus fractures. J Shoulder Elbow Surg 2023;32(3):636-644.

24. Austin DC, Torchia MT, Cozzolino NH, Jacobowitz LE, Bell JE. Decreased reoperations and improved outcomes with reverse total shoulder arthroplasty in comparison to hemiarthroplasty for geriatric proximal humerus fractures: A systematic review and meta-analysis. J Orthop Trauma 2019;33(1):49-57.

25. Rossi LA, Guillermina BM, Buljubasich M, et al. Cemented versus uncemented reverse shoulder arthroplasty for acute proximal humeral fractures. J Shoulder Elbow Surg 2022;31(2):261-268.

26. Jain NP, Mannan SS, Dharmarajan R, Rangan A. Tuberosity healing after reverse shoulder arthroplasty for complex proximal humeral fractures in elderly patients-does it improve outcomes? A systematic review and meta-analysis. J Shoulder Elbow Surg 2019;28(3):e78-e91.

27. Rossi LA, Tanoira I, Ranalletta M, et al. Cemented vs. uncemented reverse shoulder arthroplasty for proximal humeral fractures: a systematic review and metaanalysis. J Shoulder Elbow Surg 2022;31(3):e101-e119.

28. Bauer TW, Schils J. The pathology of total joint arthroplasty. II. Mechanism of implant failure. Skeletal Radiol 1999;28:483-97.