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ORIGINAL ARTICLE

Comparison of Functional Outcomes and Complications of Inlay and Onlay Reverse Shoulder Arthroplasty in Neer Type 4 Proximal Humerus Fractures and Cuff Tear Arthropathy: A Multicentric Study

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Abstract

Background This multicenter retrospective study was conducted with the objective of comparing the outcomes and complications between inlay and onlay reverse shoulder arthroplasty (RSA) in patients presenting Neer Type 4 proximal humerus fractures and cuff tear arthropathy. The primary aim of this investigation was to assess and juxtapose the clinical as well as functional outcomes of individuals who underwent onlay reverse shoulder arthroplasty with those who underwent inlay reverse shoulder arthroplasty.

Methods A retrospective cohort study was conducted, involving patients who had undergone reverse shoulder arthroplasty between the period of 2016 and 2022. The study divided the population into two groups: Group A received inlay humeral components, while Group B received onlay humeral components. Functional outcomes were evaluated using the American Shoulder and Elbow Surgeons (ASES) and Constant scores. Range of motion, infection, periprosthetic fractures, and nerve injuries were also assessed.

Results The study included 67 patients in Group A and 62 patients in Group B. Group A had significantly better functional outcomes, as indicated by higher ASES and Constant scores ($p < 0.05$). Group A also had greater shoulder joint motion ($p < 0.05$). Periprosthetic fractures were significantly more common in Group B ($p < 0.05$). However, complication rates, including infection and instability, did not significantly differ between the groups ($p > 0.05$). Nerve injuries occurred in both groups, with slightly higher occurrence in Group B.

Conclusion Inlay humeral components in reverse shoulder arthroplasty for Neer Type 4 fractures and cuff tear arthropathy resulted in better functional outcomes, increased range of motion, and lower incidence of periprosthetic fractures compared to onlay components. Onlay components showed potential advantages in reducing instability rates. Further studies with larger samples and standardized protocols are needed to confirm these findings.

Keywords Reverse shoulder arthroplasty · Inlay humeral component · Onlay humeral component · Neer Type 4 fractures · Cuff tear arthropathy · Functional outcomes · Complications

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Introduction

Proximal humerus fractures and cuff tear arthropathy are debilitating conditions that often result in significant pain, loss of function, and decreased quality of life. Traditional treatment options, including conservative management and hemiarthroplasty, have shown limited success in achieving satisfactory outcomes, particularly in cases involving complex fractures or irreparable rotator cuff tears [1]. In recent years, reverse shoulder arthroplasty (RSA) has emerged as a promising surgical intervention for addressing these challenging conditions [2].

One crucial aspect of reverse shoulder arthroplasty is the design and configuration of the humeral component. Two commonly employed designs are the onlay and inlay humeral components. The onlay humeral component involves attaching the humeral stem to the lateral aspect of the proximal humerus, providing stability and support for the glenosphere. In contrast, the inlay humeral component is inserted into the intramedullary canal of the proximal humerus, anchoring the implant within the bone itself [3, 4].

The choice between inlay and onlay humeral components is often influenced by various factors, including the patient's anatomy, bone quality, and surgeon preference. The inlay design offers the advantage of bone preservation by utilizing the existing intramedullary canal, which may be particularly beneficial in cases of compromised bone stock. On the other hand, the onlay design provides excellent stability and fixation, allowing for immediate loading of the prosthesis. While both inlay and onlay humeral components aim to restore shoulder function and alleviate pain, their comparative clinical and functional outcomes remain relatively understudied [3, 5, 6]. Understanding the specific advantages and limitations associated with each design is crucial for optimizing surgical decision-making and achieving favorable patient outcomes.

This multicenter study aimed to comprehensively compare the outcomes and complications associated with inlay and onlay reverse shoulder arthroplasty (RSA) procedures in patients diagnosed with Neer Type 4 proximal humerus fractures and cuff tear arthropathy. Through a comprehensive analysis of key outcome measures encompassing pain relief, range of motion, strength, patient-reported functional scores, and complication rates, our objective is to offer valuable insights into the comparative effectiveness and potential advantages inherent in inlay and onlay humeral component designs.

Materials and Methods

The retrospective multicenter study enrolled patients who had undergone reverse shoulder arthroplasty (RSA) surgery for Neer Type 4 proximal humeral fractures or cuff tear arthropathy between the years 2016 and 2022. The primary outcome measures in this study encompassed the clinical and functional assessments of patients undergoing inlay and onlay reverse shoulder arthroplasty (RSA) for Neer Type 4 proximal humerus fractures and cuff tear arthropathy. Secondary outcome measures focused on the occurrence of complications and adverse events associated with the two techniques. These included the incidence of periprosthetic fractures, infections, and nerve injuries.

The eligible participants, all of whom underwent the surgical procedures, were treated by surgical teams specializing in shoulder and elbow surgery at two prominent teaching and research hospitals. The procedures were conducted with the expertise of these surgical teams at the said medical institutions. Patient-related information was accessed retrospectively from medical records and patient images through the Extreme Pacs® digital medical imaging system for evaluation purposes.

The participants were categorized into two distinctive groups: Group A, which encompassed individuals who had received inlay reverse shoulder prostheses, and Group B, comprising those who had been provided with onlay reverse shoulder prostheses. Specifically, Group A comprised a total of 67 patients, among whom 42 had undergone reverse shoulder arthroplasty due to cuff tear arthropathy and 25 for Neer Type 4 proximal humeral fractures. On the other hand, Group B included 62 patients, with 34 of them having cuff tear arthropathy and 28 presenting Neer Type 4 proximal humeral fractures (Table 1). Among these participants, 14 individuals in Group A and 9 individuals in Group B had been implanted with a cemented stem. The inlay prosthesis used in Group A was manufactured by Lima SMR Reverse (Lima Corporate S.p.a, Udine, Italy), while the onlay prosthesis used in Group B was provided by Next Reverse Shoulder Prosthesis (Next Shoulder Solutions Ankara, Turkiye) (Figs. 1, 2).

In both groups, a similar fixation method was employed for tuberosity fixation due to its impact on functional outcomes. The osteotendinous junction of the greater tuberosity(GT) and lesser tuberosity (LT) was secured using three stay sutures (No. 2 Ethibond; Ethicon, Raritan, NJ, USA), while preserving all other rotator cuff muscles during the entire procedure. After retracting the tuberosities, the humeral canal was reamed to determine the appropriate size for the stem. The stem's height was adjusted based on the reduction achieved in the GT fragment.

Subsequent to placing cancellous bone grafts from the humeral head among the tuberosities, prosthesis, and diaphysis, four holes were drilled in the humeral diaphysis—two each positioned at the lateral and medial sides of the bicipital

Table 1 Distribution of patient groups

Groups	Total patients	Cuff tear arthropathy	Neer Type 4 proximal humeral fractures	Cemented stem
Group A	67	42	25	14
Group B	62	34	28	9

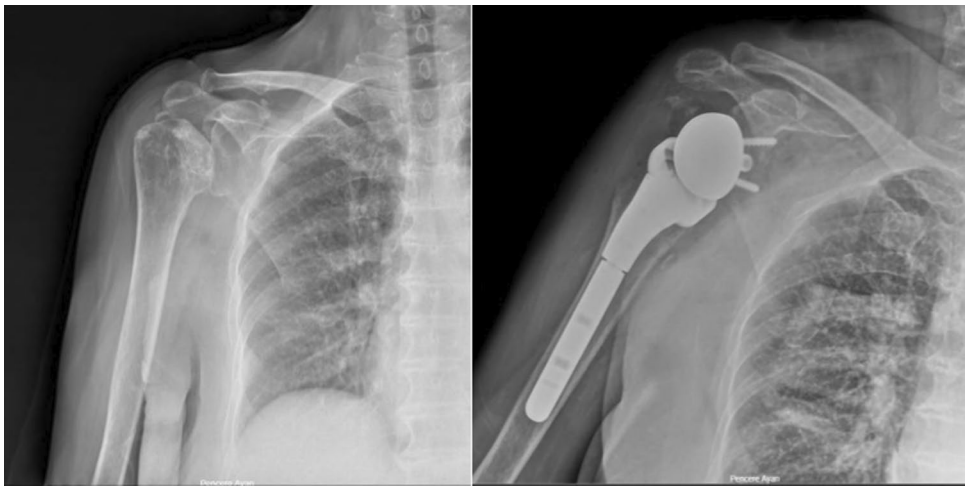

Fig. 1 An example of our patients who underwent onlay design prosthesis due to cuff arthropathy

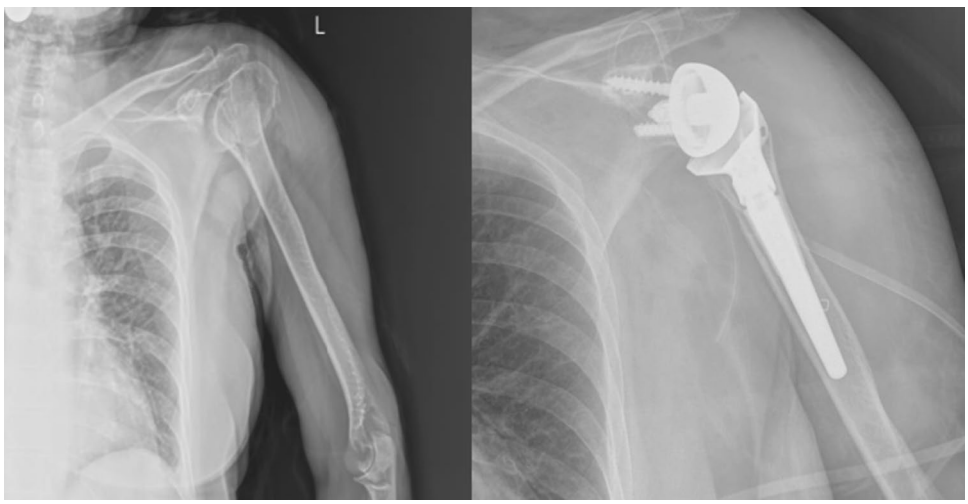

Fig. 2 An example of our patients who underwent inlay design prosthesis due to fracture

groove. Sutures originating from the most proximal part of the GT fragment were directed through the holes located at the medial aspect of the bicipital groove. Similarly, sutures arising from the most proximal part of the LT fragment were guided through the holes positioned at the lateral aspect of the bicipital groove. These sutures were intentionally positioned at least 1 cm distal to the fracture site on the humeral diaphysis to prevent potential complications. In addition, the remaining sutures within both the GT and LT fragments were securely fastened diagonally to their respective counterparts, ensuring a robust and stable fixation.

Functional outcomes, including the American Shoulder and Elbow Surgeons (ASES) and Constant scoring systems, were based on the information obtained from patient records at the 6th postoperative month. These scoring systems have been widely employed to evaluate the functional status and shoulder function of patients undergoing reverse shoulder arthroplasty. The ASES score comprises subjective and objective components, covering pain, activities of daily living, range of motion, and strength. The Constant score evaluates pain, activities of daily living, range of motion, and strength, providing a comprehensive functional assessment. Various parameters underwent evaluation and comparison between Group A and Group B. The assessment of range of motion included measurements of forward flexion, abduction and external rotation that were conducted using standardized goniometry techniques (Fig. 3).

Complication rates, encompassing infection, periprosthetic fracture, radiologically diagnosed dislocations in the postoperative period (defined as instability), vascular and nerve injuries, were meticulously documented based on the information obtained from patient files and outpatient clinic follow-up records. Moreover, instances of brachial plexus injury and axillary nerve injury were duly noted. Radiographic assessments, comprising preoperative and postoperative imaging studies, were conducted to appraise implant positioning, bone healing, and any indications of complications.

Fig. 3 Clinical images depicting the forward elevation of patients who underwent onlay (**a**) and inlay (**b**) humeral component placement, with surgical intervention performed on the right extremity in both cases

The study protocol and data collection procedures underwent a thorough review and received approval from the Institutional Review Boards under the reference number E-48670771-613.10/340-13.03.2023.

Statistical Analysis

The collected data were analyzed using appropriate statistical methods. Descriptive statistics, such as means, standard deviations, and percentages, were calculated to summarize the demographic and clinical characteristics of the patient cohorts. To assess the differences between Group A and Group B, independent *t*-tests or Mann–Whitney *U* tests were performed for continuous variables, while Chi-square tests or Fisher's exact tests were used for categorical variables. The significance level was set at $p < 0.05$.

Results

In Group A, the average age of patients who underwent surgery for inlay reverse shoulder prostheses was 65 years, with a standard deviation of 4.5 years, encompassing 35 female patients and 32 male patients. In Group B, patients who received onlay reverse shoulder prostheses had an average age of 60 years, with a standard deviation of 3.2 years, including 45 female patients and 17 male patients. Across both groups, the predominant gender was female, and the collective average age of all patients ranged from 55 to 75 years, with a standard deviation of 6.3 years.

In terms of medical history, Group A included 34 patients with hypertension and 15 patients with diabetes mellitus under treatment, while in Group B, 46 patients had hypertension, and 22 were receiving treatment for diabetes mellitus.

The functional outcomes assessed using the ASES and Constant scores demonstrated significantly better results in Group A (inlay humeral components) compared to Group B (onlay humeral components). The mean ASES score in Group A was 73.6 ± 16.2, whereas in Group B, it was 68.2 ± 15.9 ($p < 0.05$). Similarly, the mean Constant score in Group A was 75.4 ± 17.1, while in Group B, it was 70.1 ± 16.8 ($p < 0.05$). Analysis of the range of motion measurements revealed that patients in Group A exhibited significantly greater shoulder joint motion compared to Group B. The mean forward flexion in Group A was $140.2° \pm 9.3°$, whereas in Group B, it was $132.6° \pm 8.7°$ ($p < 0.05$). Similarly, the mean abduction in Group A was $135.8° \pm 8.5°$, while in Group B, it was $129.4° \pm 7.9°$ ($p < 0.05$). Mean external rotation was $26° \pm 15.3$ in Group A and $28° \pm 13.4$ in Group B ($p < 0.05$). While a slightly higher incidence of scapular notching and scapular spine fractures was observed in the inlay group, there was no statistically significant difference between the groups (Table 2).

Table 2 Postoperative functional results and complication rates of both groups

	Group A (inlay)	Group B (onlay)	Statistical test
Functional outcomes			
ASES score	73.6 ± 16.2	68.2 ± 15.9	$p < 0.05$
Constant score	75.4 ± 17.1	70.1 ± 16.8	$p < 0.05$
Range of motion			
Mean forward flexion	140.2° ± 9.3	132.6° ± 8.7	$p < 0.05$
Mean abduction	135.8° ± 8.5	129.4° ± 7.9	$p < 0.05$
Mean external rotation	26° ± 15.3	28° ± 13.4	$p < 0.05$
Complications			
Overall complication rates	Not significant	Not significant	$p > 0.05$
Periprosthetic fractures	3%	9.7%	$p > 0.05$
Instability	6%	3.2%	$p > 0.05$
Scapular spine fracture	2	1	$p < 0.05$
Scapular notching	3	2	$p < 0.05$

ASES American Shoulder and Elbow Surgeons

The overall complication rates did not significantly differ between Group A and Group B ($p > 0.05$). In Group A, two patients (3%) experienced superficial wound infections, which were effectively managed with oral antibiotics. Furthermore, one patient in Group A developed a deep infection that necessitated a two-stage infection treatment. Within Group B, three patients experienced superficial soft tissue infections, all of which resolved with oral antibiotic therapy. Two patients in Group B encountered deep infections, one of whom required debridement and liner exchange, while the other underwent a two-stage infection treatment. There were no statistically significant differences in infection rates between the two groups (Table 2). No complications related to tuberosity fixation were observed in either group.

The incidence of periprosthetic fractures was significantly higher in Group B (9.7%) compared to Group A (3%) ($p < 0.05$), particularly in cases of cuff tear arthropathy. Two patients in Group A experienced periprosthetic fractures, whereas six patients in Group B encountered such fractures (Fig. 4).

The rates of postoperative instability were lower in Group B (3.2%) compared to Group A (6%), specifically in cases of fractures. However, the difference in instability rates between the two groups was not statistically significant ($p > 0.05$) (Table 2). In Group B, three cases of temporary brachial plexus injuries were observed, while Group A had one case of brachial plexus injury and one case of axillary nerve injury (Table 2).

Fig. 4 Periprosthetic fracture in a patient who underwent an onlay design humeral component

Discussion

The present study aimed to compare the outcomes of inlay and onlay humeral components in the treatment of Neer Type 4 proximal humerus fractures and cuff tear arthropathy. The results of our study indicate that the use of inlay humeral components in the treatment of Neer Type 4 proximal humerus fractures and cuff tear arthropathy resulted in superior functional outcomes, increased range of motion, and lower incidence of periprosthetic fractures compared to onlay components. However, it is important to note that onlay components demonstrated a potential advantage in terms of reduced instability rates.

Functional outcomes are crucial indicators of the success of surgical interventions. In this study, the functional outcomes were evaluated using the American Shoulder and Elbow Surgeons (ASES) and Constant scores. Studies investigating the effects of two different humeral components on PROMs (patient-reported outcome measures) in reverse shoulder prosthesis, onlay and inlay, reported that the differences between the two groups were minimal or not

statistically significant [5, 7–9]. Our findings showed that patients who received inlay humeral components achieved significantly better functional outcomes in terms of shoulder function and pain relief compared to those with onlay components. This could be attributed to the composition of our patient group, which encompasses both cuff tear arthropathy and complex proximal humerus fractures.

Range of motion is another essential aspect of shoulder function. Upon analyzing the range of motion measurements, it was found that patients belonging to Group A exhibited significantly higher shoulder joint mobility compared to those in Group B. Group A demonstrated a mean forward flexion of $140.2° \pm 9.3°$, while Group B recorded $132.6° \pm 8.7°$ ($p < 0.05$). Furthermore, Group A displayed a mean abduction of $135.8° \pm 8.5°$, whereas Group B had a mean abduction of $129.4° \pm 7.9°$ ($p < 0.05$).

The constrained articulation of reverse shoulder arthroplasty (RSA) effectively prevents superior humeral subluxation, ensuring a stable axis of rotation. While initial beliefs suggested reduced impact of tuberosity non-union in RSA compared to hemiarthroplasty, recent research underscores its significance, especially in complex proximal humerus fractures [9, 10]. Tuberosity healing rates in RSA range from 37 to 90%, with a recent meta-analysis reporting an overall rate of 68% [11]. Achieving anatomical tuberosity healing correlates with increased active anterior elevation, external rotation, fewer complications, and prolonged prosthesis survival. Tuberosity non-union leads to a considerable decrease in joint reaction forces, emphasizing the importance of anatomical reduction and stable tuberosity fixation during RSA [9]. Similar tuberosity fixation methods were employed in both Group A and Group B to equalize the impact of tuberosity healing on functional outcomes. After passing three Ethibond sutures through the GT and LT fragments, the sutures located proximally on the fragments were tightly secured diagonally to the holes opened in the lateral and medial aspects of the humeral diaphysis, adjacent to the bicipital groove. The remaining sutures within the fragments were also firmly tied diagonally to their respective counterparts. No complications related to tuberosity fixation were observed in either group.

Periprosthetic fractures represent a potential complication following shoulder arthroplasty. The incidence of periprosthetic fractures was significantly higher in the onlay group, particularly in cases of cuff tear arthropathy. This indicates that onlay humeral components may increase the risk of periprosthetic fractures, emphasizing the importance of careful consideration when selecting the appropriate surgical technique. Due to the biomechanical features of the onlay design, the power transmitted from the shoulder girdle is reflected especially on the lateral side of the humerus. In a study, it was found that bone resorption of the proximal humerus occurred more in this design type. Since the inlay design directs the force to the intramedullary area, it is thought to prevent humeral stress shielding. The reason why more periprosthetic fractures were seen in the onlay group in our study is due to the power transfer difference between the designs [6]. The incidence of periprosthetic fractures was significantly higher in Group B (9.7%) compared to Group A (3%) ($p < 0.05$), particularly in cases of cuff tear arthropathy in our study. Our results suggest that onlay humeral components may increase the risk of periprosthetic fractures, especially in patients with cuff tear arthropathy (Table 2).

In terms of infection rates, there were no statistically significant differences in between the two groups. However, it is noteworthy that the overall complication rates were relatively low in both groups, indicating that both techniques can be performed with acceptable safety profiles. The observed cases of superficial and deep infections were effectively managed with appropriate treatment strategies, highlighting the importance of infection prevention measures in shoulder arthroplasty procedures [12–14].

The presence of radiologically confirmed dislocation in the postoperative period was considered as instability. Regarding instability rates, Group B exhibited lower rates of postoperative instability (3.2%) in comparison to Group A (6%), specifically among cases involving fractures. However, it is important to note that the disparity in instability rates between the two groups did not yield statistically significant results ($p > 0.05$). This suggests that both techniques can provide satisfactory stability outcomes, with a potential advantage for onlay components in cases of fractures. Further research with larger sample sizes may be required to establish more conclusive evidence on this aspect.

Nerve injuries represent a significant concern in shoulder arthroplasty procedures. The reported occurrence of iatrogenic nerve injuries following shoulder arthroplasty ranges from 1 to 18.7%, while distal peripheral neuropathies are documented in 1 to 12.3% of patients [15]. In Group B, three cases of temporary brachial plexus injuries were observed, while Group A had one case of brachial plexus injury and one case of axillary nerve injury. These nerve injuries were believed to be associated with the application of onlay stems, exerting force and causing stretching of the plexus during the procedure. The application of onlay stems may exert force and cause stretching of the brachial plexus during the procedure, leading to temporary brachial plexus injuries. Peripheral nerve lesions can be seen onlay in designs due to humeral distalization, especially due to stretching of the axillary nerve [16]. It is crucial for surgeons to be aware of this potential risk and take necessary precautions to minimize nerve injuries during the surgical technique [12, 17].

Several limitations should be considered when interpreting the results of this study. First, the relatively small sample size may have limited the statistical power and generalizability of the findings. In addition, the multicenter nature of

the study may have introduced variations in surgical techniques, potentially influencing the outcomes. The inability to create homogeneous groups and control for factors such as subscapularis and soft tissue repair status further adds to the limitations. Future studies with larger sample sizes, standardized surgical protocols, and more precise subgroup analyses are warranted to confirm and expand upon these findings. Despite the potential for better assessment of patients' susceptibility to periprosthetic fractures through bone mineral density measurements, this parameter could not be evaluated due to the unavailability of this information for every included patient in the medical record scans. It should be noted that this constitutes another limitation of the study.

Conclusion

Our study compared inlay and onlay humeral components for Neer Type 4 fractures and cuff tear arthropathy, revealing improved function and motion with inlay, and potential instability benefits with onlay. Surgeons should factor in these findings when selecting techniques, considering complications, and long-term data for durability and outcomes.

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Data availability Not applicable.

Declarations

Conflict of Interest The authors, their immediate family, and any research foundation with which they are affiliated did not receive any financial payments or other benefits from any commercial entity related to the subject of this article. The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval The study was approved by the Institutional Review Board.

Informed Consent Informed consent was obtained from all individual participants included in the study.

References

1. Viswanath, A., Bale, S., & Trail, I. (2021). Reverse total shoulder arthroplasty for irreparable rotator cuff tears without arthritis: A systematic review. *Journal of Clinical Orthopaedics and Trauma, 17*, 267–272.
2. Singhal, K., & Rammohan, R. (2018). Going forward with reverse shoulder arthroplasty. *Journal of Clinical Orthopaedics and Trauma, 9*(1), 87–93.
3. Jackson, G. R., Meade, J., Young, B. L., Trofa, D. P., Schiffern, S. C., Hamid, N., et al. (2023). Onlay versus inlay humeral components in reverse shoulder arthroplasty: A systematic review and meta-analysis. *Shoulder & Elbow, 15*(1), 4–13. https://doi.org/10.1177/17585732211067171
4. Levin J. M., Pugliese M., Gobbi F., Pandy M. G., Di Giacomo G., & Frankle M. A. (2023). Impact of reverse shoulder arthroplasty design and patient shoulder size on moment arms and muscle fiber lengths in shoulder abductors. *Journal of Shoulder and Elbow Surgery*.
5. Larose, G., Fisher, N. D., Gambhir, N., Alben, M. G., Zuckerman, J. D., Virk, M. S., et al. (2022). Inlay versus onlay humeral design for reverse shoulder arthroplasty: A systematic review and meta-analysis. *Journal of Shoulder and Elbow Surgery, 31*(11), 2410–2420.
6. Polisetty T. S., Baessler A. M., Levy J. C., & Badman B. L. (2021). Onlay versus inlay reverse total shoulder arthroplasty: a retrospective comparison of radiographic and clinical outcomes. In: Seminars in Arthroplasty: JSES, vol. 31, pp. 202–208. Elsevier.
7. Burden, E. G., Batten, T. J., Smith, C. D., & Evans, J. P. (2021). Reverse total shoulder arthroplasty: A systematic review and meta-analysis of complications and patient outcomes dependent on prosthesis design. *The Bone & Joint Journal, 103*(5), 813–821.
8. Jassim, S. S., Ernstbrunner, L., & Ek, E. T. (2021). Does humeral component version affect range of motion and clinical outcomes in reverse total shoulder arthroplasty? A systematic review. *Journal of Clinical Medicine, 10*(24), 5745.
9. Jo, O., Borbas, P., Grubhofer, F., Ek, E. T., Pullen, C., Treseder, T., et al. (2021). Prosthesis designs and tuberosity fixation techniques in reverse total shoulder arthroplasty: Influence on tuberosity healing in proximal humerus fractures. *Journal of Clinical Medicine, 10*(18), 4146. https://doi.org/10.3390/jcm10184146
10. Reuther, F., Petermann, M., & Stangl, R. (2019). Reverse shoulder arthroplasty in acute fractures of the proximal humerus: Does tuberosity healing improve clinical outcomes? *Journal of Orthopaedic Trauma, 33*(2), e46–e51. https://doi.org/10.1097/BOT.0000000000001338
11. Jain, N. P., Mannan, S. S., Dharmarajan, R., & Rangan, A. (2019). Tuberosity healing after reverse shoulder arthroplasty for complex proximal humeral fractures in elderly patients-does it improve outcomes? A systematic review and meta-analysis. *Journal of Shoulder and Elbow Surgery, 28*(3), e78–e91. https://doi.org/10.1016/j.jse.2018.09.006
12. Raiss, P., Edwards, T. B., Deutsch, A., Shah, A., Bruckner, T., Loew, M., et al. (2014). Radiographic changes around humeral components in shoulder arthroplasty. *JBJS, 96*(7), e54.
13. Samuelsen, B. T., Wagner, E. R., Houdek, M. T., Elhassan, B. T., Sánchez-Sotelo, J., Cofield, R., et al. (2017). Primary reverse shoulder arthroplasty in patients aged 65 years or younger. *Journal of shoulder and elbow surgery, 26*(1), e13–e17.
14. Sershon, R. A., Van Thiel, G. S., Lin, E. C., McGill, K. C., Cole, B. J., Verma, N. N., et al. (2014). Clinical outcomes of reverse total shoulder arthroplasty in patients aged younger than 60 years. *Journal of Shoulder and Elbow Surgery, 23*(3), 395–400.
15. Patel, M. S., Daher, M., Fuller, D. A., & Abboud, J. A. (2022). Incidence, risk factors, prevention, and management of peripheral nerve injuries following shoulder arthroplasty. *The Orthopedic Clinics of North America, 53*(2), 205–213. https://doi.org/10.1016/j.ocl.2021.11.006
16. Kim, H. J., Kwon, T. Y., Jeon, Y. S., Kang, S. G., Rhee, Y. G., & Rhee, S.-M. (2020). Neurologic deficit after reverse total shoulder arthroplasty: Correlation with distalization. *Journal of Shoulder and Elbow Surgery, 29*(6), 1096–1103. https://doi.org/10.1016/j.jse.2019.11.014
17. Werner, C. M. L., Steinmann, P. A., Gilbart, M., & Gerber, C. (2005). Treatment of painful pseudoparesis due to irreparable rotator cuff dysfunction with the Delta III

reverse-ball-and-socket total shoulder prosthesis. *JBJS, 87*(7), 1476–1486.