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ORIGINAL ARTICLE

Comparison of Locking Plate Osteosynthesis, Hemiarthroplasty, and Reverse Total Shoulder Arthroplasty in the Treatment of Neer Type 3 and 4 Proximal Humerus Fractures in the Elderly: A Retrospective Study

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Abstract

Background: Proximal humerus fractures (PHFs) are common in elderly individuals, and various surgical options exist for the treatment of Neer type 3 and type 4 fractures. This study aimed to compare the clinical and functional outcomes of locking plate osteosynthesis (LPO), hemiarthroplasty (HA), and reverse total shoulder arthroplasty (RTSA).

Methods: A retrospective evaluation was conducted on 44 patients with Neer type 3 or 4 PHFs who underwent LPO, HA, or RTSA. The Constant–Murley score (CMS), Disabilities of the Arm, Shoulder, and Hand (DASH) score, and American Shoulder and Elbow Surgeons (ASES) score were evaluated. Range of motion was measured in terms of forward flexion, extension, abduction, and internal/external rotation.

Results: The mean age was 76.6 ± 4.2 years, and the majority of the patients were female (70%). Compared with the LPO and RTSA groups, the HA group demonstrated significantly worse functional outcomes (CMS: 50.6 ± 2.3; ASES: 60.1 ± 2.3; DASH: 37.5 ± 2.3) and range of motion ($p<0.001$). LPO and RTSA showed comparable functional scores; however, LPO was superior in forward flexion ($p<0.001$) and abduction ($p<0.001$). No significant differences were found between the groups regarding pain visual analog scale (VAS) scores, age, sex, or fracture side ($p>0.05$).

Conclusion: In Neer type 3 and type 4 PHFs, HA results in inferior functional outcomes and range of motion compared with LPO and RTSA. While LPO may be preferred for less complex fractures with good bone quality, RTSA offers reliable results in complex fractures and supports its increasing use. Treatment selection should be based on patient-specific factors, including fracture complexity and bone quality.

Keywords: Proximal humerus fractures, Hemiarthroplasty, Reverse total shoulder arthroplasty, Locking plate osteosynthesis, Elderly.

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INTRODUCTION

Proximal humeral fractures (PHFs) account for approximately 5–6% of all fractures and represent the third most common type of osteoporotic fracture in the elderly population, following distal radius and proximal femur fractures (1-4). The incidence of PHFs is increasing due to the aging population and the increasing prevalence of osteoporosis, particularly in individuals over the age of 60 (2-5). According to the Neer classification, type 3 and type 4 fractures are complex patterns that are displaced, comminuted, and often associated with rotator cuff injury or compromised vascularization of the humeral head (1). These fractures can lead to serious consequences in elderly patients, including functional impairment, pain, and diminished quality of life, making the selection of optimal treatment a significant clinical challenge (2,6,7).

A wide range of treatment options exist for PHFs in elderly patients, from conservative management to surgical intervention; surgical options include locking plate osteosynthesis (LPO), hemiarthroplasty (HA), and reverse total shoulder arthroplasty (RTSA) (1-10). Although conservative treatment may be preferred in minimally displaced fractures or patients at high surgical risk, it is often associated with suboptimal functional outcomes in complex fractures such as type 3 and type 4 fractures (1,4,8,11). Locking plates offer the advantages of preserving bone stock and achieving anatomical reduction; however, in osteoporotic bone, they are prone to high failure rates due to complications such as screw loosening, avascular necrosis, and nonunion(2,6,8). While HA is effective in relieving pain, it is highly dependent on tuberosity healing, and complications such as rotator cuff dysfunction and limited shoulder motion may occur(2,5,8,10). In contrast, RSA has gained popularity in recent years because it offers more predictable functional outcomes and earlier mobilization, regardless of rotator cuff status (1,5,8,9). Nevertheless, there is a lack of consensus in the literature regarding the superiority of these three techniques in terms of functional outcomes and patient satisfaction (1-10).

The aim of this study was to compare the clinical and functional outcomes of LPO, HA and RTSA in the treatment of Neer type 3 and type 4 proximal humeral fractures in elderly patients. Our hypothesis is that RTSA is a safe procedure for this patient population, offering high implant survival and superior functional outcomes compared to HA, with potentially comparable outcomes to LPO.

MATERIALS AND METHODS

Patients who underwent surgery for Neer type 3 or type 4 PHFs between January 1, 2015, and January 1, 2019, were retrospectively reviewed. Among these patients, 44 patients over the age of 70 who had been treated with LPO, HA, or RTSA were included in the study. The study was conducted in accordance with the Declaration of Helsinki and was approved by the institutional ethics committee.

The inclusion criteria were as follows: patients aged over 70 years, who sustained a PHF due to low-energy trauma, who underwent surgery for Neer type 3 or type 4 fractures, and who had a minimum follow-up period of 12 months postoperatively. The exclusion criteria included pathological or open fractures; polytrauma patients; those managed conservatively; patients who did not attend follow-up visits; and those with postoperative complications such as nonunion, infection, or dislocation, as such complications could significantly alter functional outcomes and confound the comparison between surgical methods.

Demographic data (age, sex, date of fracture, fracture type, affected limb) were collected from the patients' clinical records. Fractures were evaluated via X-ray and computed tomography (CT) and classified according to the Neer classification system.

All surgeries were performed in the beach chair position using the deltopectoral approach by two experienced orthopedic surgeons with 6 and 7 years of post-specialization experience, respectively.

Locking Plate Osteosynthesis

Fracture reduction was performed under fluoroscopic guidance. Fixation was achieved via proximal humeral locking plates (Acumed-Polarus PHP; Hillsboro, Oregon, USA). The plate was positioned lateral to the bicipital groove and 5–10 mm distal to the greater tuberosity. Inferomedial calcar screws were placed to prevent varus collapse. When necessary, the tuberosities were secured with nonabsorbable sutures.

Hemiarthroplasty

Appropriate-sized humeral head and stem components (LIMA® Corporate, San Benedetto del Friuli, Italy) were selected for anatomical reconstruction. The humeral stem was cemented at 20°–30° of retroversion. Tuberosities were fixed to the prosthesis with nonabsorbable sutures whenever possible.

Reverse Total Shoulder Arthroplasty

RTSA was performed via the SMR system (LIMA® Corporate, San Benedetto del Friuli, Italy). The glenoid component was placed with a 10° inferior tilt and secured with two screws. The humeral stem was implanted uncemented at 20° of retroversion.

All the treatment groups followed a standardized rehabilitation protocol. The shoulder was immobilized in a simple sling for the first 3 weeks postoperatively. During the first week, active exercises for the elbow, wrist, and hand were allowed. Passive shoulder exercises were initiated at week 3, followed by active-assisted exercises during weeks 4–5 and unrestricted active mobilization starting from weeks 6–8. External rotation and internal rotation behind the back were restricted for 8 weeks in all the groups. Resistance exercises began 8 weeks after surgery.

Patients were evaluated clinically and radiographically on postoperative day 15; at 1, 3, 6, and 12 months; and annually thereafter. Functional outcomes were assessed via the Constant–Murley score (CMS), the Disabilities of the Arm, Shoulder and Hand (DASH) score, and the American Shoulder and Elbow Surgeons (ASES) score. Range of motion was evaluated for forward flexion, extension, abduction, external rotation, and internal rotation (assessed via the CMS system, which quantifies internal rotation on the basis of the highest vertebral level reached: lateral thigh = 0, buttock = 2, lumbosacral junction = 4, waist = 6, T12 = 8, and interscapular area = 10 points).

Statistical Analysis

The data were analyzed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables are presented as means ± standard deviations, and categorical variables as frequencies and percentages. The normality of data distribution was assessed using the Shapiro–Wilk test. One-way ANOVA and post hoc Tukey tests were used to compare continuous variables among surgical groups, while categorical variables were compared using the chi-square test. A p-value < 0.05 was considered statistically significant. To further control for the potential confounding effect of fracture type (Neer type 3 vs. type 4), an ANCOVA (Analysis of Covariance) was conducted with surgical method as the fixed factor and fracture type as the covariate. This allowed us to assess whether differences in functional outcomes (CMS, ASES, DASH) and range of motion measurements (forward flexion, abduction, external rotation, extension, and internal rotation) remained statistically significant after adjusting for fracture type. Additionally, a post hoc power analysis was performed using G*Power software to evaluate the study's ability to detect statistically significant differences across groups. Effect sizes (Cohen's f) were calculated based on group means and standard deviations for each outcome measure. The analysis assumed an alpha level of 0.05, a total sample size of 44 (LPO: n=18, HA: n=10, RTSA: n=16), and three groups for one-way ANOVA. A statistical power $(1 - \beta) \geq 0.80$ was considered sufficient to detect meaningful differences.

RESULTS

The study included a total of 44 patients: 18 underwent LPO, 10 underwent HA, and 16 underwent RTSA. The mean age was 76.6 ± 4.2 years, and 70% of the patients were female. Neer type 4 fractures predominated in the HA (70.0%) and RTSA (68.8%) groups, whereas the distribution was balanced in the LPO group (55.6% type 3, 44.4% type 4). There were no statistically significant differences between the groups in terms of age, sex, side of fracture, follow-up duration, or fracture type ($p > 0.05$). (Table 1)

The functional outcomes differed significantly according to the type of surgical procedure (ANCOVA, $p < 0.001$). The HA group had the worst results in terms of the CMS (50.6 ± 2.3), ASES (60.1 ± 2.3), and DASH (37.5 ± 2.3) scores, whereas the LPO and RTSA groups presented similar results. There were no significant differences in pain scores among the groups. According to post hoc analysis, HA was significantly inferior to the

Table 1. Patient Demographic Variables

	LPO (n = 18)	HA (n = 10)	RTSA (n = 16)	Total (n=44)	p
Age(year) Mean±Sd	76.1 ± 3.9	77.8 ± 4.6	75.3 ± 3.3	76.6 ± 4.2	0.49a
Female, % (n)	61.1 (11)	80.0 (8)	75.0 (12)	70.0 (31)	0.509a
Right Side, % (n)	66.7 (12)	50.0 (5)	50.0 (8)	56.8 (25)	0.548a
Follow-up (month) Mean±Sd	31.9 ± 11.3	28.6 ± 14.2	25.9 ± 10.5	28.7 ± 12.0	0.289a
Neer type 3%(n)	55.6 (10)	30 (3)	31.2 (5)	41 (18)	0.26b

a: One-way ANOVA b: Chi-square LPO: locking plate osteosynthesis, HA: hemiarthroplasty, RTSA: reverse total shoulder arthroplasty.

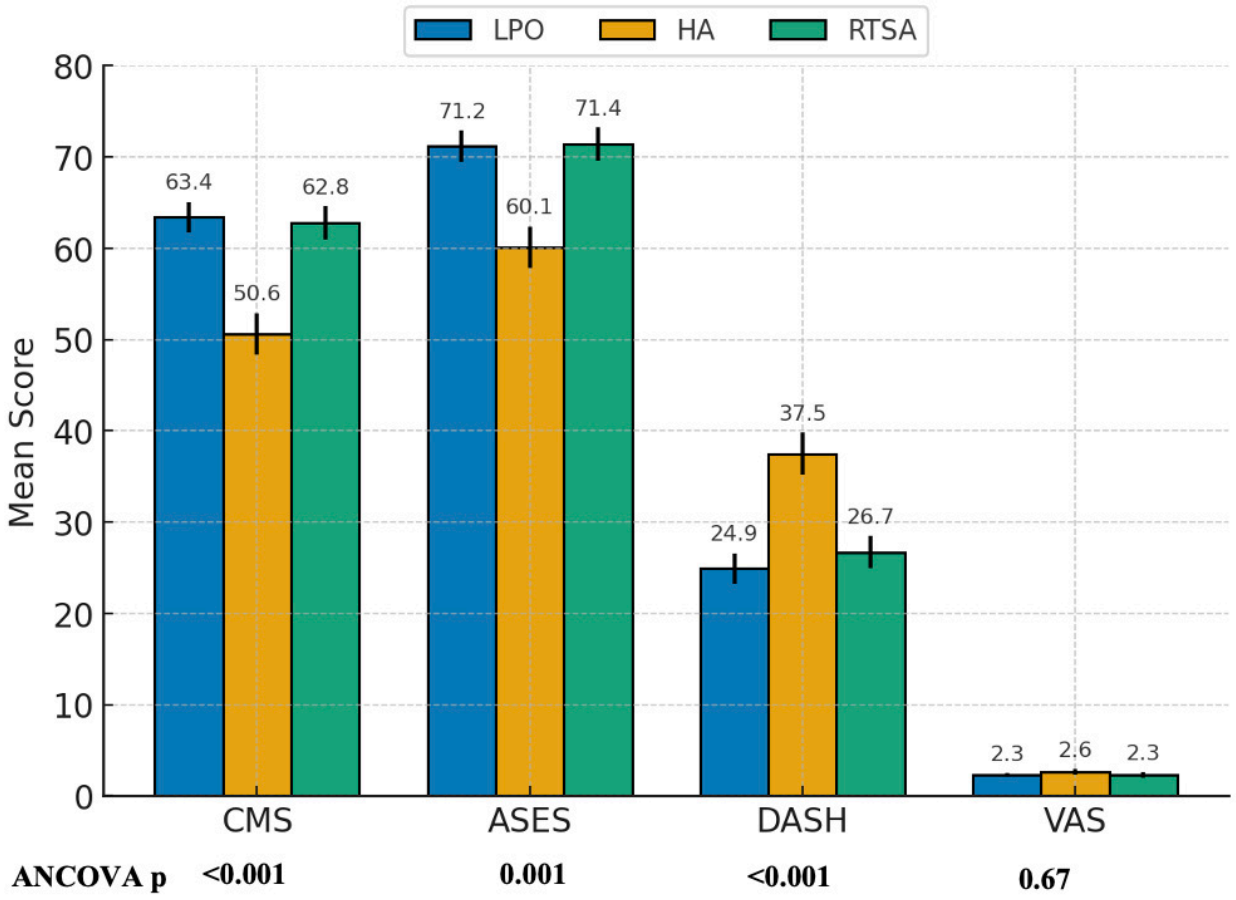

Figure 1: Comparison of Functional Scores According to Surgical Method. Bars show mean values (with error bars indicating standard deviations). LPO: locking plate osteosynthesis, HA: hemiarthroplasty, RTSA: reverse total shoulder arthroplasty. CMS: Constant–Murley score; ASES: American Shoulder and Elbow Surgeons score; DASH: Disabilities of the Arm, Shoulder and Hand score; VAS: Visual Analog Scale. $p<0.05$.

other two groups in terms of all functional parameters (p<0.001). (Figure 1)

On the basis of post hoc Tukey analysis, compared with the LPO and RTSA groups, HA had significantly lower scores by −13.5 (p<0.001) and −12.3 (p<0.001) points in the CMS group; −11.8 (p=0.001) and −11.4 (p=0.001) points in the ASES group; and significantly higher (worse) DASH scores by +13.3 (p<0.001) and +10.8 (p = 0.002) points, respectively. There were no significant differences in functional scores between the LPO and RTSA groups (p>0.05). (Table 2)

Table 2. Post Hoc Analysis of Functional Scores and Range of Motion (ROM) Values

Variables	I surgery type	J surgery type	Mean difference	p value
CMS	LPO	HA	13.53	<0.001
	LPO	RTSA	1.27	0.866
	HA	RTSA	12.26	<0.001
ASES	LPO	HA	11.81	0.001
	LPO	RTSA	0.42	0.985
	HA	RTSA	11.39	0.001
DASH	LPO	HA	-13.3	<0.001
	LPO	RTSA	-2.5	0.59
	HA	RTSA	10.8	0.002
Forward Flexion	LPO	HA	58.39	<0.001
	LPO	RTSA	20.76	<0.001
	HA	RTSA	37.63	<0.001
Abduction	LPO	HA	62.39	<0.001
	LPO	RTSA	24.51	<0.001
	HA	RTSA	37.88	<0.001
Internal Rotation	LPO	HA	1.59	0.015
	LPO	RTSA	-0.74	0.276
	HA	RTSA	-2.33	<0.001
External Rotation	LPO	HA	15.17	0.001
	LPO	RTSA	7.92	0.052
	HA	RTSA	7.25	0.156
Extension	LPO	HA	8.11	0.003
	LPO	RTSA	0.86	0.901
	HA	RTSA	-7.25	0.009

p<0.05 LPO: locking plate osteosynthesis, HA: hemiarthroplasty, RTSA: reverse total shoulder arthroplasty, CMS: Constant–Murley score, ASES: American Shoulder and Elbow Surgeons score, DASH: Disabilities of the Arm, Shoulder and Hand score.

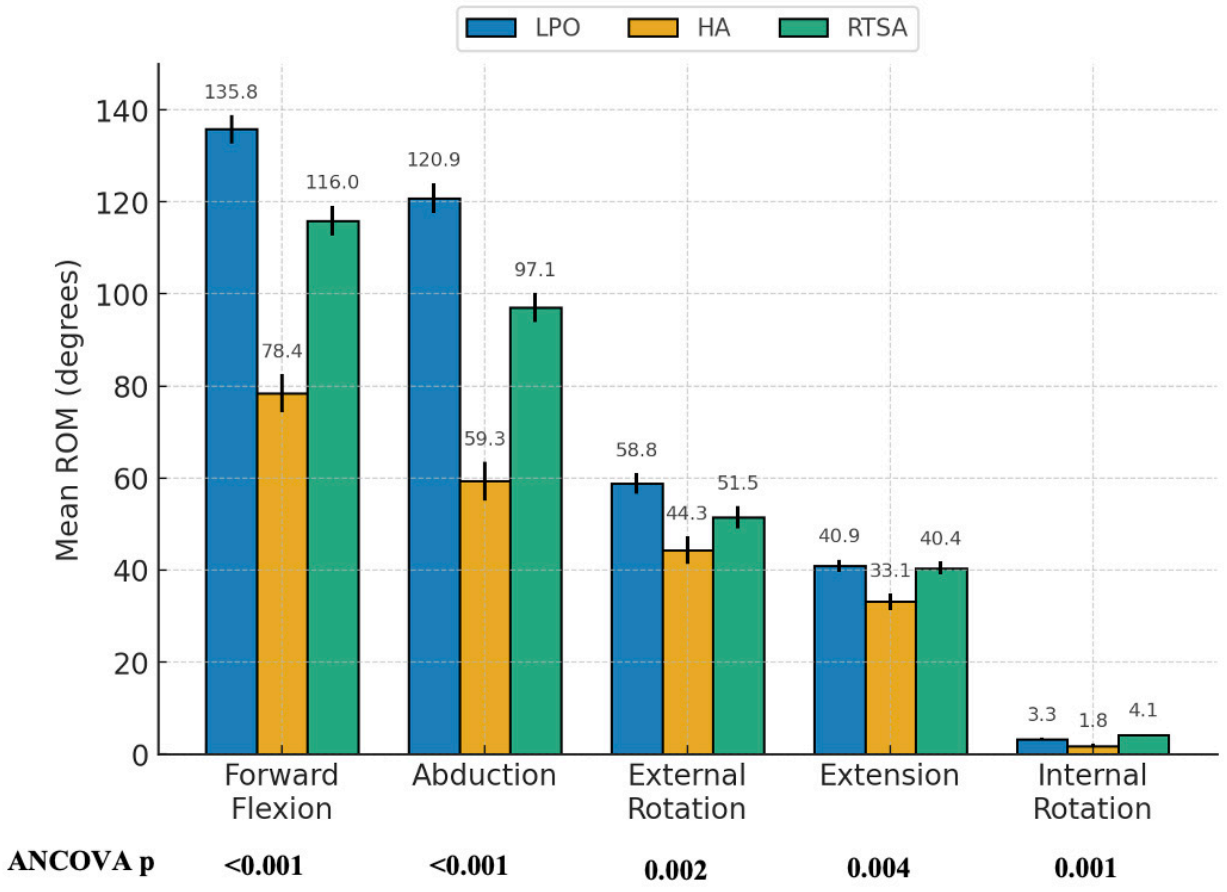

Figure 2: Comparison of Joint Range of Motion (ROM) Measurements According to Surgical Method. Bars show mean values in degrees (error bars = SD; internal rotation is measured on a point scale rather than degrees). LPO: locking plate osteosynthesis, HA: hemiarthroplasty, RTSA: reverse total shoulder arthroplasty. $p<0.05$.

Compared with the other groups, HA was associated with a significantly more limited range of motion in all planes (Tukey test, $p \leq 0.001$). Compared with the RTSA group, the LPO group presented superior results in forward flexion by +20.8° ($p<0.001$) and in abduction by +24.5° ($p<0.001$); however, there were no significant differences in other motion planes. (Table 2, Figure 2)

The difference in DASH scores (~13 points) between the HA group and the other groups exceeds the minimal clinically important difference (MCID) reported in the literature (10–15 points), indicating that this difference is likely to be perceptible by patients (12). The CMS and ASES values observed in the RTSA group were consistent with the mean values reported in the literature, whereas the outcomes in our HA cohort were notably lower (4,7,9).

Post hoc power analysis revealed that the study was adequately powered (power ≥ 0.80) to detect significant differences in the CMS, ASES, DASH, forward flexion, and abduction, with effect sizes (Cohen's f) ranging from 0.5--0.8. The power was lower (0.60–0.80) for external rotation, extension, and internal rotation, with smaller effect sizes ($f \approx 0.3$–0.4), indicating a potential risk of Type II errors for these outcomes. The nonsignificant VAS pain score ($p=0.67$) suggested insufficient power to detect small differences in pain outcomes ($f < 0.3$).

DISCUSSION

Our findings demonstrate that HA is associated with significantly poorer functional outcomes and range of

motion than both LPO and RTSA. The HA group presented the lowest CMS (50.6 ± 2.3), ASES (60.1 ± 2.3), and DASH (37.5 ± 2.3) scores, along with a significantly restricted range of motion in all planes (forward flexion, extension, abduction, and external and internal rotation). These results are consistent with the literature suggesting that HA provides suboptimal outcomes in the management of complex proximal humeral fractures (PHFs) (2,3,5). For example, a multicenter randomized controlled trial reported a superior CMS and range of motion in patients treated with RTSA than in those treated with HA (5). Similarly, another study showed that RTSA was superior to HA in terms of return to daily activities and functional mobility (2).

The subpar performance of HA may be attributed to its reliance on tuberosity healing and the integrity of rotator cuff function (1). In elderly patients, osteoporotic bone and complex multipart fractures can compromise tuberosity healing and lead to rotator cuff dysfunction, resulting in persistent pain and impaired function (4). In contrast, the RTSA offers a biomechanical construct that does not depend on the rotator cuff and allows for earlier mobilization with more predictable outcomes (2,5). Consequently, HA may not be considered the first-line option in the treatment of complex PHFs.

The comparison between LPO and RTSA is more nuanced. In our study, both techniques yielded similar functional scores (CMS, ASES, and DASH), but LPO was superior to RTSA in terms of forward flexion (+20.8°, $p<0.001$) and abduction (+24.5°, $p<0.001$). This finding contrasts with those of some studies, which reported superior functional scores and range of motion with RTSA over LPO (6). On the other hand, some studies have found no significant differences between LPO and RTSA. In fact, a few reports even suggest that LPO has advantages in certain motion parameters, especially for external and internal rotation (8,9). For example, a systematic review concluded that there was no statistically significant difference in functional outcomes between LPO and RTSA (9). Another study reported that while LPO yielded better results in terms of external and internal rotation, the overall functional scores were similar (8).

These inconsistencies in range of motion outcomes may stem from factors such as patient selection and fracture complexity. In our study, the proportion of Neer type 3 fractures was greater in the LPO group (55.6%) than in the RTSA group (31.2%). Since type 3 fractures are generally less complex, better outcomes with LPO in these patients might be expected. Moreover, the success of LPO relies on achieving and maintaining anatomical reduction, which can be challenging in osteoporotic bone and may increase the risk of complications such as screw loosening, avascular necrosis, or nonunion (6,13). However, in our series, the LPO group yielded satisfactory outcomes, likely reflecting careful patient selection and surgical expertise.

The choice between LPO and RTSA should be individualized on the basis of patient-specific factors. In patients with good bone quality and less complex fractures (e.g., Neer type 3), LPO may offer the advantages of preserving native anatomy and potentially better range of motion. In contrast, the RTSA may provide more reliable results and a lower risk of complications in cases of more complex fractures (e.g., Neer type 4) or when rotator cuff integrity is in question (8). Although our study did not report complication rates, the literature suggests that LPO may be associated with higher rates of complications and revision surgeries (8,13).

Other considerations in treatment selection include patient age, activity level, and surgeon experience. While RTSAs are generally more expensive than LPOs because of implant costs, there may also be concerns about the long-term durability of the prosthesis in elderly patients. However, previous studies have shown that RTSA can provide durable outcomes with low revision rates (2,6). In our study, with a mean follow-up period of approximately 29 months, no significant difference in functional outcomes was observed between LPO and RTSA, suggesting that both techniques may be effective in the short to medium term. Longer follow-up periods are necessary to assess the long-term durability of these treatments.

Although complication data were not collected in our study, the literature clearly demonstrates differing complication profiles among LPO, HA, and RTSA. LPO carries a high risk of mechanical failure in elderly osteoporotic bone, with reported complication rates of 30–50% and reoperation rates up to 25% (10,14). RTSA, by contrast, is associated with more favorable outcomes and lower complication rates—typically under 15%—with fewer revisions required (6,9). HA has moderate complication rates, but its effectiveness is heavily de-

pendent on tuberosity healing. Failure or resorption of the tuberosities is common and can lead to shoulder dysfunction and implant migration (14,15). These complication trends support our findings: the inferior functional outcomes in the HA group likely reflect tuberosity-related issues. Our LPO group included only successfully healed fractures, which may have biased outcomes favorably. In clinical settings, RTSA is increasingly preferred for complex Neer type 3–4 fractures in elderly patients due to its predictable results and independence from tuberosity integrity (5,6).

This study has several limitations. First, the retrospective design, limited sample size, and unequal distribution of patients across treatment groups may restrict the generalizability of the findings. Post hoc power analysis indicated that the study was adequately powered (power ≥ 0.80) to detect significant differences in the CMS, ASES, DASH, forward flexion, and abduction, supporting the robustness of these findings. However, the lower power (0.60–0.80) for external rotation, extension, and internal rotation suggests a potential risk of Type II errors, possibly due to smaller effect sizes or the limited sample size. The nonsignificant VAS pain scores likely reflect insufficient power to detect small differences. Additionally, there was an imbalance in fracture types among the treatment groups (with a greater proportion of type 3 fractures in the LPO group), which may have introduced selection bias, and we did not evaluate complication rates or revision surgeries. Future prospective studies with larger patient cohorts and longer follow-up periods are needed to validate these findings. Such studies should also evaluate the long-term outcomes and cost-effectiveness of different surgical interventions.

In conclusion, both LPO and RTSA can provide satisfactory functional outcomes when treating Neer type 3 and 4 proximal humeral fractures in patients aged 70 and above. Each method offers specific advantages depending on the clinical scenario. Given its association with poorer functional results, HA should be approached with caution. Treatment selection should be individualized on the basis of patient age, fracture pattern, bone quality, and surgeon experience. Our findings support RTSA as a reliable option for complex fractures, whereas LPO remains an effective alternative in appropriately selected patients.

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Abbreviations List

PHF: proximal humerus fracture
LPO: locking plate osteosynthesis
HA: hemiarthroplasty
RTSA: reverse total shoulder arthroplasty
CMS: Constant–Murley score
DASH: Disabilities of the Arm, Shoulder and Hand score
ASES: American Shoulder and Elbow Surgeons score
ROM: range of motion
VAS: Visual Analog Scale
CT: computed tomography
ANCOVA: analysis of covariance
SD: standard deviation
MCID: minimal clinically important difference

Ethics Approval and Consent to Participate

The study was approved by the ethical committee Istanbul Okmeydanı Training and Research Hospital in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration (Date: 04.02.2020, Decision No: 49). Patient records were reviewed retrospectively and were de-identified prior to analysis. Written informed consent was handled according to the ethics committee decision and institutional policy (e.g., obtained from participants/legal guardians or waived due to the retrospective design).

Consent for Publication

Not applicable. The manuscript does not contain any individual person's identifiable data (e.g., images, videos, or personal details).

Availability of Data and Materials

De-identified data that support the findings of this study are not publicly available due to patient confidentiality and institutional restrictions. Data may be made available by the corresponding author upon reasonable request and with permission from the relevant institution/ethics committee.

Competing Interests

The authors declare that they have no competing interests.

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Author Contributions

Idea/Concept: Nİ, SSF. Desıgn: Nİ, SSD. Control/Supervısıon Nİ, AK, AFB. Data Collectıon And/Or Processıng: AK, MBA, SG. Analysıs And/Or Interpretatıon: AK, MS, SG. Lıterature Revıew: Nİ, MS, AFB. Wrıtıng The Artıcle: Nİ. Crıtıcal Revıew: SSD, AK, AFB. References And Fundıngs: Nİ, AK.

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