ORIGINAL ARTICLE

European Archives of Medical Research

DOI: 10.14744/eamr.2026.94824
Eur Arch Med Res 2026;42(3):278-285

Clinical And Radiological Outcomes of Three Fixation Techniques For Isolated Greater Tuberosity Fractures

Yusuf Altuntas,[1] Mehmet Ali Bozca,[2] Enver Ipek,[1] Isin Kizilkan,[1] Muhammed Mansuroglu,[1] Osman Tugrul Eren[1]

[1]Department of Orthopedic and Traumatology, Health Science University Sisli Hamidiye Etfal Training and Research Hospital, Istanbul, Türkiye
[2]Department of Orthopedic and Traumatology, Health Science University Bakirkoy Sadi Konuk Training and Research Hospital, Istanbul, Türkiye

ABSTRACT

Objective: The objective of the study was to compare the clinical and radiological outcomes of anatomical plate fixation, open reduction with cannulated screw fixation, and percutaneous cannulated screw fixation in patients with isolated greater tuberosity fractures of the proximal humerus.

Materials and Methods: A retrospective comparative study was conducted on 36 patients who underwent surgical treatment for isolated greater tuberosity fractures. Patients were divided into three groups according to the fixation technique: Plate fixation (n=12), open cannulated screw fixation (n=14), and percutaneous cannulated screw fixation (n=10). Functional outcomes were evaluated using the Constant-Murley score, pain using the visual analog scale (VAS), and shoulder range of motion measurements. Radiological outcomes and complications were also assessed.

Results: The mean Constant score was significantly higher in the open cannulated screw fixation group compared with the plate fixation and percutaneous screw fixation groups (89.0±2.9 vs. 80.7±5.7 and 78.6±4.1, respectively; $p<0.001$). Patients treated with open screw fixation demonstrated significantly greater forward flexion, abduction, external rotation, and internal rotation. No significant differences were observed among the groups regarding VAS scores ($p=0.602$). Complication rates were comparable among the three groups.

Conclusion: All three fixation techniques provided satisfactory clinical and radiological outcomes in the treatment of isolated greater tuberosity fractures. However, open reduction with cannulated screw fixation was associated with superior functional outcomes and improved shoulder range of motion.

Keywords: Bone plates, Bone screws, Fracture fixation, Humeral fractures, Shoulder joint

Cite this article as: Altuntas Y, Bozca MA, Ipek E, Kizilkan I, Mansuroglu M, Eren OT. Clinical and radiological outcomes of three fixation techniques for ısolated greater tuberosity fractures Eur Arch Med Res 2026;42(3):278-285.

Address for correspondence: Yusuf Altuntas. Department of Orthopedic and Traumatology, Health Science University Sisli Hamidiye Etfal Training and Research Hospital, Istanbul, Türkiye

E-mail: dryusufaltuntas@gmail.com **ORCID ID:** 0000-0001-8561-7736

Submitted: 14.06.2026 **Revised:** 08.07.2026 **Accepted:** 10.07.2026 **Available Online:** 18.09.2026

European Archives of Medical Research – Available online at www.eurarchmedres.org

INTRODUCTION

Fractures of the proximal humerus represent one of the most frequently encountered injuries of the shoulder girdle in adults, accounting for approximately 5% of all fractures.[1,2] Approximately 20% of proximal humeral fractures involve the greater tuberosity as an isolated injury.[3] While proximal humerus fractures are predominantly observed in the elderly osteoporotic population following low-energy trauma, isolated greater tuberosity fractures are more frequently encountered in relatively younger adults.[2,4] Because the greater tuberosity serves as the insertion site of the rotator cuff tendons, fractures involving this region may significantly affect shoulder biomechanics and function.[5-7] Superior or posterior displacement of the fragment may result in subacromial impingement, restricted range of motion, and impaired shoulder function.[8]

Most isolated greater tuberosity fractures can be successfully managed conservatively, and more than 80% of cases do not require surgical intervention.[3,9] However, surgical treatment is generally recommended for fractures with displacement >5 mm.[4,10,11] In athletes and manual laborers, some authors have advocated surgical intervention even for displacement exceeding 3 mm.[9,12] The primary goals of treatment are to achieve anatomical reduction, provide stable fixation, and facilitate early rehabilitation.

Various surgical techniques have been described for the treatment of isolated greater tuberosity fractures, including open reduction and plate osteosynthesis, open reduction with cannulated screw fixation, percutaneous cannulated screw fixation, and arthroscopically assisted suture or screw techniques.[7,13] The choice of surgical method is influenced by fracture morphology, fragment size, direction of displacement, bone quality, and patient-related factors. Although satisfactory clinical and radiological outcomes have been reported with different surgical techniques, each method has its own advantages and disadvantages.[14] However, clinical studies directly comparing anatomical plate fixation, open reduction with cannulated screw fixation, and percutaneous cannulated screw fixation remain scarce.[13-17] Therefore, the current level of evidence regarding the optimal fixation method for isolated greater tuberosity fractures remains insufficient.

This retrospective comparative study evaluated the clinical and radiological performance of three fixation strategies; anatomical plate fixation, open reduction with cannulated screw fixation, and percutaneous cannulated screw fixation in patients with isolated greater tuberosity fractures. We hypothesized that, although different fixation techniques may provide comparable union rates, they may differ with respect to functional outcomes and complication profiles.

MATERIALS AND METHODS

Institutional ethics committee approval was obtained from the Health Sciences University Şişli Hamidiye Etfal Teaching and Research Hospital Health Practice and Research Center Clinical Research Ethics Committee before data collection (approval date/number: March 31, 2026/3434), and the study was conducted in accordance with the Declaration of Helsinki.

This study was designed as a retrospective, single-center, comparative observational study.

Medical records and radiographic images of patients who underwent surgical treatment for isolated greater tuberosity fractures between January 2015 and March 2024 were retrospectively reviewed.

Adult patients (≥18 years) who underwent surgical fixation, open cannulated screw fixation, or percutaneous cannulated screw fixation for isolated greater tuberosity fractures and had a minimum follow-up period of 12 months were included in the study.

Patients with concomitant surgical neck fractures, three- or four-part proximal humerus fractures, previous surgery involving the affected shoulder, pathological fractures, associated neurovascular injuries, concomitant rotator cuff repair, insufficient radiographic records, or incomplete clinical follow-up were excluded.

After screening according to predefined eligibility criteria, a total of 36 patients were enrolled in the study. Patients were divided into three groups according to the fixation method used:

- Plate fixation group (*n*=12)
- Open cannulated screw fixation group (*n*=14)
- Percutaneous cannulated screw fixation group (*n*=10) (Fig. 1).

Surgical treatment was indicated for isolated greater tuberosity fractures with displacement >5 mm. In overhead athletes and heavy manual workers, surgical fixation was also indicated for fractures with displacement >3 mm.

Surgical Technique

Surgical treatment was carried out under general anesthesia in the beach-chair position by experienced shoulder surgeons. In the plate fixation group, fracture reduction was achieved through a deltoid-splitting approach followed by fixation with a proximal humeral locking plate. In the open cannulated screw fixation group, fracture reduction was performed through a limited open approach and stabilized using partially

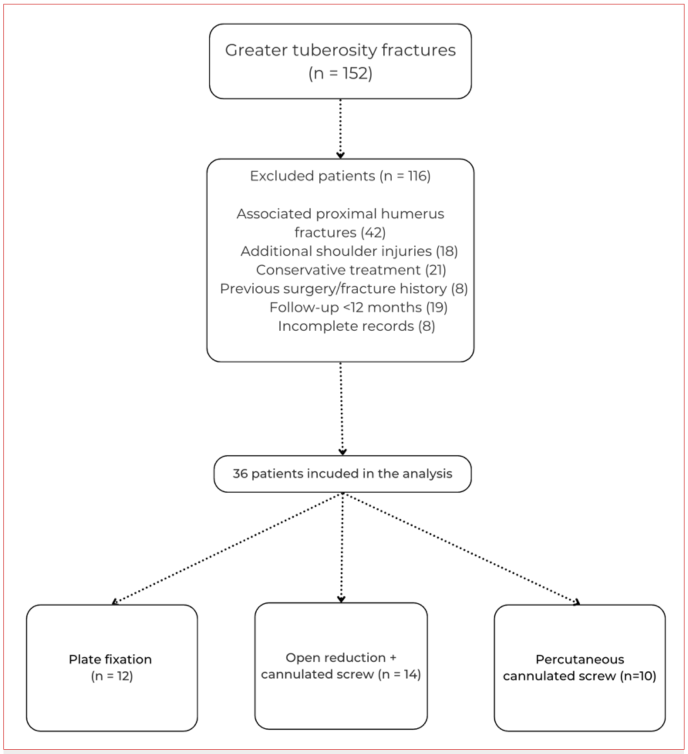

Figure 1. Patient selection flow chart.

threaded cannulated screws. In the percutaneous cannulated screw fixation group, closed or minimally invasive reduction was achieved under fluoroscopic guidance followed by percutaneous cannulated screw fixation.

Postoperatively, all patients followed the same rehabilitation protocol. Elbow, wrist, and hand range-of-motion exercises were initiated on the first post-operative day, while the shoulder was immobilized in a sling for 6 weeks. Pendulum and passive shoulder range-of-motion exercises were initiated after 3 weeks. Active-assisted and active range-of-motion exercises were started after 6 weeks, followed by strengthening exercises at 8–12 weeks. Patients were allowed to return to unrestricted daily activities after 3 months and to sports activities after 6 months.

Clinical Evaluation

Demographic variables including age, sex, injured side, dominant extremity involvement, mechanism of injury, and duration of follow-up were recorded. Functional assessment included the Constant–Murley score, while pain was evaluated using the visual analog scale (VAS). At the final follow-up visit, shoulder range of motion was evaluated, including forward flexion, abduction, external rotation, and internal rotation.

Radiological evaluation

Pre-operative computed tomography (CT) scans and plain radiographs were retrospectively reviewed. Fractures were classified according to the Mutch classification. Fragment displacement was measured on pre-operative CT images as the maximum displacement of the greater tuberosity fragment.

Standard anteroposterior shoulder radiographs obtained preoperatively, immediately postoperatively, and during routine follow-up visits were reviewed. Radiological assessment included fracture union, time to union, reduction loss, secondary displacement, and implant-related complications.

Fracture union was defined as the presence of bridging trabeculation across the fracture site on radiographs together with the absence of clinical tenderness at the fracture site. Time to union was recorded as the interval between surgery and radiographic evidence of fracture healing.

Reduction loss was defined as any deterioration in fracture reduction observed on follow-up radiographs compared with the immediate post-operative radiographs. Secondary displacement was defined as any post-operative displacement of the fracture fragment detected during follow-up. Radiographic evaluations were performed by reviewing the patients' follow-up radiographs and medical records.

Outcome Measures

The primary outcome measures were functional outcomes assessed by the Constant-Murley Score at final follow-up. Secondary outcome measures included VAS score, shoulder range of motion, time to union, reduction loss, secondary displacement, reoperation, and implant-related complications.

Statistical Analysis

Statistical analyses were performed using IBM Statistical Package for the Social Sciences Statistics software (Version 26.0; IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean±standard deviation (SD) and categorical variables as frequency and percentage.

The normality of data distribution was assessed using the Shapiro–Wilk test. Homogeneity of variances was evaluated using Levene's test. Comparisons of continuous variables among the three treatment groups were performed using one-way analysis of variance for normally distributed data. When a significant overall difference was detected, pairwise comparisons were conducted using Tukey's honestly significant difference test. Because VAS scores did not demonstrate normal distribution, comparisons among groups were performed using the Kruskal–Wallis test.

Categorical variables were compared using Pearson's chi-square test or Fisher's exact test, as appropriate. For all analyses, a two-tailed p<0.05 was considered statistically significant. In addition to p-values, 95% confidence intervals (95% CIs) were reported for key continuous outcome measures.

RESULTS

A total of 36 patients were included in the study, comprising 12 patients treated with plate fixation, 14 patients treated with open reduction screw fixation, and 10 patients treated with percutaneous screw fixation. All fractures were classified as Type II (split-type). The mean pre-operative fragment displacement was 7.8±2.1 mm (range, 3.5–12.4 mm), and all fractures demonstrated superior displacement of the greater tuberosity fragment. The mean age was 53.9±9.3 years in the plate group, 51.8±9.1 years in the open reduction screw group, and 50.1±7.8 years in the percutaneous screw group. Mean follow-up duration was 43.7±12.0 months, 40.3±10.3 months, and 41.6±7.9 months, respectively. Baseline demographic and clinical variables were comparable across treatment groups regarding age, sex, diabetes mellitus, smoking status, trauma mechanism, follow-up duration, or time from injury to surgery (all p>0.05). However, operative time differed significantly among the groups (p<0.001), with the percutaneous cannulated screw fixation group demonstrating the shortest mean operative time (115.1±18.4 min) compared with the plate fixation (157.5±10.2 min) and open cannulated screw fixation groups (152.7±16.8 min). Baseline demographic and clinical characteristics are presented in Table 1.

Table 1. Baseline demographic and clinical characteristics of the study groups

Variable	Plate (*n*=12)	Open screw (*n*=14)	Percutaneous screw (*n*=10)
Age (years)	53.9±9.3	51.79±9.1	50.10±7.79
Follow-up duration (months)	43.7±12.0	40.3±10.3	41.6±7.9
Gender, *n* (%)			
Male	6 (50.0)	6 (42.9)	6 (60.0)
Female	6 (50.0)	8 (57.1)	4 (40.0)
Diabetes mellitus, *n* (%)			
Yes	2 (16.7)	4 (28.6)	2 (20.0)
No	10 (83.3)	10 (71.4)	8 (80.0)
Smoking, *n* (%)			
Yes	7 (58.3)	9 (64.3)	7 (70.0)
No	5 (41.7)	5 (35.7)	3 (30.0)
Trauma type, *n* (%)			
High-energy	2 (16.7)	2 (14.3)	2 (20.0)
Low-energy	10 (83.3)	12 (85.7)	8 (80.0)
Time from injury to surgery (days)	2.08±0.79	1.86±0.86	1.60±0.70
Operation time (minutes)	157.5±10.2	152.7±16.8	115.1±18.4

Data are presented as mean±SD or *n* (%)

At final follow-up, the mean VAS score was 0.67±0.65 in the plate group, 0.57±0.51 in the open reduction screw group, and 0.40±0.52 in the percutaneous screw group. No statistically significant difference was observed among the groups (p=0.602).

The mean Constant score was 80.7±5.7 (95% CI, 77.1–84.4) in the plate group, 89.0±2.9 (95% CI, 87.4–90.7) in the open reduction screw group, and 78.6±4.1 (95% CI, 75.7–81.5) in the percutaneous screw group. Group comparisons demonstrated a significant effect among the groups (p<0.001) (Fig. 2).

Mean forward flexion was 143.75±9.80° (95% CI, 137.52–149.98°) in the plate group, 151.07±7.89° (95% CI, 146.52–155.63°) in the open reduction screw group, and 142.00±10.33° (95% CI, 134.61–149.39°) in the percutaneous screw group. The overall comparison demonstrated a statistically significant difference (p=0.046).

Mean abduction was 139.17±7.64° (95% CI, 134.31–144.02°) in the plate group, 148.57±11.17° (95% CI, 142.12–155.02°) in the open reduction screw group, and 137.00±6.75° (95% CI, 132.17–141.83°) in the percutaneous screw group. A statistically significant difference was identified among the groups (p=0.007).

Mean external rotation was 57.08±7.22° (95% CI, 52.50–61.67°) in the plate group, 64.29±6.75° (95% CI, 60.39–68.18°) in the open reduction screw group, and 55.50±9.27° (95% CI, 48.87–62.13°) in the percutaneous screw group. The overall comparison was statistically significant (p=0.016).

Mean internal rotation was 49.58±4.98° (95% CI, 46.42–52.75°) in the plate group, 55.71±6.16° (95% CI, 52.16–59.27°) in the open reduction screw group, and 49.50±3.69° (95% CI, 46.86–52.14°) in the percutaneous screw group. A statistically significant difference was observed among the groups (p=0.006). Detailed clinical outcome data are presented in Table 2.

Fracture healing was confirmed radiographically in every patient. No cases of non-union or additional secondary displacement were observed during follow-up. Complications occurred in 3 patients (25.0%) in the plate fixation Group, 2

Eur Arch Med Res 2026;42(3):278-285

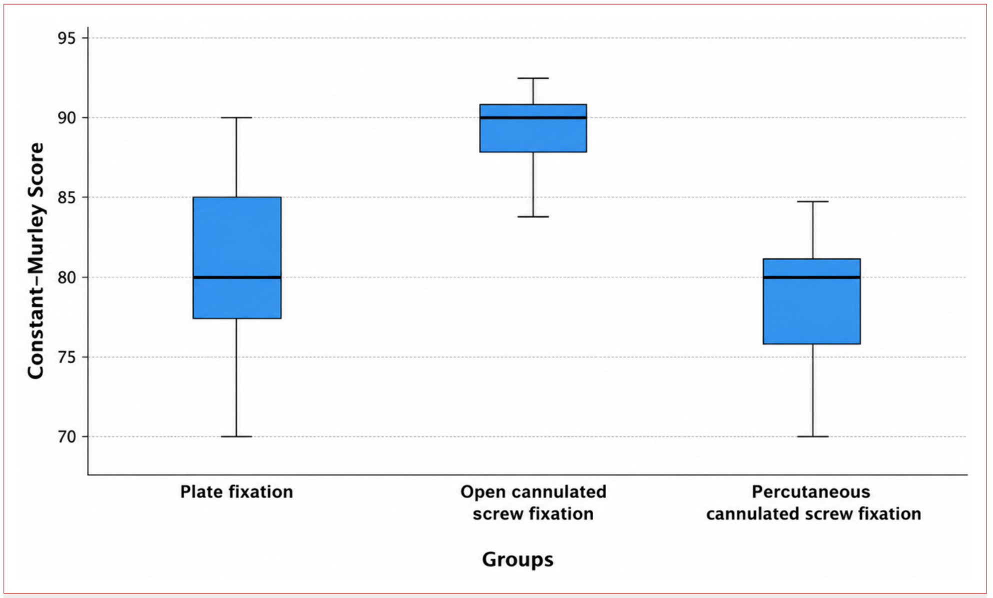

Figure 2. Box plot showing the distribution of Constant-Murley scores among the three fixation groups. Patients treated with open reduction and cannulated screw fixation demonstrated higher functional scores than those treated with plate fixation or percutaneous screw fixation.

patients (14.3%) in the open reduction screw fixation group, and 3 patients (30.0%) in the percutaneous screw fixation group. There was no statistically significant difference in the overall complication rates among the three groups (p=0.633). In the plate group, complications included two infections and one case of shoulder stiffness. In the open reduction screw fixation group, two cases of loss of reduction were observed. In the percutaneous screw fixation group, three cases of screw back-out occurred. Reoperation was performed in all patients with complications, including debridement for infection, manipulation under anesthesia for shoulder stiffness, revision surgery for loss of reduction, and implant removal for screw back-out (Table 3).

DISCUSSION

There is still no consensus regarding the optimal surgical treatment for isolated greater tuberosity fractures. The principal observation of the present study was that patients treated with open reduction and cannulated screw fixation achieved higher Constant scores and better shoulder range of motion compared with those treated with anatomical plate fixation or percutaneous cannulated screw fixation. In contrast, no substantial differences were observed among the groups in terms of pain levels, union rates, or complication profiles. These findings suggest that all three techniques can provide acceptable clinical and radiological outcomes, whereas open reduction with cannulated screw fixation may offer certain advantages with respect to functional recovery.

Table 2. Comparison of clinical outcomes between fixation groups

Variable	Plate (*n*=12)	Open screw (*n*=14)	Percutaneous screw (*n*=10)	p
VAS score	0.67±0.65	0.57±0.51	0.40±0.52	0.602†
Constant score	80.7±5.7	89.0±2.9	78.6±4.1	**<0.001**
Forward flexion (°)	143.75±9.80	151.07±7.89	142.00±10.33	**0.046**
Abduction (°)	139.17±7.64	148.57±11.17	137.00±6.75	**0.007**
External rotation (°)	57.08±7.22	64.29±6.75	55.50±9.27	**0.016**
Internal rotation (°)	49.5±4.9	55.71±6.16	49.50±3.69	**0.006**

Data are presented as mean±standard deviation. VAS: Visual Analog Scale, ANOVA: Analysis of variance. †Kruskal–Wallis test; all other comparisons performed using one-way ANOVA

Table 3. Radiological outcomes, implant-related complications, and reoperations

Variable	Plate (*n*=12)	Open screw (*n*=14)	percutaneous Screw (*n*=10)	p
Infection, *n* (%)	2 (16.7)	0	0	
Shoulder stiffness, *n* (%)	1 (8.3)	0	0	
Loss of reduction, *n* (%)	0	2 (14.3)	0	
Screw back-out, *n* (%)	0	0	3 (30.0)	
Reoperation, *n* (%)	3 (25.0)	2 (14.3)	3 (30.0)	
Fracture union, *n* (%)	12 (100)	14 (100%)	10 (100)	
Overall complication, *n* (%)	3 (25.0)	2 (14.3)	3 (30.0)	0.633

Data are presented as *n* (%). Overall complication rates were compared using Pearson's Chi-square test

Previous studies have demonstrated favorable outcomes with various surgical techniques for isolated greater tuberosity fractures.[10,13,16-19] Tao et al.,[6] in their study comparing three different plate-based fixation techniques, reported satisfactory clinical outcomes across all groups. Similarly, Choi et al.[7] demonstrated high union rates and good functional outcomes in patients treated with low-profile locking plates. In a systematic review, Levy et al.[19] concluded that although fixation techniques generally provide satisfactory outcomes, plate-based fixation may result in greater construct stiffness and an increased risk of post-operative motion restriction compared with screw fixation. Studies have also shown that plate fixation, screw fixation, and arthroscopic techniques can provide satisfactory results when used with appropriate indications.[11,16,20,21] Consistent with these findings, all three groups in the present study achieved low pain scores and acceptable functional outcomes.

In the current study, patients treated with open reduction and cannulated screw fixation exhibited superior Constant scores and better range of motion compared with the other groups. One possible explanation is that open reduction allows more reliable restoration of anatomical alignment, while cannulated screw fixation provides adequate stability with less implant bulk. Although anatomical plates offer the advantage of rigid fixation, particularly in comminuted fractures, they require more extensive soft-tissue dissection and greater implant volume, which may adversely affect post-operative shoulder motion in some patients. On the other hand, previous studies have reported favorable clinical outcomes with percutaneous screw fixation, highlighting the advantages of a minimally invasive approach and lower soft-tissue morbidity. Furthermore, previous biomechanical and clinical studies have shown that cannulated screw fixation provides biomechanical stability comparable to, or greater than, that of other commonly used fixation methods.[11,14,22-24] Therefore, the superior functional outcomes observed in the open reduction and cannulated screw fixation group in the present study are unlikely to be explained solely by differences in fixation strength. More accurate restoration of anatomical reduction achieved through direct visualization during open reduction may have contributed to these findings.

Another notable finding was the significantly shorter operative time in the percutaneous cannulated screw fixation group. In our study, the operative time in the percutaneous cannulated screw fixation group was found to be significantly shorter than in the other groups. This finding can be explained by the minimally invasive nature of the percutaneous approach, which requires less soft-tissue dissection and less surgical exposure. Previous studies have also reported that minimally invasive or percutaneous techniques can shorten operative time and reduce soft-tissue damage.[25] However, in our study, this perioperative advantage did not translate into superior functional outcomes. Therefore, operative time alone should not be the sole determining factor in the selection of a surgical method; fracture morphology, the achievement of stable fixation, and expected functional outcomes must be evaluated together.

Complication rates were relatively low in all three groups. Infections and shoulder stiffness were observed in the plate fixation group, loss of reduction occurred in the open reduction screw fixation group, and screw back-out was encountered in the percutaneous screw fixation group. Nevertheless, no substantial differences in complication rates were identified among the groups. Overall, the complication profile observed in the present study was consistent with those reported in previous studies. In particular, screw back-out and loss of reduction are recognized complications of cannulated screw fixation, whereas infection and post-operative stiffness have been reported following open surgical procedures.[5,11,15,19,20,24]

Because fracture morphology plays an important role in treatment selection, only Mutch Type II (split-type) fractures were included in this study. This fracture pattern generally provides sufficient bone stock for different fixation strategies, including plate fixation and cannulated screw fixation, allowing a more homogeneous comparison of the evaluated osteosynthesis techniques.[12,13,15,23,25] Although several fixation methods have been described for Mutch Type II fractures, direct comparisons between open and percutaneous cannulated screw fixation remain limited. Therefore, our findings should be interpreted primarily in the context of Mutch Type II fractures and may not be directly generalizable to other fracture patterns.

This study has several strengths. To the best of our knowledge, studies directly comparing anatomical plate fixation, open reduction with cannulated screw fixation, and percutaneous cannulated screw fixation are scarce. In addition, all patients were treated at a single institution and followed according to a similar post-operative protocol, thereby reducing heterogeneity among the groups. Furthermore, the inclusion of both clinical and radiological outcomes, as well as complication profiles, enhances the comprehensiveness of the study.

Limitations

Certain limitations should be taken into account when interpreting the results. First, the retrospective design introduces the possibility of selection bias. Second, no a priori sample size or power calculation was performed because of the retrospective design of the study. Therefore, the relatively small sample size may have limited the statistical power, particularly for detecting differences in infrequent outcomes such as post-operative complications. Accordingly, non-significant differences in complication rates should be interpreted with caution. Third, because the choice of surgical technique was based on surgeon preference rather than randomization, the possibility of selection bias and residual confounding cannot be excluded.

CONCLUSION

Overall, anatomical plate fixation, open reduction with cannulated screw fixation, and percutaneous cannulated screw fixation all provided satisfactory clinical and radiological outcomes in the treatment of isolated greater tuberosity fractures. However, patients treated with open reduction and cannulated screw fixation achieved higher Constant scores and better shoulder range of motion. Larger prospective comparative studies are warranted to further clarify the optimal fixation strategy for isolated greater tuberosity fractures.

DECLARATIONS

Ethics Committee Approval: The study protocol was approved by the Health Sciences University Şişli Hamidiye Etfal Teaching and Research Hospital Health Practice and Research Center Clinical Research Ethics Committee (No: 3434 Date: 31/03/2026).

Informed Consent: Informed consent was obtained from all patients involved in this study.

Conflict of Interest: The authors declare that there is no conflict of interest.

Funding: The authors received no financial support for the research and/or authorship of this article.

Use of AI for Writing Assistance: Not declared.

Authorship Contributions: Concept – YA, OTE; Design – YA, OTE, MAB; Supervision – OTE; Resources – OTE; Materials – EI, IK, MM; Data collection &/or processing – YA, MAB, OTE; Analysis and/or interpretation – YA, MAB, OTE; Literature search – YA, MAB; Writing – YA; Critical review – MAB, EI, IK, MM, OTE.

Acknowledgment: The authors thank the clinical staff of the Orthopaedics and Traumatology Department at Istanbul Sisli Hamidiye Etfal Training and Research Hospital for their assistance during data collection.

Peer-review: Externally peer-reviewed.

REFERENCES

1. Şeşen H, Taşkesen A, Tağral AS, Özdemir M, Demirkale İ, Altay M. Humerus cisim kırıklarının cerrahi tedavisinde konvansiyonel plaklama mı minimal invaziv plak osteosentezi mi daha üstün? Abant Med J 2017;6:1–5.
2. Walter N, Szymski D, Kurtz SM, Lowenberg DW, Alt V, Lau E, et al. Proximal humerus fractures - epidemiology, comparison of mortality rates after surgical versus non-surgical treatment, and analysis of risk factors based on Medicare registry data. Bone Joint Res 2023;12:103–12.
3. Bell JE, Leung BC, Spratt KF, Koval KJ, Weinstein JD, Goodman DC, et al. Trends and variation in incidence, surgical treatment, and repeat surgery of proximal humeral fractures in the elderly. J Bone Joint Surg Am 2011;93:121–31.
4. Gruson KI, Ruchelsman DE, Tejwani NC. Isolated tuberosity fractures of the proximal humeral: current concepts. Injury 2008;39:284–98.
5. Kumar S, Mishra A, Singh H, Clark D, Espag M, Tambe A. Surgical fixation of isolated greater tuberosity fractures of the humerus- systematic review and meta-analysis. J Clin Orthop Trauma 2021;23:101670.
6. Tao F, Li L, Wang D, Dong J, Zhou D, Song W. Comparison study among three surgical methods in the treatment of isolated fractures of the greater tuberosity of the humerus. Ther Clin Risk Manag 2024;20:483–93. Erratum in: Ther Clin Risk Manag 2024;20:557–8.

7. Choi S, Shin D, Kim S, Kwack BH. Outcomes of open reduction and internal fixation using 2.0/2.4 mm locking compression plate in isolated greater tuberosity fractures of humerus. J Musculoskelet Trauma 2025;38:32–9.
8. Saleem J, Guevel B, Gillott E, Mitchell C, Widjono A, Qavi A, et al. Radiological analysis and outcomes of isolated greater tuberosity fracture-dislocations. Ann R Coll Surg Engl 2024;106:270–6.
9. Platzer P, Kutscha-Lissberg F, Lehr S, Vecsei V, Gaebler C. The influence of displacement on shoulder function in patients with minimally displaced fractures of the greater tuberosity. Injury 2005;36:1185–9.
10. Dimakopoulos P, Panagopoulos A, Kasimatis G. Transosseous suture fixation of proximal humeral fractures. J Bone Joint Surg Am 2007;89:1700–9.
11. Nóbrega Catelas D, Correia L, Adan E Silva F, Ribau A, Claro R, Barros LH. Greater tuberosity fractures of the humerus: complications and long-term outcomes after surgical treatment. Eur J Orthop Surg Traumatol 2024;34:2541–7.
12. Park TS, Choi IY, Kim YH, Park MR, Shon JH, Kim SI. A new suggestion for the treatment of minimally displaced fractures of the greater tuberosity of the proximal humerus. Bull Hosp Jt Dis 1997;56:171–6.
13. Liao W, Zhang H, Li Z, Li J. Is Arthroscopic technique superior to open reduction ınternal fixation in the treatment of ısolated displaced greater tuberosity fractures? Clin Orthop Relat Res 2016;474:1269–79.
14. Colò G, Fusini F, Faoro L, Popolizio G, Ferraro S, Ippolito G, et al. Current evidence and surgical strategies in the management of greater tuberosity fracture-dislocations: A narrative review. J Clin Med 2025;14:5159.
15. Lee WY, Shin HD, Kim KC, Cha SM, Jeon YS, Kim DH. Open reduction and stable internal fixation using a 3.5-mm locking hook plate for isolated fractures of the greater tuberosity of the humerus: A 2-year follow-up study using an innovative fixation Method. Clin Orthop Surg 2021;13:293–300.
16. Lee KR, Bae KC, Yon CJ, Cho CH. Hook plate fixation for isolated greater tuberosity fractures of the humerus. Clin Shoulder Elb 2017;20:222–9.
17. Elshahhat A, Nour K. Modified hook wiring technique for greater tuberosity fractures: a prospective study. Acta Orthop Belg 2025;91:209–20.
18. Williams GR Jr, Wong KL. Two-part and three-part fractures: open reduction and internal fixation versus closed reduction and percutaneous pinning. Orthop Clin North Am 2000;31:1–21.
19. Levy DM, Erickson BJ, Harris JD, Bach BR Jr, Verma NN Jr, Romeo AA. Management of isolated greater tuberosity fractures: A systematic review. Am J Orthop (Belle Mead NJ) 2017;46:E445–53.
20. Dussing F, Plachel F, Grossauer T, Hoffelner T, Schulz E, von Keudell A, et al. Anterior shoulder dislocation and concomitant fracture of the greater tuberosity: Clinical and radiological results. Obere Extrem 2018;13:211–7.
21. Elkady RH, Fuda N. Percutaneous screw fixation of isolated fractures of the greater tuberosity of the humerus. Int J Orthop Sci 2017;3:256–60.
22. Braunstein V, Wiedemann E, Plitz W, Muensterer OJ, Mutschler W, Hinterwimmer S. Operative treatment of greater tuberosity fractures of the humerus--a biomechanical analysis. Clin Biomech (Bristol) 2007;22:652–7.
23. Chang CJ, Su WR, Hsu KL, Hong CK, Kuan FC, Chang CH, et al. Augmented cerclage wire improves the fixation strength of a two-screw construct for humerus split type greater tuberosity fracture: a biomechanical study. BMC Musculoskelet Disord 2021;22:350.
24. Rouleau DM, Mutch J, Laflamme GY. Surgical treatment of displaced greater tuberosity fractures of the humerus. J Am Acad Orthop Surg 2016;24:46–56.
25. Cao L, Weng W, Song S, Li H, Su J. Comparison of effectiveness between minimally invasive cannulated screw and open reduction and plate fixation in treatment of humeral greater tuberosity fracture. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi 2013;27:418-22.