Cerrahpaşa Med J 2026; 50: 1-5 ORIGINAL ARTICLE

# Trend of Convergent Screw Placement in Variable Angle Proximal Humerus Plates

Olgar Birsel, Buğra Güllü, İlker Eren, Mehmet Demirhan

Department of Orthopaedics and Traumatology, Koç University, School of Medicine, İstanbul, Türkiye

***Cite this article as:*** Birsel O, Güllü B, Eren İ, Demirhan M. Trend of convergent screw placement in variable angle proximal humerus plates. *Cerrahpaşa Med J*. 2026, 50, 0116, doi:10.5152/cjm.2026.25116.

### *What is already known on this topic?*

- *Locking plate fixation of proximal humerus fractures is associated with high complication rates, including screw penetration and loss of reduction.*
- *Despite their theoretical advantages, variable angle plates have not consistently shown superior clinical outcomes compared with fixed angle plates.*

### *What this study adds to this topic?*

- *Radiological analysis showed that screws inserted through variable angle proximal humerus plates tend to be placed in a convergent configuration, resulting in reduced screw divergence and smaller humeral head coverage compared with fixed angle constructs.*
- *This convergent screw placement may limit the biomechanical advantages that variable angle technology is designed to provide.*
- *Awareness of this tendency may encourage more deliberate screw trajectory planning and guide future clinical research.*


## *Abstract*

**Objective:** Variable angle locking plates were developed to allow flexible screw trajectories and broader fixation within the humeral head in proximal humerus fractures, where fixation failure remains a common challenge. Whether this theoretical advantage is utilized in clinical practice remains unclear.

**Methods:** This retrospective radiographic study evaluated 43 patients treated with locking plate fixation for proximal humerus fractures between 2015 and 2023. Eighteen patients received variable angle plates and 25 fixed angle plates. Screw trajectories were assessed on early postoperative radiographs and intraoperative fluoroscopy. Vertical screw distribution was measured as the percentage of anatomical neck coverage in the coronal plane, and axial screw spread was defined as the angle between the 2 most divergent screws on lateral fluoroscopic images.

**Results:** Screws placed through variable angle plates covered a smaller proportion of the anatomical neck compared with fixed angle constructs. In the axial plane, fixed angle plates demonstrated a mean screw divergence of 40°, whereas variable angle plates showed significantly narrower spread, with a mean divergence of 15.4° ($P < .001$). Variable angle screws were therefore placed in a more convergent configuration despite the availability of angular freedom.

**Conclusion:** Despite their intended design, variable angle proximal humerus plates demonstrated a consistent tendency toward convergent screw placement in clinical practice, resulting in reduced humeral head coverage compared with fixed angle constructs. Further clinical studies are required to determine whether this radiographic mismatch has clinical relevance and whether deliberate screw divergence influences fixation durability and outcomes.


**Keywords:** Fixed angle, locking plate, poliaxial screw, proximal humerus fracture, variable angle

## Introduction

Proximal humerus fractures account for approximately 5% of all adult fractures and are particularly common in the elderly population.[1] Despite advances in surgical techniques and implant design, locking plate fixation continues to carry high complication rates, reported between 12% and more than 50%, with reoperation rates approaching 25%.[2,3,4] One of the most frequent failure modes is screw penetration into the glenohumeral joint, often associated with loss of reduction or avascular necrosis of the humeral head.[5,6]

The evolution of periarticular fracture fixation has increasingly focused on fragment-specific strategies, supported by computed tomography (CT)-based classification systems that identify key articular and metaphyseal fragments requiring targeted stabilization.[4,5] Variable angle locking plates were developed within this framework to allow individualized screw trajectories toward specific fragments or regions of optimal bone quality, rather than following predetermined fixed orientations.[7,8] Although these implants provide the theoretical ability to optimize screw placement and enhance screw divergence within the humeral head, previous authors have noted that screw orientation in clinical practice often depends on surgeon intuition rather than an objective or standardized strategy.[9] Whether this available angular freedom results in broader, fragment-specific screw distribution during actual surgeries remains uncertain.

**Received:** January 5, 2026 **Revision Requested:** January 19, 2026 **Last Revision Received:** January 19, 2026 **Accepted:** February 11, 2026 **Publication Date:** March 9, 2026
**Corresponding author:** Olgar Birsel, Department of Orthopaedics and Traumatology, Koç University, School of Medicine, İstanbul, Türkiye. **e-mail:** olgarbirsel@gmail.com
**DOI:** 10.5152/cjm.2026.25116

This study aimed to radiologically evaluate screw trajectory patterns in the humeral head when using variable angle locking plates and to compare them with traditional fixed angle locking constructs. It was hypothesized that surgeons tend to place screws in a convergent configuration to avoid early cortical penetration and to maximize screw length, thereby limiting the potential divergence offered by variable angle systems.

## Methods

This retrospective radiographic study was conducted by screening institutional databases for patients who underwent open reduction and internal fixation for proximal humerus fractures between January 2015 and January 2023. Patients were included if early postoperative radiographs and intraoperative fluoroscopic images were available and if all proximal screws were clearly visualized in both coronal and axial planes. Revision procedures, periprosthetic fractures, and pathological fractures were excluded. One patient was excluded due to inadequate imaging, leaving 43 patients for final analysis, of whom 18 were treated with a variable angle locking plate and 25 with a fixed angle locking plate. Institutional review board approval was obtained from Koç University Ethical Committee (Approval No.: 2025.611.IRB2.278, Date: December 18, 2025), and all participants provided written informed consent before their inclusion in the study.

All imaging was evaluated independently by 2 fellowship-trained shoulder surgeons, and final measurements were reached by consensus. Any discrepancies were resolved through joint review of the images. Coronal assessments were performed on the glenohumeral oblique view. A reference line was drawn along the anatomical neck, and the points where the most superior and most inferior screws intersected this line were identified (Figure 1). The distance between these points was measured, and the percentage of anatomical neck length spanned by the screws defined the vertical screw distribution.

Since postoperative radiographs did not reliably include true axillary views, axial screw assessments were performed using intraoperative fluoroscopic images where a true lateral projection of the plate was consistently recorded (Figure 2). For each screw row, the longitudinal axes of the screws were identified, and the angle between the 2 most divergent screws was measured. This value was recorded as the axial screw spread.

Statistical analyses were performed using SPSS version 28.0. (IBM SPSS Corp.; Armonk, NY, USA). Continuous variables were compared using the Mann–Whitney *U*-test, and a *P* value of less than .05 was considered statistically significant.

## Results

A total of 43 patients were included in the analysis, of whom 25 were treated with a fixed angle locking plate and 18 with a variable angle locking plate. Fracture patterns were classified as varus posteromedial impaction (VPM), valgus impacted (VI), surgical neck (SN), fracture-dislocation or head-split (FD/HS), and isolated greater tuberosity (GT) fractures. In the fixed-angle group, there were 6 VPM, 6 VI, 11 SN, and 2 FD/HS fractures, with no GT fractures. In the variable-angle group, there were 8 VPM, 3 VI, 5 SN, 1 FD/HS, and 1 GT fracture. The distribution of fracture types was comparable between groups. However, the study was not powered to perform fracture-type–specific subgroup analyses. The mean age of the patients with fixed angle plate was 63.5 years (range, 40 to 88), and the mean age of variable angle plate patients was 59.7 years (range, 20 to 72). There were 16 female and 9 male patients in the fixed angle group; 8 females and 10 males in the variable angle group. Age and sex distributions were comparable between the 2 groups.

In the coronal plane, the mean anatomical neck diameter was 50.35 mm (range, 41.6% to 61.7%). The distance between the most superior and most inferior proximal screws averaged 28.38 mm (range, 18.0% to 38.6%), corresponding to an average coverage of 55.98% of the anatomical neck height (range, 30% to 78%). Screws placed through variable angle plates consistently covered a smaller proportion of the anatomical neck compared with fixed angle plates (*P* = .015)(Figure 3).

In the axial plane, the mean angle between the 2 most divergent screws across the entire cohort was 29.7 degrees (range, 0 to 40).

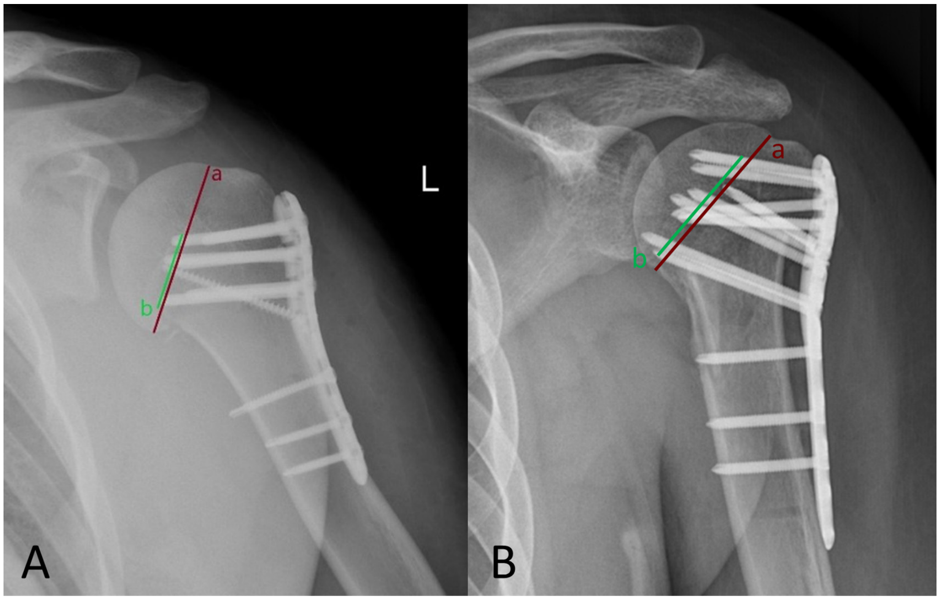


**Figure 1.** Anteroposterior radiographic comparison of variable angle and fixed angle proximal humerus plate constructs. (A) Variable angle construct and (B) fixed angle construct. Line a represents the anatomical neck of the humerus, and line b represents the vertical distance between the most superior and most inferior proximal screws intersecting the anatomical neck. The ratio b/a defines the percentage of anatomical neck height covered by the proximal screws and was used to quantify coronal screw distribution.

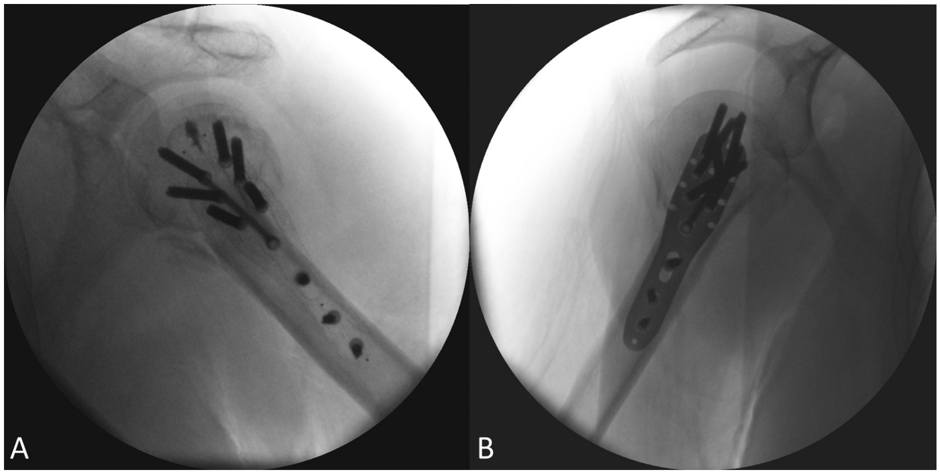


**Figure 2.** Intraoperative fluoroscopic axillary views demonstrating different axial screw trajectory patterns in 2 patients treated with variable angle proximal humerus plates. (A) Example of a divergent screw configuration with broad axial dispersion within the humeral head. (B) Example of a convergent screw configuration, with screws directed toward a central endpoint. A carbon fiber plate was used in patient A, accounting for the radiolucent appearance of the implant.

Fixed angle plates demonstrated a mean divergence of 40 degrees on fluoroscopic lateral images, whereas variable angle plates demonstrated significantly narrower screw spread, with a mean divergence of 15.4 degrees ($P < .001$). Screws inserted through variable angle constructs were therefore placed in a more convergent configuration compared with those in fixed angle plates.

## Discussion

Radiological comparison of 25 fixed angle and 18 variable angle plate fixations for proximal humeral fractures revealed a consistent tendency toward convergent screw placement in the variable angle group, resulting in reduced screw distribution and smaller humeral head coverage compared with fixed angle constructs.

Variable angle locking technology was introduced to support fragment-specific fixation by allowing surgeons to direct screw trajectories toward individual fracture fragments or regions of optimal bone quality.[7,8] Unlike fixed angle systems, polyaxial plates theoretically permit controlled divergence of proximal screws, enabling capture of a broader bone volume within the humeral head, a feature that is particularly relevant in proximal humerus fractures with heterogeneous bone quality.[10]

Biomechanical studies in the distal radius have highlighted a major advantage of variable angle technology, namely its ability to compensate for suboptimal plate positioning.[11,12] Polyaxial constructs allow independently directed screws to maintain fixation stability even when the plate cannot be placed in the ideal

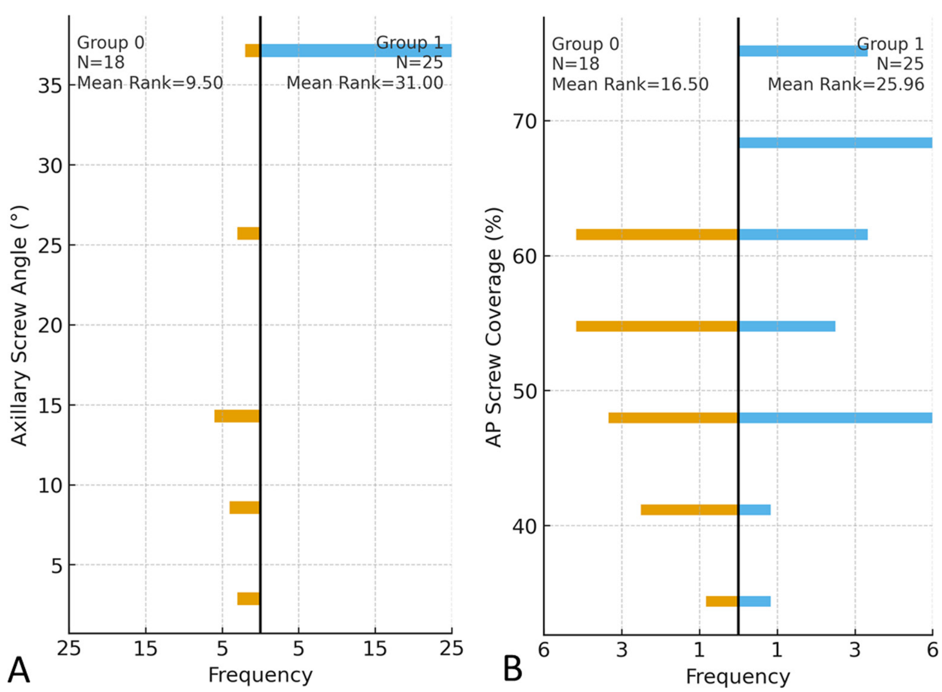


**Figure 3.** Comparison of screw distribution between variable angle (Group 0) and fixed angle (Group 1) locking plate constructs. (A) Axial screw spread measured on lateral fluoroscopic images, demonstrating a constant axial distribution in fixed angle plates and variable (B) Anteroposterior screw coverage expressed as the percentage of anatomical neck height spanned by proximal screws, showing variability in both constructs related to humeral head size.

location, and this flexibility facilitates fragment-specific fixation in complex fractures.[7] Similarly, finite element analyses have demonstrated that altering screw trajectories can substantially influence local bone strain, overall construct stiffness, and stress distribution.[13] Configurations that distribute screws more widely within the humeral head achieve lower strain concentrations at screw tips and more uniform load transfer, findings that are particularly relevant in osteoporotic bone. These studies indicate that screw trajectory, in addition to screw number, is a critical determinant of construct stability.[12,13] Notably, several authors have observed that even when variable angle implants are used, screw orientation is frequently selected intuitively rather than according to a defined biomechanical strategy.[14]

Early clinical investigations of polyaxial locking systems have already documented this discrepancy between theoretical potential and clinical application.[8,11,14,15] Studies assessing screw distribution using quadrant-based methods reported largely similar screw positions between polyaxial and monoaxial constructs, suggesting that the available angular freedom was not fully exploited.[14] These observations were proposed as a possible explanation for why comparative clinical studies failed to demonstrate the advantages of variable angle plates over fixed angle systems. Although quadrant-based assessment is inherently dependent on radiographic projection and does not directly quantify screw divergence, the underlying concept aligns closely with the findings. The study supports this observation by providing direct angular measurements, demonstrating that screws placed through variable angle plates tend to converge, thus offering a quantitative explanation for the limited clinical differentiation between implant types.

The importance of selective screw targeting is particularly evident at the inferomedial calcar.[15,16] Multiple clinical and biomechanical studies have identified insufficient medial metaphyseal support and absence of a calcar screw as independent predictors of secondary varus alignment and screw perforation.[5,15,16,17] Padegimas et al defined objective criteria for optimal calcar screw placement and suggested that the calcar screw must be inserted within an absolute distance threshold of 12 millimeters from the inferomedial calcar or within the lowest 25% of the humeral head diameter.[17] In their analysis, quality of reduction, calcar distance, and calcar ratio were all independently associated with radiographic success. Building on this concept, Kimmeyer et al later demonstrated that calcar screws placed within the inferior 12 millimeters were associated with more favorable clinical outcomes and fewer complications.[7] In a cadaveric study, Patel et al reported that the inferomedial screw failed to engage the calcar in 36% of specimens treated with fixed angle plates, whereas adequate calcar engagement was achieved in all specimens treated with variable angle constructs.[18] Together, these data emphasize that angular freedom is particularly valuable for achieving accurate inferomedial support, especially when plate positioning is constrained or suboptimal. Recent implant designs have adopted a more selective approach by maintaining predefined proximal screw trajectories while allowing angular variability specifically at the calcar level. This reflects an evolving design strategy that places angular freedom where accurate inferomedial support is most critical and may reduce the tendency toward unintended screw convergence.

An additional clinical scenario where variable angle technology becomes useful is an anatomical mismatch between plate contours and native proximal humerus anatomy.[19] Several anatomical studies have shown that proximal humerus plates often span the lateral cortex rather than conform to it.[20] When intraoperative reduction is dictated primarily by the plate contour, this mismatch may compromise restoration of the medial calcar and induce varus malreduction, potentially leading to varus collapse and subsequent screw penetration. In such situations, surgeons may intentionally position the plate slightly off the lateral cortex to preserve anatomic reduction. This strategy, however, increases the importance of flexible screw trajectories to ensure that all proximal screws remain safely within the humeral head. Variable angle constructs can accommodate these adjustments, but only if the angular freedom is used deliberately.

The mechanical characteristics inherent to polyaxial systems should also be considered. Variable angle locking screws typically have smaller diameters and engage the plate through discontinuous thread interfaces to permit multidirectional motion.[21] This design may reduce fatigue strength and limit dissipation of hoop stresses at the screw–plate junction compared with fixed angle constructs.[22] While these compromises are acceptable when angular freedom is used to achieve broader screw divergence, they may become detrimental when screws are inserted in a convergent configuration, leading to reduced spatial distribution without corresponding biomechanical benefit.[9]

Finally, the observed tendency toward convergence likely reflects a combination of technical and cognitive factors. In the absence of a defined intraoperative strategy for screw divergence, surgeons may default to a perceived safe trajectory aimed toward the center of the humeral head. This approach may be driven by concern for early cortical penetration, particularly in osteoporotic bone, as well as by the desire to maximize screw length. Although these considerations are understandable, they may inadvertently compromise the fundamental rationale of variable angle fixation by converging screws toward a central region of the humeral head. The findings suggest that without deliberate planning and execution, the theoretical advantages of variable angle technology may remain underutilized.

**Strengths and Limitations of this Study**

A major strength of the study is that it employs a structured and reproducible radiological approach to assess proximal screw trajectories in both coronal and axial planes, allowing direct visualization of screw distribution rather than relying on indirect or quadrant-based descriptions. Importantly, the analysis emphasizes real-world intraoperative screw placement behavior rather than theoretical implant capabilities, thereby providing insight into surgeon-dependent factors that may influence fixation patterns.

The study also has several limitations. It was not powered to evaluate potential interactions between fracture morphology and screw trajectory patterns, and therefore cannot determine whether fracture complexity influenced intraoperative screw orientation.

In addition, blinding of observers to implant type was not feasible due to recognizable differences in screw design, which may have introduced observer-related bias.

Another major limitation is the absence of postoperative CT imaging to assess screw configuration in 3 dimensions. Although CT would provide the most accurate evaluation of screw trajectories, its routine use in this setting is not justified due to additional radiation exposure and lack of clinical indication. For this reason, axial screw orientation was assessed using intraoperative fluoroscopy, where multiple attempts were made to obtain a true lateral projection of the plate with substantially lower radiation dose. While this approach allowed reliable assessment of axial screw spread in 2 orthogonal planes, it cannot fully replicate the precision of postoperative 3-dimensional imaging.

This radiological study demonstrated that, despite the theoretical flexibility offered by variable angle proximal humerus plates, screw placement tends to be convergent in clinical practice, resulting in reduced screw divergence and smaller humeral head coverage compared with fixed angle constructs. These findings suggest that the angular freedom of variable angle systems is not consistently utilized as intended.

Although the clinical implications of this radiographic mismatch remain to be established, surgeons should be aware of the inherent tendency toward convergence and make a deliberate effort to maintain adequate screw spread in order to maximize the potential biomechanical advantages of variable angle fixation. Future studies are needed to determine whether these radiographic findings translate into differences in clinical outcomes. Preoperative 3-dimensional imaging and fracture-specific planning may help identify key fragments and guide intentional screw trajectory selection, allowing more effective use of variable angle technology.

### Conflict of Interests Statement

There are no conflict of interest and outside funding sources for the article titled "Trend of Convergent Screw Placement in Variable Angle Proximal Humerus Plates." All 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.

**Data Availability Statement:** The data that support the findings of this study are available on request from the corresponding author.

**Ethics Committee Approval:** Ethics committee approval was received for this study from the ethics committee of Koç University (Approval No.: 2025.611.IRB2.278; Date: December 18, 2015).

**Informed Consent:** Written informed consent was obtained from all participants in this study.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept – O.B., B.G.; Design – O.B., B.G.; Supervision – İ.E., M.D.; Resources – B.G.; Materials – O.B., B.G.; Data Collection and/or Processing – O.B., B.G., İ.E.; Analysis and/or Interpretation – O.B., M.D.; Literature Search – B.G.; Writing – O.B., B.G.; Critical Review – İ.E., M.D.

**Declaration of Interests:** The authors have no conflict of interest to declare.

**Funding:** The authors declared that this study has received no financial support.

## References

1. Relvas Silva M, Linhares D, Leite MJ, et al. Proximal humerus fractures: epidemiology and trends in surgical management of hospital-admitted patients in Portugal. *JSES Int*. 2022;6(3):380-384. [CrossRef]
2. Barlow JD, Logli AL, Steinmann SP, et al. Locking plate fixation of proximal humerus fractures in patients older than 60 years continues to be associated with a high complication rate. *J Shoulder Elbow Surg*. 2020;29(8):1689-1694. [CrossRef]
3. Klug A, Wincheringer D, Harth J, et al. Complications after surgical treatment of proximal humerus fractures in the elderly-an analysis of complication patterns and risk factors for reverse shoulder arthroplasty and angular-stable plating. *J Shoulder Elbow Surg*. 2019;28(9):1674-1684. [CrossRef]
4. Spross C, Platz A, Rufibach K, et al. The PHILOS plate for proximal humeral fractures--risk factors for complications at one year. *J Trauma Acute Care Surg*. 2012;72(3):783-792. [CrossRef]
5. Xu D, Tu Z, Ji M, et al. Preventing secondary screw perforation following proximal humerus fracture after locking plate fixation: a new clinical prognostic risk stratification model. *Arch Orthop Trauma Surg*. 2024;144(2):651-662. [CrossRef]
6. Birsel O, Eren İ, Chodza M, et al. Proximal humerus fractures treated with Proximal humerus Inter Locking system: minimum 10-year clinical and radiological outcomes. *J Shoulder Elbow Surg*. 2025;35(2):e273-e281. [CrossRef]
7. Kimmeyer M, Schmalzl J, Rentschler V, et al. Correct positioning of the calcar screw leads to superior results in proximal humerus fractures treated with carbon-fibre-reinforced polyetheretherketone plate osteosynthesis with polyaxial locking screws. *J Orthop Traumatol*. 2023;24(1):54. [CrossRef]
8. Ockert B, Braunstein V, Kirchhoff C, et al. Monoaxial versus polyaxial screw insertion in angular stable plate fixation of proximal humeral fractures: radiographic analysis of a prospective randomized study. *J Trauma*. 2010;69(6):1545-1551. [CrossRef]
9. Mini D, Reynolds KJ, Taylor M. Assessing the influence of screw orientation on fracture fixation of the proximal humerus using finite element informed surrogate modeling. *Int J Numer Method Biomed Eng*. 2025;41(7):e70060. [CrossRef]
10. Hachadorian ME, Berger GK, Smith KM, et al. Variable angle locking mesh plate for fixation of comminuted greater tuberosity fractures. *JSES Rev Rep Tech*. 2025;5(3):567-572. [CrossRef]
11. Nourbakhsh A, Hirschfeld AG, Dhulipala S, et al. Biomechanical Comparison of Fixed- versus Variable-Angle Locking Screws for Distal humerus Comminuted Fractures. *Clin Orthop Surg*. 2019;11(3):302-308. [CrossRef]
12. Hart A, Collins M, Chhatwal D, et al. Can the use of variable-angle volar locking plates compensate for suboptimal plate positioning in unstable distal radius fractures? A biomechanical study. *J Orthop Trauma*. 2015;29(1):e1-e6. [CrossRef]
13. Liu J, Zhang Z, Li P, et al. Enhancing fixation stability in proximal humerus fractures: screw orientation optimization in PHILOS plates through finite element analysis and biomechanical testing. *Sci Rep*. 2024;14(1):27064. [CrossRef]
14. Ockert B, Pedersen V, Geyer L, et al. Position of polyaxial versus monoaxial screws in locked plating for proximal humeral fractures: analysis of a prospective randomized study. *Eur J Orthop Surg Traumatol*. 2014;24(5):747-752. [CrossRef]
15. Connelly JW, Covarrubias O, Toavs TL, et al. Comparison of variable and fixed angle proximal humeral locking plates for the treatment of displaced proximal humerus fractures. *Injury*. 2025;56(8):112440. [CrossRef]
16. Hwang K, Yu K, Lee JH, et al. Purchase of both proximal and distal fragments by the calcar screw is critical when using a locking plate in the treatment of proximal humeral fractures: the role of the calcar screw as a medial bridging screw. *Bone Joint J*. 2025;107-B(9):942-949. [CrossRef]
17. Padegimas EM, Zmistowski B, Lawrence C, et al. Defining optimal calcar screw positioning in proximal humerus fracture fixation. *J Shoulder Elbow Surg*. 2017;26(11):1931-1937. [CrossRef]
18. Patel M, Castaneda P, Kisana H, et al. Using the greater tuberosity as a reference for placement of proximal humerus plates leads to a high rate of calcar screw malposition. *J Orthop Trauma*. 2022;36(10):525-529. [CrossRef]
19. Ravindra A, Roebke A, Goyal KS. Cadaveric analysis of proximal humerus locking plate fit: contour mismatch may lead to malreduction. *J Orthop Trauma*. 2017;31(12):663-667. [CrossRef]
20. Rungchamrussopa P, Jiamton C, Kittithamvongs P, et al. Anatomical mismatch between the proximal humerus and PHILOS plate could result in varus malreduction. *Acta Orthop Belg*. 2025;91(2):221-227. [CrossRef]
21. Gavaskar AS, Srinivasan P, Ayyadurai P, et al. Breakage of 2.7 mm variable angle locking screws at implant removal. Study of incidence and risk factors during removal of distal humerus and distal tibia implants. *J Orthop Trauma*. 2025. [CrossRef]
22. Tidwell JE, Roush EP, Ondeck CL, et al. The biomechanical cost of variable angle locking screws. *Injury*. 2016;47(8):1624-1630. [CrossRef]