Original Article Clinics in Orthopedic Surgery 2025;17:740-746 • https://doi.org/10.4055/cios25137

Can the Inverted Application of the PHILOS Plate Be an Alternative in Extra-articular Distal Humerus Fractures? A Comparative Analysis with the Extra-articular Distal Humerus Plate

Yong-Jun Lee, MD*[,†,#], Joon-Ryul Lim, MD[†,‡], Tae-Hwan Yoon, MD[†,‡], Yong-Min Chun, MD[†]

*Department of Joint Center, Ansan Ace Hospital, Ansan,
[†]Department of Orthopedic Surgery, Arthroscopy and Joint Research Institute, Severance Hospital, Yonsei University College of Medicine, Seoul,
[‡]Department of Orthopedic Surgery, Severance Hospital, Yonsei University College of Medicine, Seoul, Korea

Background: The Proximal Humeral Internal Locking System (PHILOS) plate, designed for the treatment of proximal humeral fractures, demonstrates versatility when used in an inverted (upside-down) configuration. We aimed to retrospectively compare the clinical and radiographic outcomes of patients who underwent surgical treatment for extra-articular diaphyseal distal humeral fractures using either an extra-articular distal humerus plate (EADHP) or a modified PHILOS locking compression plate.

Methods: This study included 58 patients: 39 in the EADHP group (group A) and 19 in the PHILOS plate group (group B). Clinical outcomes were assessed using a visual analog scale for pain rating, the Mayo Elbow Performance Score, and range of motion measurements. Radiological evaluation was performed using anteroposterior, lateral, and oblique views of the humerus. The presence of radial nerve symptoms was evaluated before and after surgery.

Results: Patients in group B exhibited substantially shorter average operation times (105.8 minutes) and less mean blood loss (250.0 mL) than those in group A with an average operation time of 123.3 minutes and mean blood loss of 456.4 mL. Furthermore, a higher incidence of hardware removal was observed in group A (23.1%) than in group B (15.8%), with the procedure typically occurring approximately 15 months postoperatively in both groups. However, no significant discrepancies were found in clinical outcomes between the 2 groups, including time to fracture union and radial nerve injury rates, with no statistically significant distinctions detected between them.

Conclusions: Application of the modified PHILOS plate demonstrated outcomes comparable to those of the EADHP in treating extra-articular diaphyseal distal humerus fractures, with significantly reduced operation time and blood loss.

Keywords: *Distal humerus fracture, PHILOS plate, Extra-articular distal humerus plate, Radial nerve palsy*

Humeral fractures comprise an estimated 2%–7% of all adult fractures, and fractures involving the distal one-third of the humerus represent approximately 30% of humeral fractures.[1,2] Recently, surgical treatment of humeral fractures has yielded superior results compared with nonoperative treatment.[3-5] However, the management of distal humeral fractures presents significant challenges due to anatomical complexity; the distal segment is relatively short and does not allow sufficient plate length and number of screws for conventional locking plates due to the

Received April 15, 2025; Revised May 30, 2025;
Accepted June 2, 2025
Correspondence to: Yong-Min Chun, MD
Department of Orthopedic Surgery, Arthroscopy and Joint Research Institute, Severance Hospital, Yonsei University College of Medicine, 50-1 Yonsei-ro, Seodaemun-gu, Seoul 03722, Korea
Tel: +82-2-2228-2180, Fax: +82-2-363-6248
E-mail: min1201@hanmail.net
[#]Current affiliation: Department of Joint Center, Ansan Ace Hospital, Ansan, Korea

presence of the olecranon fossa.

The locking compression plate (LCP) extra-articular distal humerus plate (EADHP) is commonly used for distal extra-articular diaphyseal humerus fractures because of its ability to easily contour the lateral column of the proximal part and provide sufficient fixation points when the lateral column is intact.[6] Additionally, when radial nerve palsy is present, the posterior approach is advantageous for exploration,[7] leading to the use of the EADHP, which can be applied posteriorly in such cases. However, it is important to consider the potential risk of the radial nerve passing over the plate, which could cause iatrogenic injury during surgery or potential injury during hardware removal (Fig. 1).[8,9] Furthermore, thin skin on the outer aspect may cause irritation or discomfort if there is protrusion.[10]

The Proximal Humeral Internal Locking System (PHILOS) plate, designed for the treatment of proximal humeral fractures, demonstrates versatility when used in an inverted (upside-down) configuration.[11] This modification allows for the use of multiple distal locking screws while maintaining an anterior approach that prevents the radial nerve from directly crossing over the plate. In terms of stability, biomechanical research suggests no disparity between the modified PHILOS plate and EADHP in relation to anterior/posterior bending, internal/external torsion, and axial compression torsion, except for load to failure.[12] However, the clinical differences between these two fixation methods remain unclear.

We aimed to compare the clinical and radiographic outcomes of patients who underwent surgery with either the EADHP or a modified PHILOS plate for the treatment of extra-articular diaphyseal distal humerus fractures. We hypothesized that the PHILOS plate would demonstrate clinical and radiological outcomes comparable to those of the EADHP.

METHODS

The Institutional Review Board of Severance Hospital approved the study in accordance with relevant guidelines and regulations (IRB No. 2024-0413), and the requirement for informed consent was waived due to the retrospective nature of the study.

Study Population

The retrospective analysis included 65 patients who underwent surgical intervention for extra-articular diaphyseal humeral fractures extending to the distal one-third of the humerus between January 2012 and December 2021. Two patient groups were created based on the type of implant they received: group A underwent open reduction and internal fixation with an LCP EADHP (Depuy Synthes) (Fig. 2A), whereas group B underwent fixation with a PHILOS plate (Depuy Synthes) (Fig. 2B). When posterior approaches through the prone or lateral decubitus positions were unfeasible due to additional injuries or trauma, the anterolateral approach with the PHILOS plate was used; otherwise, the EADHP was used. The criteria for surgical treatment were based on the AO Foundation/Orthopaedic Trauma Association (AO/OTA) classifica-

Fig. 1. The course of the radial nerve passing over the extra-articular distal humerus plate. The white arrow indicates the radial nerve.

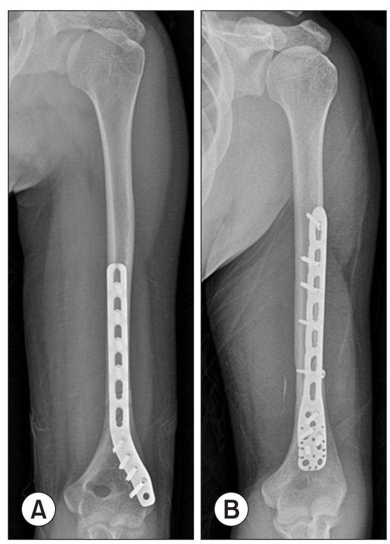

Fig. 2. (A) Postoperative x-ray demonstrating fixation with an extra-articular distal humerus plate. (B) Postoperative x-ray demonstrating fixation with a Proximal Humeral Internal Locking System (PHILOS) plate.

tions 12A (c), 12B (c), and 12C (c), which correspond to extra-articular diaphyseal humeral fractures in the distal one-third. Patients with a follow-up period of < 2 years (n = 6) and those with open fractures (n = 2) were excluded from the study. A total of 58 patients were included, with 39 in group A and 19 in group B.

Functional and Radiological Evaluation

The assessment process comprised various measures, including a visual analog scale (VAS) pain rating and the Mayo Elbow Performance Score (MEPS). We evaluated the elbow joint's range of motion, specifically the angles of extension lag and full flexion, as well as the functional arc. All clinical outcomes were recorded and compared at the 2-year postoperative follow-up. Additionally, we assessed the presence of radial nerve symptoms before and after surgery. In most cases, plate removal was not performed unless specific reasons existed, such as discomfort and irritation.

Radiological evaluation included humeral anteroposterior (AP), lateral, and bilateral oblique views. During preoperative fracture assessment, the shortest cortical length was measured on the AP view, which represents the distance from the upper margin of the coronoid fossa to the most distal end of the distal humeral fragment.[11] Follow-up evaluations were performed at 2 weeks, 6 weeks, 3 months, 6 months, 1 year, and 2 years.

Surgical Procedure

All surgical procedures were performed by 1 experienced surgeon (YMC). Initially, when employing the EADHP for fixation, the patient was placed in a lateral position under general anesthesia, with the elbow resting on an arm board at a 90° angle, and the procedure was performed through a posterior approach. After the incision, further dissection was performed using a triceps-splitting approach, the fracture site was identified, and the path of the radial nerve was observed during the proximal dissection process. Following reduction of fractures with reduction forceps, fixation was accomplished through the application of several lag screws, if necessary. After confirming the appropriate length, the plate was aligned to the central portion of the posterior aspect of the bone. The curved end of the plate was modified to correspond with the lateral column of the distal end for secure attachment and to ensure that the plate was positioned at a sufficient distance from the olecranon fossa, allowing the elbow to extend fully. In the case of plate removal after bone union, a skilled hand surgeon (YRC) and a microneurosurgeon (YRC) identified and separated any radial nerve that adhered to the plate.

When applying the PHILOS plate through the anterolateral approach, the patient was positioned supine under general anesthesia with a radiolucent hand table utilized for support. An anterolateral approach to the humerus was used, and upon identification of the biceps brachii, it was retracted medially. The brachialis muscle was split in the middle to expose the site of the fracture. During this process, the radial nerve running between the brachialis and the brachioradialis was checked only when radial nerve palsy was suspected. After inspecting the fracture site, reduction was performed using reduction forceps, and if necessary, fixation was achieved using several lag screws. After verifying length and contouring, the PHILOS plate was positioned upside down to align with the central portion of the bone. We verified and recorded the start and end times of all surgeries together with the anesthesiologist and the operating room nurse, and checked the bleeding volume.

Statistical Analysis

IBM SPSS Statistics version 26.0 (IBM Corp.) was used for all statistical analyses. The Mann-Whitney *U*-test was used to evaluate differences in continuous variables between the 2 groups. Fisher's exact test was used to compare categorical data between the 2 groups. The significance level was set at $p < 0.05$.

RESULTS

Patient Characteristics

The patient demographic information is provided in Table 1. There were no statistically significant differences between the 2 groups in terms of sex, time between injury and surgery, or involvement of the dominant arm. However, a statistically significant difference was observed in the operation time, with group A having a mean time of 123.3 minutes (range, 80–160 minutes) and group B having a mean time of 105.8 minutes (range, 80–160 minutes). Significant differences were also observed in blood loss, with group A experiencing a mean loss of 456.4 mL (range, 200–800 mL) and group B experiencing a mean loss of 250.0 mL (range, 100–500 mL). Hardware removal due to discomfort from skin irritation or a foreign body sensation was performed in 9 cases (23.1%) in group A and 3 cases (15.8%) in group B. The removal procedure was performed at an average of 15.1 months and 15.7 months after surgery for group A and B, respectively. No incidents of radial nerve palsy were reported after the removal surgery.

Table 1. Patient Demographics

Variable	Group A (n = 39)	Group B (n = 19)	*p*-value
Sex (male : female)	29 : 10	13 : 6	0.756
Age at surgery (yr)	42.9 ± 19.0	38.6 ± 14.3	0.721
Interval between injury and surgery (day)	2.0 ± 2.0	1.6 ± 0.8	0.911
Dominant arm involvement	31 (79)	14 (74)	0.740
Operation time (min)	123.3 ± 30.6	105.8 ± 19.2	0.033
Blood loss (mL)	456.4 ± 147.4	250.0 ± 121.3	< 0.001

Values are presented as mean ± standard deviation or number (%). Group A: extra-articular distal humerus plate group, Group B: Proximal Humeral Internal Locking System (PHILOS) plate group.

Clinical and Radiologic Outcomes

The patient clinical scores and range of motion are shown in Table 2. The clinical scores for group A revealed a mean VAS score of 0.6, and group B also had a mean VAS score of 0.6. In terms of MEPS, group A had a mean of 90.4, compared to group B with a mean of 91.1. The clinical scores did not differ significantly between the 2 groups. Regarding range of motion, group A had an elbow extension lag of 3.8° and an elbow full flexion mean value of 136.3°, while group B had mean values of 2.6° and 138.4°, respectively. The mean functional arc of motion was 132.4° in group A and 135.8° in group B. No significant differences were observed between the 2 groups.

Radiographic evaluations in our study revealed the timeframe for fracture union in both groups. Group A achieved a mean union time of 5.7 ± 2.0 months (range, 3–12 months), while group B had a mean time of 5.9 ± 2.6 months (range, 3–13 months). No significant differences were observed between the 2 groups. Each group recorded 1 case of nonunion. In terms of the short cortical length, measurements for group A averaged 3.6 ± 0.8 cm (range, 2.4–5.4 cm), and for group B, the mean was 3.9 ± 0.9 cm (range, 2.7–5.7 cm). Statistical analyses revealed no significant differences between the groups. However, a significant difference was observed in the number of distal screws used between the groups. Group A utilized an average of 4.4 ± 0.7 screws (range, 4–6), whereas Group B used an average of 5.4 ± 0.9 screws (range, 4–7), demonstrating a statistically significant difference ($p < 0.05$).

Table 2. Clinical Outcome Measures

Variable	Group A (n = 39)	Group B (n = 19)	*p*-value
Clinical score			
VAS score	0.6 ± 0.5	0.6 ± 0.8	0.654
MEPS	90.4 ± 9.3	91.1 ± 7.0	0.956
ASES score	87.4 ± 9.7	89.0 ± 7.6	0.814
Range of motion (°)			
Extension lag	3.8 ± 5.1	2.6 ± 4.8	0.402
Flexion	136.3 ± 7.8	138.4 ± 7.5	0.578
Functional arc	132.4 ± 8.9	135.8 ± 9.0	0.298

Values are presented as mean ± standard deviation (range). Group A: extra-articular distal humerus plate group, Group B: Proximal Humeral Internal Locking System (PHILOS) plate group.
VAS: visual analog scale, MEPS: Mayo Elbow Performance Score, ASES: American Shoulder and Elbow Surgeons.

Complications

Before the surgical procedure, 7 patients in group A and 4 patients in group B exhibited incomplete radial nerve palsy. Following the surgery, only 1 patient in group A experienced permanent symptoms, while the remaining cases showed recovery in an average of 5.6 months (range, 3–6 months) for group A, and an average of 5.5 months (range, 3–10 months) for group B. There were no significant differences in radial nerve injury or recovery times between the 2 groups. Postoperatively, only 1 patient in group A experienced iatrogenic radial nerve palsy, which resolved completely after 4 months. No significant complications were observed.

DISCUSSION

We aimed to evaluate the clinical and radiographic outcomes of patients who received either the EADHP or a modified PHILOS plate for the treatment of extra-articular diaphyseal distal humerus fractures. Consistent with our hypothesis, no significant differences in outcomes were found. However, we observed that group B, which utilized the anterolateral approach, had significantly shorter operation times and less blood loss than in group A, which used the posterior triceps-splitting approach.

The distal portion of the humerus warrants meticulous attention for distal fixation owing to its anatomical features, including the olecranon fossa and medial and lateral columns. The LCP EADHP, with its pre-contoured J-shape, has been specifically designed to align with these column contours and can be successfully utilized through a posterior approach.[13] Typically, stable fracture fixation necessitates the use of at least 3 screws per fragment.[14,15] The EADHP plate has been designed with 3.5-mm locking holes in its shaft and 2.7-mm locking holes distally, which permit at least 4 stable distal fixations. This widely used technique provides sufficient stable fixation through 1 column.[16] Nevertheless, hardware has been reported to cause irritation on the posterior aspect of the elbow in up to 66% of cases, owing to the thin portion of soft tissue in this area, posing a significant issue.[10]

Alternative methods, including anterior plating, have been explored to address this issue. The distal end of the humerus exhibits a triangular shape, corresponding to the proximal portion of the PHILOS plate applied in an inverted manner for therapeutic purposes.[11] The anterior surface of the humerus has a cylindrical shape that becomes more triangular as it approaches the distal end. The PHILOS plate features nine locking screw holes with a diameter of 3.5 mm, strategically placed within a 4.5-cm radius of the proximal area, which ensures a much greater number of screw placements compared to the EADHP. A statistically significant screw fixation was achieved in this study. Furthermore, there was no difference in short cortical lengths between the 2 groups. However, if the length is too short, the application of the PHILOS plate may be challenging. If the fragment was too short to allow for the insertion of a sufficient number of screws, the application of the EADHP would be more appropriate.

Using the anterolateral approach for PHILOS fixation significantly reduced both operative time and blood loss compared to fixation with other implants applied via the posterior triceps-splitting approach. The anterolateral approach typically requires splitting through the bulky triceps, leading to increased bleeding; identifying the radial nerve is also complex as one moves proximally.[17-19] However, except in cases where positioning was impossible, we generally preferred the posterior approach over the anterolateral approach for fixation. This preference stems from the ability to secure a longer distal fragment during posterior fixation and the provision of ample working space medially and laterally at the fracture site, which facilitates the insertion of multiple lag screws. In addition, if stability is a concern, dual plating on the medial side is feasible, enhancing stability.[20] However, biomechanical studies have confirmed sufficient stability,[12] and the anterolateral approach with anterior plating has demonstrated comparable results, making it a worthwhile alternative.

Radial nerve injury is a notable concern in extra-articular distal humeral fractures during both index surgery and implant removal.[21,22] During the posterior approach, the incidence of iatrogenic injury to the radial nerve has been reported to be high, ranging from 5.3% to 11.3%. This is likely due to the fact that the radial nerve runs over the plate, resulting in increased irritation during its identification and mobilization from the plate, compared to anterolateral plating.[23,24] Iatrogenic injuries are possible, but if the nerve's path is maintained and identified, temporary radial nerve injuries usually recover within approximately 3 months.[25] In our study, only 1 patient with iatrogenic nerve injury fully recovered within 4 months. In addition, a combination of hand and micro-neurosurgeons during implant removal on the posterior side helped prevent any cases of radial nerve injury.

This study has several limitations. First, this was a non-randomized retrospective study, which may have introduced selection bias. Second, the sample size was relatively small, which could have reduced statistical power and increased the likelihood of type II errors. Third, when fractures prevented prone or lateral decubitus positioning, we used the PHILOS plate in the supine position, suggesting that these cases, likely caused by higher-energy trauma, may have a different trauma pathogenesis.

In conclusion, the application of the modified PHILOS plate demonstrated outcomes comparable to those of the EADHP in the treatment of extra-articular diaphyseal distal humerus fractures, with a significant reduction in operation time and blood loss.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ACKNOWLEDGEMENTS

The authors would like to thank Yun-Rak Choi (Severance Hospital) for his valuable surgical assistance.

ORCID

Yong-Jun Lee https://orcid.org/0009-0001-9760-5510
Joon-Ryul Lim https://orcid.org/0000-0002-0123-7136
Tae-Hwan Yoon https://orcid.org/0000-0002-2859-5240
Yong-Min Chun https://orcid.org/0000-0002-8147-6136

REFERENCES

1. Pidhorz L. Acute and chronic humeral shaft fractures in adults. Orthop Traumatol Surg Res. 2015;101(1 Suppl):S41-9.
2. Robinson CM, Hill RM, Jacobs N, Dall G, Court-Brown CM. Adult distal humeral metaphyseal fractures: epidemiology and results of treatment. J Orthop Trauma. 2003;17(1):38-47.
3. Hosseini Khameneh SM, Abbasian M, Abrishamkarzadeh H, et al. Humeral shaft fracture: a randomized controlled trial of nonoperative versus operative management (plate fixation). Orthop Res Rev. 2019;11:141-7.
4. Jawa A, McCarty P, Doornberg J, Harris M, Ring D. Extra-articular distal-third diaphyseal fractures of the humerus: a comparison of functional bracing and plate fixation. J Bone Joint Surg Am. 2006;88(11):2343-7.
5. Matsunaga FT, Tamaoki MJ, Matsumoto MH, Netto NA, Faloppa F, Belloti JC. Minimally invasive osteosynthesis with a bridge plate versus a functional brace for humeral shaft fractures: a randomized controlled trial. J Bone Joint Surg Am. 2017;99(7):583-92.
6. Scolaro JA, Hsu JE, Svach DJ, Mehta S. Plate selection for fixation of extra-articular distal humerus fractures: a biomechanical comparison of three different implants. Injury. 2014;45(12):2040-4.
7. Noaman H, Khalifa AR, El-Deen MA, Shiha A. Early surgical exploration of radial nerve injury associated with fracture shaft humerus. Microsurgery. 2008;28(8):635-42.
8. Claessen FM, Peters RM, Verbeek DO, Helfet DL, Ring D. Factors associated with radial nerve palsy after operative treatment of diaphyseal humeral shaft fractures. J Shoulder Elbow Surg. 2015;24(11):e307-11.
9. Shon HC, Yang JY, Lee Y, Cho JW, Oh JK, Lim EJ. Iatrogenic radial nerve palsy in the surgical treatment of humerus shaft fracture -anterolateral versus posterior approach: a systematic review and meta-analysis. J Orthop Sci. 2023;28(1):244-50.
10. Jung HS, Won YS, Choi YS, Lee JS. Risk factors for hardware-related complications after extra-articular distal humerus fracture fixation using an anatomical locking plate. Eur J Trauma Emerg Surg. 2023;49(1):125-31.
11. Sohn HS, Shin SJ. Modified use of a proximal humeral internal locking system (PHILOS) plate in extra-articular distal-third diaphyseal humeral fractures. Injury. 2019;50(7):1300-5.
12. Lim JR, Yoon TH, Choi YR, Lee HM, Chun YM. Biomechanical evaluation of a modified proximal humeral locking plate application for distal extra-articular diaphyseal humeral fractures. J Orthop Res. 2021;39(9):1877-83.
13. Capo JT, Debkowska MP, Liporace F, Beutel BG, Melamed E. Outcomes of distal humerus diaphyseal injuries fixed with a single-column anatomic plate. Int Orthop. 2014;38(5):1037-43.
14. Izaham RM, Kadir MR, Muslim DA. Screws placement effect on locking compression plate (LCP) for tibial oblique fracture fixation. In: Proceedings of 2010 IEEE EMBS Conference on Biomedical Engineering and Sciences (IECBES); 2010 Nov 30-Dec 2; Kuala Lumpur. IEEE; 2011. p. 236-41.
15. Palierne S, Blondel M, Swider P, Autefage A. Biomechanical comparison of use of two screws versus three screws per fragment with locking plate constructs under cyclic loading in compression in a fracture gap model. Vet Comp Orthop Traumatol. 2022;35(3):166-74.
16. Jain D, Goyal GS, Garg R, Mahindra P, Yamin M, Selhi HS. Outcome of anatomic locking plate in extraarticular distal humeral shaft fractures. Indian J Orthop. 2017;51(1):86-92.
17. Gerwin M, Hotchkiss RN, Weiland AJ. Alternative operative exposures of the posterior aspect of the humeral diaphysis with reference to the radial nerve. J Bone Joint Surg Am. 1996;78(11):1690-5.
18. Lee TJ, Kwon DG, Na SI, Cha SD. Modified combined approach for distal humerus shaft fracture: anterolateral and lateral bimodal approach. Clin Orthop Surg. 2013;5(3):209-15.
19. Mills WJ, Hanel DP, Smith DG. Lateral approach to the humeral shaft: an alternative approach for fracture treatment. J Orthop Trauma. 1996;10(2):81-6.
20. Lee JK, Choi YS, Sim YS, Choi DS, Han SH. Dual plate fixation on distal third diaphyseal fracture of the humerus. Int Orthop. 2017;41(8):1655-61.
21. DeFranco MJ, Lawton JN. Radial nerve injuries associated with humeral fractures. J Hand Surg Am. 2006;31(4):655-63.
22. Shao YC, Harwood P, Grotz MR, Limb D, Giannoudis PV.

Radial nerve palsy associated with fractures of the shaft of the humerus: a systematic review. J Bone Joint Surg Br. 2005; 87(12):1647-52.

23. Meloy GM, Mormino MA, Siska PA, Tarkin IS. A paradigm shift in the surgical reconstruction of extra-articular distal humeral fractures: single-column plating. Injury. 2013; 44(11):1620-4.

24. Yin P, Zhang L, Mao Z, et al. Comparison of lateral and posterior surgical approach in management of extra-articular distal humeral shaft fractures. Injury. 2014;45(7):1121-5.

25. Antoniadis G, Kretschmer T, Pedro MT, Konig RW, Heinen CP, Richter HP. Iatrogenic nerve injuries: prevalence, diagnosis and treatment. Dtsch Arztebl Int. 2014;111(16):273-9.