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Minimally invasive plate osteosynthesis for segmental humerus fractures with a helical plate. Which distal fixation—the anterior or lateral—is superior?

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ABSTRACT

Aim: In order to achieve adequate stability in segmental humerus fractures, the PHILOS fixation with minimal invasive approach comes into use instead of conventional plating. However, according to the AO classification, 12C type segmental humerus fractures treated with minimally an invasive method are prone to complications. The purpose of this prospective study is to compare functional outcomes and complication rates following two different angled helical PHILOS plate fixation.

Material and Method: This multicenter study is a prospective review of cases with a final follow-up outcome. Twenty-two patients with AO 12-C humerus fractures underwent PHILOS fixation with contoured PHILOS plates between January 2016 and June 2019. Patients evaluated in two groups. Group 1 consisted 12 patients who were treated with a 30° helical plate and Group 2 consisted 10 patients who were treated with 70° helical plate. Clinical outcomes were noted according to the Constant-Murley scoring system.

Results: The mean age of patients treated in groups 1 and 2 were 49±15.8 and 50.7±17, respectively. Fractures healed in an average of 13.1±3.9 weeks in Group 1 and 13.8±3.1week in Group 2, respectively. The mean follow-up period of the patients was 18±6.1months in Group 1 and 22±4.2 months in Group 2. Mean Constant-Murley scores at final follow-up were 88±2.7 and 90±2.5 in Groups 1 and 2 respectively (p=.665). Radial nerve neuropraxia was seen in 2 cases in Group 1, and a sensorial injury of the musculocutaneous nerve was seen in 1 patient in Group 2 (p=.365).

Conclusion: Similar union rates and successful clinical results were obtained from both groups. However, this study suggests that the 70° angled helical PHILOS technique could be performed relatively easily in AO 12-C fractures with fewer complication rates. Musculocutaneous nerve affliction can be as functionally destructive as radial nerve affliction.

Keywords: Humerus shaft fracture, radial nerve palsy, minimally invasive plate osteosynthesis, safe zone, pre-contoured plate

INTRODUCTION

Although segmental fractures of the humeral diaphysis are generally seen in older age groups, they are occur in young individuals who sustain high-velocity injuries (1,2). Decision making for the treatment of segmental humerus fractures extending to proximal or distal 1/3 diaphysis varies depending on patient age and comorbidities (3). The choice of implant in patients requiring surgical treatment is an important factor that determines the success rate. Because of the anisotropic morphology of the humerus, intramedullary and extramedullary differences between the proximal and distal parts were decided as factors that complicate plate osteosynthesis (4). Plate osteosynthesis was found to require safe incisions and less invasive techniques because of the neurovascular structures of the arm that contains potential risks at every level (5).

Anatomical structures in the proximal, middle and distal zones should be known and preserved during surgery with the MIPO technique (6). The main neural structures located in the path of the implant are the axillary nerve, radial nerve, musculocutaneous and lateral cutaneous nerves of the forearm (6,7). While the radial nerve is likely to be damaged, especially in lateral and posterior approaches, the risk was found to be less in anterior plating (2). However, fixation of proximal and distal fractures is not possible with the anterior opening

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MIPO technique. For this purpose, it has been reported in a limited number of studies that extended segment fractures could be treated by using the anatomical PHILOS plate (2,8,9). Hence, it is possible to protect the deltoid insertion, to use the distal anterior surface for fixation of the distal screws, and to move away from the radial nerve zone by applying PHILOS plates that are helically shaped manually.

PHILOS plates provide excellent fixation for proximal fractures. The extension to the distal region provides a bridge plate formation in diaphyseal fractures (10,11). However, the angular difference in the sagittal plane between the humeral head and its distal is approximately 30 degrees. This particular point makes it difficult to manage treatment with conventional plates (12). On the other hand, the radial nerve in the middle third and distal diaphysis is frequently in danger (13).

In the present study, the treatment of Arbeitsgemeinschaft für Osteosynthesefragen (AO) 12-C type humeral fractures extending from the proximal humerus to distal diaphysis with 30° and 70° contoured PHILOS plates was compared. Additionally, clinical and radiological results of distal lateral and anterior fixation in segmental fractures detected by the bridging MIPO technique were compared.

Our hypothesis was that the 70° contoured PHILOS plate might be more advantageous as compared to the 30° contoured plate regarding the treatment of AO 12-C fractures extending from the proximal humerus to distal diaphysis. Contoured plate fixation can be performed as safely as a standard lateral fixation.

MATERIAL AND METHOD

The study was carried out with the permission of Süleyman Demirel University/Training and Research Hospital, Clinical Researches Ethics Committee (Date: 25.02.2022, Decision No: 5/65). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants who participated in this study.

Patients were operated on by 2 senior trauma surgeons in two trauma centers with the same method. Twenty-two patients with segmental humerus fractures, specifically AO 12-C type fractures according to AO/OTA classification, treated with two different types of helical plates between January 2016 and June 2019 were included. AO 12-C type fractures were included in the study according to the AO/OTA classification. Patients (>18 years) with closed segmental humeral fractures admitted to the emergency department were included in the study. The demographic data of the patients are summarized in **Table 1**. All cases were examined in the emergency department and immobilized with a temporary 'u' splint until surgery. All cases were treated with the long PHILOS plate in accordance with the MIPO technique in the beach chair position under general anesthesia. While distal lateral locking was performed in 12 of the cases with a 30° contoured plate (Group 1), distal anterior locking was performed in 10 cases with a 70° helical plate (Group 2).

Table 1. Preoperative and postoperative patient demographics

	30° Encountered Group 1		70° Encountered Group 2		P values
	N	Mean, SD	N	Mean, SD	P<0,05
Age	12	49±15.8	10	50.7±17	.811
Side Involvement	13	R:7 L: 6	10	R: 4 L: 6	-
Follow-up (mo.)	12	18±6.1	10	22±4.2	.335
AO/OTA Classification	12	AO12C2-C3	10	AO12C2-C3	-
Fluoroscopy time (sec)	13	21.9±6.7	10	21.5±7.2	.890
Surgery time (min)	12	46±7.5	10	52±9.1	.107
Polytrauma	4/12	11.6%	2/13	7.7%	-
Average hospitalization (days)	12	9.1±4.7	10	4.8±1.7	.261

Open fractures, pathologic fractures, pseudoarthrosis, periprosthetic fractures, neglected fractures, short oblique/ transverse fractures that can be fixed with intramedullary nail or conventional plates were excluded from this study. Patients who admitted with nerve involvement were excluded from the study. In all cases, the MIPO technique was applied by utilizing proximally deltopectoral and distally anterior or lateral approaches. All cases were followed up using anteroposterior and lateral radiographs at the 1st, 2nd, 4th, 6th and 12th months to evaluate bone healing. In all patients, adequate fracture healing was documented by both X-ray and satisfactory clinical evaluation at follow-up. Cases resulted from 12 motor vehicle accidents, 6 industrial accidents and 4 were reported as falls from a height and all were operated on with in the first week of the initial injury. All patients were mobilized after surgery with an arm sling and range of motion exercises were started at the 2nd week post-operatively. A dynamic dorsal wrist splint was applied to patients with radial neuropraxia (9.09%, n=2).

Patients were excluded from the close follow-up period after fractures healed and were asked for a final check after 1-year or more. There was no loss of follow-up. Trabecular continuity and an absence of pain at the fracture site was considered to be a union of the fracture. Functional outcomes were assessed according to Constant-Murley scores.

Surgical Technique

All patients were placed in the beach-chair position under general anesthesia. First, a proximal incision was made with a minimal deltopectoral approach, making a 5- to 6-cm proximal incision approximately 4 cm distal to the anterior portion of the acromion process and exposure between the deltoid and pectoral muscles. The anterior one third of deltoid insertion was subperiosteally elevated from the insertion to prepare lateral cleavage for the long PHILOS plate. For the distal incision, the length of the plate was measured and 3 distal screw holes were marked roughly before plate placement in both groups.

A sterile humerus sawbones model was used for an ideal plate twisting under surgery conditions. Approximate degree of 30 and 70 was determined with goniometer. Distal and proximal end points of the plate were marked and angle between these two planes were measured. In order to determine the correct implant length, an equal size comparison was made on the contralateral arm under fluoroscopy. In Group 1, a 5-cm incision was made in the skin on the lateral projection of the distal humerus. For the 30° contoured plate group, an intermuscular approach between brachialis and brachioradialis was preferred. Regardless of the length of the fractured segment, the radial nerve was identified and protected in all cases in Group 1 followed by placement of the distal. A long PHILOS plate was located submuscularly through the distal anterior or lateral humerus. Fractures were then reduced indirectly. The distal end of the plate was bent upwards and adapted to the lateral epicondyle anatomy for distal screw placement. In Group 1, a 30-degree inward contour was given to the plate manually in order to not cause rotation resulting in greater dominance of the supracondylar region, and thus, the double cortex was fixed distally. When the length of the humerus was approximately restored and both ends of the plate in the correct positions, guide pins were placed to the both ends of plate. The proximal and distal portions of the plate were fixed under the C-arm respectively (**Figure 1**).

For the 70° contoured helical PHILOS plate Group, a 5-cm skin incision was made on the anterior projection of the distal humerus. The brachial muscle was split into the medial and lateral portions, and the anterior aspect of the humerus exposed. The musculocutaneous nerve branches were not routinely identified and dissected. Distal and proximal screw fixation was made as described in Group 1. At least 3 bicortical screws were used for distal screw fixation in both groups. From the posterior tip of the acromion to the olecranon, the length/shortening of the limb was measured with a ruler and compared to the contralateral side (**Figure 2**).

Figure 1. An image of 70-degree contoured PHILOS plate

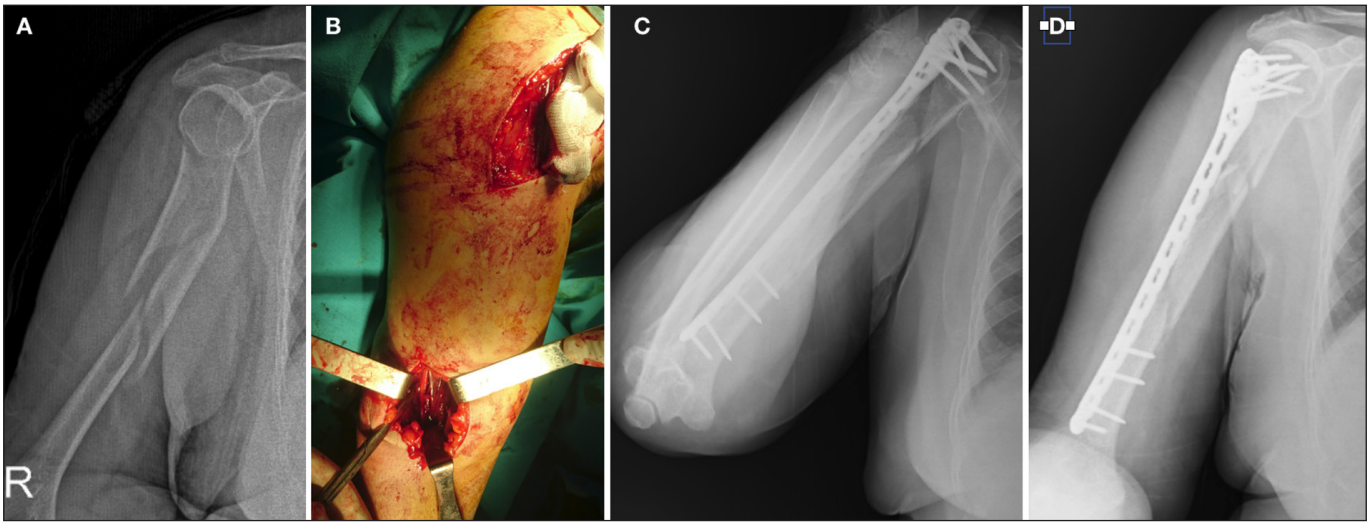

Figure 2. A 43-year-old male with AO 12-C type humerus fracture sustained in a traffic accident. (A) Anteroposterior plain radiograph of humerus fracture (B) Intraoperative image of the patient demonstrating MIPPO technique with incisions (C/D) Postoperative anteroposterior and lateral radiographs at 6th month follow-up.

Statistical Analysis

Statistical analyses were performed using SPSS version 23.0 software (IBM, Armonk, NY, USA). Comparisons of postoperative follow-up measurements and clinical outcomes were performed using a paired T-test and the analysis of variance and non-parametric Wilcoxon signed-rank tests. A post hoc power analysis, with an alpha error of 0.05, was conducted using SPSS (SPSS Inc, Chicago, IL). The observed power was .95% for all comparisons. A calculated effect size was found 0.76. The sample size planning showed an actual power of 0.951 with a total sample size of 20 patients. The nonparametric analysis of the two independent groups was compared using the Mann-Whitney U test. A value of $p<0.05$ was considered statistically significant.

RESULTS

The mean age of the patients included in the study was 49±15.8 (range 24 to 70) years in Group 1 and 50.7±17 (range 27 to 77) years in Group 2, respectively. One case in Group 1 was a bilateral humerus segmentary fracture, all other cases were unilateral humerus fractures. Mean surgery time was noted as 46±7.5 minutes in Group 1 and 52±9.2 minutes in Group 2 (p=.107). While the mean time to union was 13.2±3.9 weeks in Group 1, it was 13.8±3.1 weeks in Group 2. There was no statistical difference between the two methods in terms of union (p=.683). No intraoperative complications were encountered in any of the patients. The mean fluoroscopy time during surgery was 21.9±6.7 in Group 1 and 21.5±7.2 seconds in Group 2. The mean follow-up duration was

18±6.1 (range: 12-30) months in Group 1 and 22±4.2 (range 12-24) months in Group 2. A minimum of 3 and a maximum of 4 bicortical screws were used for distal fixation. Regardless of the length of the fractured segment, plate-screw insufficiency was not observed in any of the cases. The mean number of distal screws in both groups was 3.2 and 3.25 respectively. There was no significant difference between the 2 groups with respect to measured parameters (**Table 2**). Mean Constant-Murley scores were 88±2.7and 90±2.5 in Group 1 and Group 2 respectively at the final check-up. There was no statistically significant difference between the groups with regard to the Constant-Murley score.

Table 2. Clinical and radiological outcomes

Clinical and Radiological Outcomes	30° Encountered Group 1		70° Encountered Group 2		P values
	N	Mean, SD	N	Mean, SD	
Constant-Murley Scores	12	88.5±2.7	10	90±2.5	.665
Time to fracture union (w.)	12	13.1±3.9	10	13.8±3.1	.683
Follow-up	12	19.6±5.2	10	18±4.1	

SD: Standard deviation, w: week

Complications Implant related complications were seen in two cases. Plate related shoulder impingement was observed in 1 patient, and a 10° loss of extension at the elbow joint was observed in 1 patient from Group 1. In Group 1, temporary neuropraxia was observed in 2 cases. In these cases, symptoms related to nerve damage completely regressed within 6 months. The sensory bundle of the musculocutaneous nerve was affected in 1 case from Group 2 (**Figure 3**).

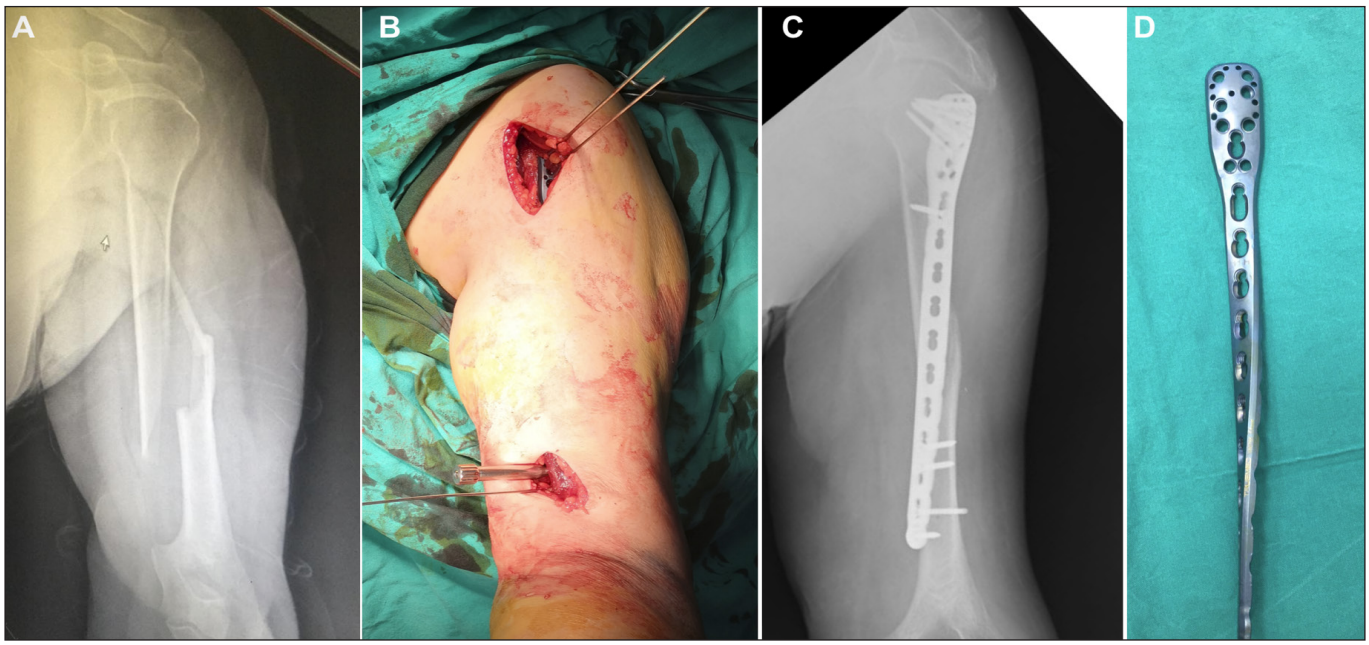

Figure 3. A 68-year-old female with AO type 12-C type humerus fracture. (A) Anteroposterior plain radiograph of humerus fracture (B) An intraoperative photo of the patient showing the both deltopectoral approach and distal- anterior incisions (C) Postoperative anteroposterior and lateral radiographs at 2nd month follow-up.

DISCUSSION

The present study reported the results of a series of segmental humerus fractures with proximal or distal extensions to the diaphysis treated with a minimally invasive long PHILOS plate. To minimize possible radial nerve damage and to adapt the PHILOS plate to the humeral anatomy, a helical plate model was created by contouring 30 and 70 degrees intra-operatively. To our knowledge, there is no study comparing anterior and lateral approaches for distal fixation of segmental humeral fractures treated using a helical PHILOS plate with different angles. Successful radiological and clinical results have been obtained with both methods. While nerve exposure is not required with helical plates angled at 70 degrees, it is essential to find and protect the radial nerve in 30° helical plates.

Due to high-energy trauma, multifocal fractures of the humerus were frequently seen in the elderly and young age groups, as well. The majority of these cases treated conservatively were reported to be associated with high rates of non-union, joint contracture or frozen shoulder (10). Surgical treatment was reported to produce good results for these types of fractures due to advantages such as allowing for early joint movement and a high rate of union (10). Although recent studies reported that plate fixation results are similar to the open or minimally invasive technique, minimally invasive techniques are becoming more popular (10).

Proximal humeral fractures have been treated with locking plates (PHILOS) since 2002. Rancan et al. (1) first reported the use of long PHILOS plates with a minimally invasive technique in metaphysiodiaphyseal humerus fractures. Opening could be achieved with a lateral split or deltopectoral approach in the proximal and a lateral mini-incision in the distal, but the radial nerve must be preserved. Although it was technically possible to find and protect the radial nerve, safe zones have been the most important subject of research due to the current risk. For this reason, many cadaveric studies have concluded that the anterior submuscular zone is safe (14,15). In the light of the available evidence, the idea of twisting and bending long PHILOS plates to conform to the humeral anatomy and to use them for fixation in metaphysiodiaphyseal fractures was first reported by Brunner et al. (16), in 2012. In the following years, a series of cases treated with the open or minimally invasive percutaneous osteosynthesis (MIPO) principle using long PHILOS or helical plates have been reported (2,6,8,12,13,17–22)

Conventional helical plate application was first introduced in 2005 by Yang et al. (23), however, the fixation was usually not possible in fractures extending to the proximal humerus with conventional helical plates (23). In these types of fractures, there may not be enough proximal fixation area for screw insertion. With the introduction of locking plates into clinical practice, it was predicted that angular stability could be achieved with a locking plate in proximal humerus fractures (24). Therefore, today long PHILOS plates are replacing conventional narrow plates. In 2014, 12 cases by Moon et al. (25), 46 cases by Wang et al. (15), in 2018, and 8 cases by Zamboni et al. (21), in 2019 a small number of cases were treated with the minimally invasive technique using the helical plate. The common aim of these cases was to create a safe submuscular tunnel between the distal and proximal humerus while bridging the fractured segment. The consensus of these studies was that less iatrogenic damage was noted with the MIPO technique using a helical plate (6,13,21).

Although there are case studies in which iatrogenic radial nerve damage was never seen in patients who underwent bridge plating with the MIPO technique, 3.4-4% radial nerve palsy and 3.4% nonunion complications were reported (6,10,14). On the other hand, the non-union rates with MIPO technique were reported to be lower than the functional brace (10,14). According to some meta-analyses, the MIPO technique did not have a clear advantage in terms of treatment time and union rates, but it resulted in lower complication rates and less iatrogenic radial damage when compared to ORIF (12,26). In our study, iatrogenic radial nerve injury (transient neuropraxia) was found in 2 cases in Group 1 (%16.6), and the sensory brunch of the musculocutaneous nerve was affected in 1 case in Group 2 (%10). These neural complications very likely occurred due to traction to the nerve during fixation of the plate distally. A deltopectoral approach was performed for proximal fixation and no axillary nerve damage was seen in any of cases.

There are some studies showing short-term results of humeral shaft fractures treated with the MIPO technique in the literature. In these studies, Constant-Murley scores have been reported between 76 to 88.6 (6,8,13,20,27). Clinical results of our study showed similar outcomes with the literature. In addition to the current research, there was no difference in clinical outcomes and union rates between distal anterior or lateral locking approaches (p=.665). The studies which addressed the MIPO technique for the treatment of humerus fractures reported between 13.2 to 17.9 weeks for the time of union (8,13,18). In our study, the mean time to radiological union was 13.2 in Group 1, and 13.8 weeks in Group 2. No superiority was observed between the distal anterior or lateral fixation methods over the duration of fracture union (p=.683).

Perioperative helical shaping of long plates may cause loss of strength and deterioration of locking screw holes

(8,12,23). No implant failure was found in our study, which confirms this prediction. Attention was paid especially to the twisting of the plate more proximal by preserving the last three screw holes in the distal.

The limitations of our study include the small number of patients (n=22) and short follow-up time, limiting advanced conclusions on rare complications and short-term outcomes. Even though segmentary humerus fractures are seen in individuals of all ages, including the elderly, examples tended to be from older individuals. Older specimens are more likely to be osteopenic, which this would more likely affect healing time and rehabilitation negatively.

CONCLUSION

Our prospective, randomized study suggests that the anterior or lateral distal fixation techniques in the treatment of AO 12-C type segmental humerus fracture provides good outcome. In order to minimize possible iatrogenic complications, contoured long PHILOS plate might be considered as a rational approach, but due to the anisometric structure of the humerus, a safe zone could not be precisely defined.

Depending on the direction in which the fracture line extends to the distal humerus, lateral or anterior fixation could be preferred. Considering the length of the fractured segment, fixation with at least three bicortical screws seems sufficient at the distal end of the plate for relative stability. This study concluded that intra-operative twisting of long PHILOS plates applied to AO 12-C type humerus fractures could be considered as a safe and effective surgical option with good radiographic and clinical outcomes and low complication rates.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of Süleyman Demirel University/ Training and Research Hospital, Clinical Researches Ethics Committee (Date: 25.02.2022, Decision No: 5/65).

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

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper and that they have approved the final version.

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