Three- and Four-part Fractures Have Poorer Function Than One-part Proximal Humerus Fractures

Crispin Ong MD, Christopher Bechtel BA,
Michael Walsh PhD, Joseph D. Zuckerman MD,
Kenneth A. Egol MD

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Abstract

Background Locking plates have become a commonly used fixation device in the operative treatment of three- and four-part proximal humerus fractures. Examining function in patients treated nonoperatively and operatively should help determine whether and when surgery is appropriate in these difficult-to-treat fractures.

Questions/purposes We compared functional scores, ROM, and radiographs in patients with one-part proximal humerus fractures treated nonoperatively to those in patients with displaced three- and four-part proximal humerus fractures treated with open reduction and internal fixation using locking plates.

Patients and Methods We retrospectively reviewed 142 patients with proximal humerus fractures treated with a standardized treatment algorithm over a 6-year period. Three- and four-part fractures were treated surgically while one-part fractures were treated nonoperatively. Functional scores, ROM, and radiographs were used to evaluate outcomes. American Shoulder and Elbow Surgeons and SF-36 scores were obtained at 12 months. Of the 142 patients, 101 (51 with three- or four-part fractures and 50 with

one-part fractures) had a minimum followup of 12 months (average, 19 months; range, 12–64 months).

Results The fractures united in all patients. At 1 year, the patients with one-part fractures had better SF-36 physical and mental scores and American Shoulder and Elbow Surgeons scores than the three- and four-part fractures. Both groups had similar shoulder ROM. Nine patients treated operatively had complications, four of which were related to screw penetration into the joint.

Conclusions Patients with three- and four-part fractures should be advised of the likelihood of persistent functional impairment and a relatively higher risk of complications when treated operatively with locked plates.

Level of Evidence Level III, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

Proximal humerus fractures represent approximately 5% of all fractures and occur in a bimodal frequency with greatest incidence in the elderly population [13]. Roughly 80% of these fractures are minimally displaced and can be successfully treated with nonoperative management. In the remaining 20%, fracture fragments are displaced and may exhibit an unstable fracture pattern. In these cases where there is marked displacement and instability, nonoperative treatment can yield less than satisfactory results and operative fixation is often indicated [3, 10].

A wide variety of fixation devices have been developed over the past several decades to treat displaced and unstable proximal humerus fractures [3, 10]. In our review of the literature, however, we found there is little agreement on the choices of treatment of these complex

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Each author certifies that his/her institution has approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of our institutional ethical review board and that informed consent was obtained from all participants.

C. Ong, C. Bechtel, M. Walsh, J. D. Zuckerman, K. A. Egol (✉)
Department of Orthopaedic Surgery, NYU Hospital for Joint
Diseases, 301 E 17th Street, New York, NY 10003, USA
e-mail: Kenneth.egol@nyumc.org

fractures. Furthermore, the incidence of complications from surgery reportedly varies between 11% and 50% [25, 28]. Surgery for these complex fractures can pose a difficult task for the operating surgeon. The use of locking plates has become our treatment of choice for complex fractures of the proximal humerus amenable to operative fixation.

While this new technology appears promising, critical analysis of the functional scoring, ROM, and radiographic imaging of patients treated with locking plates is still emerging. In a previous study, we examined the early complications of proximal humerus fractures treated with locking plates; 24% of patients had complications and a majority of these were related to intra-articular penetration of screws into the glenohumeral joint [7]. Locking plates reportedly provide comparable ROM, subjective scoring, and pain relief to other forms of fixation and reportedly are associated with better ROM compared to hemiarthroplasty with variable pain relief [2, 6, 12, 24].

We therefore compared (1) functional scores, (2) shoulder ROM, and (3) radiographic appearance in a cohort of patients who underwent open reduction and internal fixation (ORIF) of displaced three- and four-part proximal humerus fractures utilizing a locking plate and standard treatment and rehabilitation protocol to a cohort of patients with one-part fractures treated nonoperatively using a standard treatment protocol.

Patients and Methods

We retrospectively reviewed all 142 patients who presented to our affiliated institutions from February 2003 to January 2008 with an isolated proximal humerus fracture without glenohumeral dislocation treated either with ORIF with a locking plate or nonoperatively, depending on the fracture pattern. All patients sustained their injuries from a low-energy fall from standing height. The indications for surgery were (1) displaced three- or four-part fracture, (2) in medically stable patients, (3) with a fracture pattern determined intraoperatively to be amenable to treatment with ORIF with a locking plate by the operating surgeon. The contraindications for surgery were (1) patients not medically stable enough for surgery and (2) minimally displaced fracture patterns judged appropriate for nonoperative treatment by the treating surgeon. For the study, we used the following inclusion criteria: (1) acute proximal humerus fractures in patients 18 years of age and older, (2) treatment within 2 weeks of fracture with a locking plate or nonoperative treatment, and (3) minimum followup of 1 year. We excluded from the operative group any patients presenting with nonacute fractures or nonunions. Forty-one of the 142 patients were excluded because of

inadequate followup or because they had inadequate data, ie, incomplete radiographs or functional scores. We attempted to recall patients with inadequate data specifically for this study. Patients were contacted by telephone and asked to return for physical examination and to complete functional scoring questionnaires. Despite these efforts, 12 patients were lost from the operative group and 29 were lost from the nonoperative group, leaving 101 patients: 51 patients with three- or four-part fractures in the operative cohort and 50 patients with one-part fractures in the nonoperative cohort. The included patients had a minimum followup of 12 months (average, 19 months; range, 12–64 months). We had prior Institutional Review Board (IRB) approval.

We recorded patient demographics such as age, sex, date of fracture, and type of fracture. The demographics of the two groups were comparable, with no differences with regard to age, sex, and duration of followup (Table 1). The only demographic variable different between the two groups was that the percentage of smokers was greater in patients with one-part fractures.

We classified all the three- and four-part fractures according to the Neer [20] and Orthopaedic Trauma Association [19] classification systems (Table 2). The most common injury pattern in the one-part group was a fracture of the surgical neck, either as an isolated injury or with fracture of the greater tuberosity (36 patients, 72%). The next most common injury was an isolated greater

Table 1. Patient demographics

Variable	Nonoperative cohort (one-part proximal humerus fractures)	Operative cohort (three- or four-part proximal humerus fractures)	p Value
Number of patients	50	51	
Age (years)*	64.7 (17.1)	62.8 (12.5)	0.55
Sex (% women)	32	33	> 0.99
Smoking (% yes)	45	9	< 0.001

* Values are expressed as mean, with SD in parentheses.

Table 2. Classification of three- and four-part fractures

Classification	Number of fractures
Neer	
Three-part	42 (82%)
Four-part	9 (18%)
OTA	
Type A	10 (20%)
Type B	18 (35%)
Type C	23 (45%)

OTA = Orthopaedic Trauma Association.

tuberosity fracture (12 patients, 24%). The remaining two patients had lesser tuberosity fractures associated with an anatomic neck fracture [26]. For all fractures treated non-operatively, the degree of displacement, angulation, and/or reduction of the fractures fell within the parameters of a one-part fracture pattern.

Patients with one-part fractures were treated nonoperatively with a standardized treatment regimen, including a short-term sling immobilization combined with early shoulder ROM rehabilitation program. A previously published study from our institution reported the functional outcome after one-part proximal humerus fractures [26]. At initial presentation, clinical examination and radiographic evaluation were used to determine the patient's fracture was indeed a one-part fracture. The injured shoulder was

assessed to confirm the humerus moved as a unit and there was no motion at the fracture site [15]. The affected shoulder was immobilized in a sling for comfort for a period of 1 week. All patients were then seen at 1 week and were encouraged to start passive and assisted ROM exercises. Patients were seen every week for the first 3 weeks and then at 6, 12, 24, and 52 weeks to assess for radiographic displacement. Upon radiographic evidence of fracture healing, patients then began active ROM exercises in a formal physiotherapy program.

Patients with three- and four-part fractures indicated for operative fixation (Fig. 1) were treated with ORIF using a deltopectoral approach with application of a lateral locking plate (PHILOS®; Synthes, Inc, Paoli, PA) and supplemental suture fixation through the rotator cuff musculature.

Fig. 1A–F (A) An AP view, (B) a scapular Y view, and (C) a Velpeau view of a 67 year-old woman who fell and sustained a displaced three-part fracture are shown. (D) An AP view in external rotation, (E) an AP view in internal rotation, and (F) an axillary view taken postoperatively show near-anatomic reduction of this patient's proximal humerus.

The humeral head was elevated if impacted through a lateral cortical window or reduced indirectly if displaced off the shaft, followed by grafting of the defect with either cancellous chips or calcium phosphate cement if deemed necessary by the operating surgeon; this was required in 61% of patients who were treated operatively. One of five surgeons (KAE, JDZ, LJ, RM, NT) performed all surgeries. Resident surgeons had a variable role, depending on year in resident training and the discretion of the attending surgeon. We recorded the patient position, length of surgery, blood loss, and number of screws utilized.

After surgery, all patients were treated with a similar protocol. Isometric deltoid, biceps, and triceps strengthening were begun immediately on the first postoperative day. Patients were placed in a standard arm sling and were instructed in early passive ROM exercises. Patients performed passive ROM exercises postoperatively until radiographic evidence of fracture healing. Patients then began active ROM exercises in a formal physiotherapy program.

All patients were seen in followup at 1, 6, 12, 24, and 52 weeks and assessed by physical and radiographic examination. All patients were evaluated by their treating surgeon, at which time active ROM of the involved shoulder was recorded. Development of a complication was documented at each followup visit if indicated. Major complications such as those cited in the literature included infection, osteonecrosis, hardware penetration, malunion, nonunion, hardware failure, and subacromial impingement. Minor complications were defined as complications that did not substantially impair patient function [3, 8–10, 12, 18, 22, 24, 25, 28]. Functional outcome was measured utilizing two separate scoring systems: the American Shoulder and Elbow Surgeons (ASES) evaluation form and the SF-36 [23, 27].

At each followup visit, we obtained a standard shoulder trauma imaging series: scapular AP, scapular Y, and axillary views. One observer, who was not one of the treating surgeons (CO), evaluated all films for fracture healing, hardware positioning, and anatomic alignment and to identify the presence of osteonecrosis. Fracture healing was based on the disappearance of visible fracture lines on all radiographic views. Hardware positioning and anatomic alignment were based on plate positioning relative to the humeral head, head-neck angle, and presence or absence of screw penetration on all radiographic views [2, 10]. To determine changes in hardware positioning and fracture collapse, we measured and compared “humeral head height” as described by Gardner et al. [9] in sequential radiographs. Humeral head height was measured as the distance between a line perpendicular to the long axis of the plate at its superior edge and a line perpendicular to the superior edge of the humeral head on an AP radiograph. Anatomic alignment of the fracture was based on the

changes in measured head neck-angle as described by Agudelo et al. [1] on sequential radiographs. Agudelo et al. [1] described the neck-shaft angle as the angle between a line drawn perpendicular to the articular surface and a line through the humeral shaft on an AP radiograph. The presence of osteonecrosis was determined based on the Ficat classification system modified by Cruess [5]. Radiographs were examined for sclerosis, subchondral fracturing, articular flattening, and frank collapse of the humeral head [5].

Patient data were analyzed to compare the baseline characteristics (age, smoking, sex) and results (ASES score, SF-36 scores, ROM) of the two groups (nonoperative with one-part fractures versus operative with three- or four-part fractures). We determined whether there were differences in age, functional scores, and ROM between the two groups using the *t* test for continuous variables. We analyzed the categorical variables of smoking and sex between the two groups using Fisher exact test for categorical variables. All tests were two-tailed. Statistical data analysis was performed with software from STATA[®] (StataCorp LP, College Station, TX).

Results

Patients with one-part fractures had higher mean SF-36 physical scores ($p < 0.001$) and SF-36 mental scores ($p = 0.0085$) than those with three- and four-part fractures at 1 year. Patients with the one-part fractures treated nonoperatively also had better ($p < 0.001$) ASES scores. However, there was no difference in the mean shoulder ROM between patients treated nonoperatively and operatively. The mean ($\pm$ SD) forward elevation was similar ($p = 0.08$) in patients treated nonoperatively compared to those treated operatively ($147^\circ \pm 33.5^\circ$ versus $133.9^\circ \pm 32.8^\circ$, respectively); the mean external rotation was also similar ($p = 0.81$) in patients treated nonoperatively and those treated operatively ($40.4^\circ \pm 17.1^\circ$ versus $41.5^\circ \pm 19.7^\circ$, respectively) (Table 3).

All fractures treated nonoperatively united radiographically. We observed no substantial loss of reduction or change in fracture pattern requiring reclassification of the fracture to a higher grade. In 28% of the one-part fractures treated nonoperatively, there was minimal displacement (< 5 mm) in the surgical neck region based on comparisons of sequential radiographic images [26]. In fractures treated operatively, all 51 fractures united. One patient had a greater tuberosity malunion. One shoulder in one patient (2%) developed osteonecrosis of the humeral head.

No patients treated nonoperatively experienced complications, while nine patients (17%) treated with surgery developed complications (Table 4). One patient had

Table 3. Functional and radiographic outcomes

Variable	Nonoperative cohort (one-part proximal humerus fractures)	Operative cohort (three- or four-part proximal humerus fractures)	p Value
ROM			
Forward elevation (°)	147.0 (33.5)	133.9 (32.8)	0.08
External rotation (°)	40.4 (17.1)	41.5 (19.7)	0.81
Functional score (points)			
SF-36 (physical)	81.5 (13.7)	67.9 (24.5)	< 0.001
SF-36 (mental)	83.1 (9.4)	74.0 (22.1)	0.0085
ASES	91.7 (11.4)	74.5 (20.5)	< 0.001
Radiographs			
Fracture union	100% (28% with minimal displacement < 5 mm)	100% (8% with displacement resulting in screw penetration)	

Values are expressed as mean, with SD in parentheses; ASES = American Shoulder and Elbow Surgeons.

Table 4. Complications and select patient and surgical variables

Patient	Sex	Age (years)	Smoker	Neer classification	SF-36 score (points) (physical/mental/total)	ASES score (points)	ROM (FE/ER) (°)	Complication type
1	Female	83	No	Three-part	13/25/17	12	90/30	Screw cutout, osteonecrosis
2	Male	58	No	Four-part	85/84/87	82	60/10	Heterotopic ossification
3	Male	61	No	Four-part	64/88/75	63	100/10	Greater tuberosity malunion, postoperative infection
4	Male	46	Yes	Three-part	13/25/17	12	90/30	Hardware failure
5	Female	71	No	Three-part	57/68/57	72	110/30	Screw cutout
6	Female	69	No	Three-part	40/36/36	48	110/5	Screw cutout
7	Female	61	No	Three-part	39/76/54	62	170/40	Postoperative infection
8	Female	74	No	Three-part	46/66/52	62	95/30	Screw cutout
9	Male	57	No	Four-part	65/89/76	75	110/30	Postoperative infection

ASES = American Shoulder and Elbow Surgeons; FE = forward elevation; ER = external rotation.

substantial postoperative heterotopic ossification, one had early fixation failure in a noncompliant patient, three had acute postoperative infections, and four had screw penetration into the glenohumeral joint as a result of fracture settling. One of the patients with screw penetration also developed osteonecrosis.

Discussion

The operative treatment of three- and four-part fractures using locking plates has gained increasing usage; however, whether this sort of surgery improves function is not well documented. While a number of studies report function in terms of validated scoring, ROM, and radiographic imaging (Table 5), none directly compare function in patients treated nonoperatively and those treated operatively. We therefore compared functional outcomes of patients with displaced three- and four-part proximal humerus fractures

treated with ORIF using a locking plate to patients with one-part proximal humerus fractures treated nonoperatively.

There are several limitations to our study. First, several surgeons performed the procedures. Despite a standard operating protocol, variations in individual technique, as well as each surgeon's personal learning curve, may have influenced our observations. On the other hand, by including several surgeons in our study, we tried to reflect our institution's experience with locking plate technology applied to proximal humerus fractures and so our observations may be more generalizable. Second, the decision to indicate patients for surgery and to use the locking plate was at the discretion of the treating surgeon, as were the number of screws used in the humeral head, which may have potentially affected our complication rate. Other investigators have noted the number of screws in the head may influence cutout, fixation, fracture healing, or perfusion of the humeral head [21]. We only analyzed patients who underwent surgical treatment with a locking plate and

Table 5. Overview of functional outcomes for treatment of displaced proximal humerus fractures with a locking plate reported in the literature

Study	Number of cases	Mean followup (months)	Neer classification	Functional score*	ROM (°)*	Complications
Bjorkenheim et al. [3]	72	12	Two- to four-part	Constant-Murley score Two-part 84 (79–93) Three-part 78 (70–90) Four-part 60 (30–72)	NA	2 nonunion, 3 osteonecrosis, 2 implant failures
Gerber et al. [10]	34	63	Three- to four-part	Constant-Murley score Three- to four-part 77	FE 156 ER 39	12 osteonecrosis 6 required additional surgery
Owsley and Gorczyca [21]	54	31	Two- to four-part	SMFA 47 (34–94) QuickDASH 15	NA	12 screw cutout, 13 varus displacement, 2 osteonecrosis
Solberg et al. [24]	38	36	Three- to four-part	Constant-Murley score 68.6 ± 9.5	Constant-Murley score for ROM 25.1 ± 9.8	3 wound infection, 6 osteonecrosis, 6 screw cutout, 4 implant failure
Handschin et al. [12]	31	19	Two- to four-part	Constant-Murley score 80 ± 11	NA	1 implant failure, 1 secondary dislocation, 2 osteonecrosis, 2 subacromial impingement
Krivohlavek et al. [17]	49	12	Two- to four-part	Constant-Murley score 74.5	NA	NA
Fankhauser et al. [8]	29	12	Two- to four-part	Constant-Murley score 74.6 (37–96)	NA	1 implant failure, 4 fracture displacement, 2 osteonecrosis
Koukakis et al. [14]	20	16.2	Two- to four-part	Constant-Murley score 76.1 (30–100)	NA	1 implant failure, 1 subacromial impingement, 1 infection, 1 osteonecrosis
Ong et al.	51	19	Three- to four-part	SF-36 (physical) 67.9 ± 24.5 SF-36 (mental) 74 ± 22.1 ASES 74.5 ± 20.5	FE 133.9 ± 32.8 ER 41.5 ± 19.7	1 heterotopic ossification, 1 implant failure, 3 infection (including 1 greater tuberosity malunion), 4 screw cutout (including 1 osteonecrosis)

* Values are expressed as mean, or mean ± SD, or mean, with range in parentheses; SMFA = Short Musculoskeletal Functional Assessment; ASES = American Shoulder and Elbow Surgeons; NA = not available; FE = forward elevation; ER = external rotation.

did not include patients who underwent arthroplasty or other fixation methods. Third, it is not possible to tease out how much of the subjective functional results was influenced by the severity of each patient's individual fracture pattern. The operative cohort had more severe fracture patterns than the nonoperative comparison group and this biased our findings. In several other studies, minimally displaced fractures have had "satisfactory to excellent results" reported in more than 90% of patients [4, 16]. However, we used this study design because we believed randomization of patients with displaced fractures into operative and nonoperative groups could not be justified based on the available literature and would not have been approved by our IRB. In addition, we believed using a less severe fracture pattern rather than age- and sex-matched patients without fracture would lessen this bias effect. Another limitation of the study is that physical therapy was self-directed initially in both groups and formal physiotherapy was begun only after radiographic evidence of

fracture healing was present. The variation in self-directed ROM exercises and initiation of a formal physiotherapy program is a potential source of bias. Another limitation is that there is some variability in the radiographic measurements we used to evaluate hardware positioning and anatomic alignment. We tried to limit measurement variability by having one person perform all measurements using parameters described in the literature [1, 9]. Finally, although we followed patients for a minimum of 1 year, longer duration of followup may have shown a progression toward osteonecrosis in more patients.

We found patients with more severe (three- and four-part) proximal humerus fractures treated surgically did not gain as much function at 1 year as those who sustained less severe (one-part) fractures treated nonsurgically. Patients treated operatively had lower mean SF-36 mental and physical scores and ASES scores than the nonoperative cohort. Our study was designed this way to assess the predictive value of the Neer classification and to model a

proximal humerus fracture cohort treated nonoperatively. Neer [20] advocated the nonoperative treatment of minimally displaced fractures. In our study, we used patients with one-part fractures as a control to compare operative versus nonoperative treatment.

The shoulder ROM we achieved with fixation is on a par with that of lesser fractures treated nonoperatively and better than what is reported after hemiarthroplasty [11]. We found patients treated with ORIF for three- or four-part fractures had ROM at followup comparable to that of patients treated nonoperatively for one-part fractures. Our data confirm other studies in the literature showing ORIF with preservation of the patient's anatomy provides superior ROM to hemiarthroplasty, with variable pain relief. An earlier study from our institution found hemiarthroplasty for acute three- and four-part proximal humerus fractures resulted in effective pain relief but less predictable function and ROM [11]. Dietrich et al. [6] and Solberg et al. [24] independently observed function is better with locking plate fixation compared to hemiarthroplasty but found no difference in pain reported between the two treatment groups and found a greater incidence of revision surgery/complications in patients treated operatively.

Current literature also shows the locking plate compares favorably to alternative fixation techniques. Handschin et al. [12], comparing the function of patients treated with $\frac{1}{3}$ tubular plates with the PHILOS® implant, reported similar complication rates and function and suggested locking plates may be advantageous in specific situations such as osteoporotic bone. Another recent study comparing the use of the plate fixation with angular stable screws and intramedullary nailing found no difference in function between the two groups at 1-year followup [17].

Radiographically, all fractures healed whether treated nonoperatively or operatively. We noted minimal fracture displacement in 28% of patients with one-part fractures treated nonoperatively and 8% in those treated operatively (owing to fracture displacement associated with subsequent screw penetration). Our incidence of osteonecrosis was lower than what has been reported historically. Only one of our patients (treated operatively) developed osteonecrosis (2%). There has been a variable incidence of osteonecrosis cited in the literature from 4% to 16% [3, 8, 14, 22]. These results provide useful information for surgeons who treat these fractures as they counsel patients with regard to expected outcomes.

Although locking plates have the potential to improve the treatment and outcome of some complex fracture patterns, its use about the proximal humerus is not a panacea and the data on functional outcomes are still developing. We found no differences in ROM between three- and four-part proximal humerus fractures treated with locking plates and one-part fractures treated nonoperatively but found

differences in functional scores: patients with lower-grade fractures had better SF-36 and ASES scores. Both groups experienced comparable radiographic healing although one patient treated operatively had a greater tuberosity malunion. Our study shows, despite similar objective functional measures (radiographs and ROM), patients treated operatively had less subjective satisfaction in terms of pain and function.

We had a complication rate of 17% in patients treated operatively, with six (12%) having further surgery as of last followup. In analyzing these data, one must keep in mind it is always difficult to compare complication rates for operative and nonoperative treatments because fracture severity dictates the indications for surgery and influences complication rates and postoperative function. The operative group clearly had more severe fracture patterns with greater displacement, comminution, and angulation, which may have adversely affected fracture site vascularity and the biologic potential for fracture healing, which may, in turn, have contributed to a greater incidence of complications than that in the nonoperative group. Intra-articular screw perforation was our most prevalent complication, and it can arise because of improper hardware placement due to poor intraoperative imaging, screw migration/implant shifting, or collapse of the subchondral bone onto the stationary hardware [9]. The incidence of this complication is well documented in the current literature and ranges from 5% to 23% [8, 9, 14, 18, 21]. This complication can cause substantial injury to the glenohumeral joint, require reoperation, and lead to permanent loss of joint function [29].

In conclusion, our observations suggest, despite comparable rates of radiographic fracture union and comparable shoulder ROM, patients who underwent ORIF for three- and four-part proximal humerus fractures had poorer functional scores than patients who sustained simpler fracture patterns treated nonoperatively. As locking plates gain greater usage for this application, it is prudent that orthopaedic surgeons scrutinize the appropriateness of the procedure and device for each individual patient in the context of the extent of trauma and the fracture pattern. Once operative treatment is indicated, one must always keep in mind complications may arise from the fixation device, the technique, the fracture pattern, or the surgery itself. Among these parameters, the patient's specific fracture pattern and native bone quality can greatly influence the indication for and success of operative management. Future studies should evaluate longer-term functional outcomes and reoperation rates of operatively treated three- and four-part fractures, including randomized, controlled trials between ORIF and primary arthroplasty, with the goal of determining the best treatment for these injuries.

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