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Plate fixation with autogenous bone grafting for longstanding humeral shaft nonunion

A retrospective study of 6 cases

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Abstract

Longstanding humeral shaft nonunion is uncommon because humeral shaft fractures often respond well to conservative and surgical treatments. However, when it occurs, the treatment of longstanding humeral shaft nonunion is challenging. This study is a retrospective analysis of the clinical and radiographic findings in a consecutive series of patients with longstanding humeral shaft nonunions who underwent locking compression plate (LCP) fixation and autogenous iliac crest bone grafting.

Six patients were surgically treated at Xi'an Hong Hui Hospital for longstanding humeral shaft nonunions between February 2011 and June 2015. Four patients were of synovial pseudarthrosis, 1 was atrophic, and 1 was hypertrophic. Follow-up was for at least 12 months after intervention. Standardized treatment included a thorough debridement, LCP and screw fixation, and autogenous iliac crest bone grafting. In 3 patients, a single plate was applied, and in the other 3 patients, double plates were used. The main outcome measurements were shoulder and elbow function (Constant and Murley scale, and Mayo elbow performance index [MEPI]) and the visual analog scale (VAS) for pain. In addition, all complications were documented.

Our series included 6 male patients with an average age of 56.3 years and an average nonunion duration of 19.5 years. All patients had previously undergone at least 1 operation. At a mean of 26 months follow-up, all fractures had achieved solid union and none of the implants had evidence of loosening or breakage. Postoperative alignment was within 10° of anatomic in 4 patients, 1 patient had 23° of valgus angulation, and 1 patient had a posterior angulation of 12°. Mean humeral shortening was 2.8 cm. The mean Constant and Murley joint function score was 88.3 points, the mean MEPI was 96.7 points, and the mean VAS was 0.7. All patients reported significant improvement in shoulder and elbow function, and each patient was able to resume work and was satisfied with the treatment.

Plate fixation combined with autogenous iliac crest bone grafting is an excellent option for the treatment of longstanding humeral shaft nonunion.

Abbreviations: LCP = locking compression plate, MEPI = Mayo elbow performance index, ORIF = open reduction and internal fixation, VAS = visual analog scale.

Keywords: autogenous bone grafting, humerus, locking compression plate, longstanding, nonunion

1. Introduction

Fractures of the humeral shaft comprise approximately 3% to 5% of all fractures.[1] Most humeral shaft fractures are initially managed nonsurgically, with some progressing to delayed union or nonunion. The incidence of nonunion after humeral shaft fractures is generally reported to be low because of the favorable results of nonoperative treatment and occasionally with strict indications, surgical treatment. The prevalence of humeral shaft nonunion after conservative management is 8%, and ranges from 0% to 13% after surgical treatment, with atrophic nonunions being the most common type of nonunion.[2,3]

Patients with humeral shaft nonunion is often accompanied by upper extremity pain and prolonged disability, as well as the inability to participate in work and impaired quality of life, which resulting in surgical intervention. Many fixation methods have been recommended for nonunion of humeral shaft fractures, including single or dual plates fixation augmented with autologous bone graft, intramedullary device with bone morphogenetic proteins, cortical augmentation with fibular strut, and Ilizarov frame fixation.[4–7] However, many authors have advocated that the first option for humeral shaft nonunion is open reduction and internal fixation (ORIF) with rigid compression plating and autogenous bone grafting.[5,8,9]

There are few reports in the literature on the outcomes of longstanding humeral shaft nonunions.[3,5] In this study, we present a series of 6 patients with longstanding humeral shaft nonunion, with the duration of nonunion being more than 10 years. In this series, an osteosynthesis of the humeral diaphysis, supplemented with locking compression plate (LCP) fixation and autogenous iliac crest bone grafting, resulted in union in all patients. The purpose of this study was to report our

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clinical experience with plate fixation of 6 longstanding humeral shaft nonunions following previously failed surgical treatment.

2. Patients and methods

2.1. Ethical statement

This study was approved by the Ethics Committee of Hong Hui Hospital, Xi'an Jiaotong University (no: 2016060). The patients provided written informed consent for the publication of individual clinical details and accompanying images. And this study was performed in accordance with the international ethical guidelines for studies involving human subjects according to the Declaration of Helsinki.[10]

2.2. Study design and patients

This study was a retrospective review of the medical records of 6 consecutive male patients with longstanding humeral shaft nonunions who underwent plate fixation and autogenous iliac crest bone grafting between February 2011 and June 2015 in Hong Hui Hospital, Xi'an Jiaotong University School of Medicine, Xi'an, Shaanxi, China. Nonunion is defined by the American Food and Drug Administration (FDA, 1988) as when "a minimum of 9 months has elapsed since injury and the fracture shows no visible progressive signs of healing for 3 months." The indication for surgery was pain and weakness in the upper limb, and patients with an aseptic longstanding diaphyseal nonunion of the humerus were included. Other inclusion criteria were a minimum 12-month follow-up period, and a procedure including internal plate fixation and autogenous bone graft. Patients with a nonunion of a proximal or distal humerus fracture, an infected humeral shaft nonunion, or those who received treatment that included a fibular strut graft or vascularized bone graft, were excluded from this study.

2.3. Preoperative preparation

Two orthogonal radiographs were taken preoperatively, this allowed visualization of the fracture configurations of both the shoulder and elbow joints. And also, this facilitated the development of a strategy for reduction and placement of the surgical implants, so computed tomography scans were not necessary unless there were bone fragment or gap details that could not be obtained from X-rays. Preoperative laboratory tests included a complete blood count and C-reactive protein and erythrocyte sedimentation rate levels.

2.4. Surgical technique

The surgical interventions aimed to correct deformity and rotation, maintain bone alignment, and provide adequate fixation across the fracture through indirect reduction, while simultaneously fostering an environment conducive to bone healing. All operative procedures were performed by 1 trained orthopedic surgeon. After administration of prophylactic antibiotics, the patients were placed under general anesthesia in the supine position. The approach to the humerus was largely dependent on previous surgical procedures and the location of the nonunion, and efforts were made to use prior incisions. Midshaft humerus fractures were exposed through an anterolateral approach, while the posterior approach was employed when the nonunion involved the junction of the middle and distal thirds. In this series, we used the anterolateral approach in 4 patients and the posterior approach in 2 patients.

In all patients, soft tissue stripping was minimized as much as possible. The radial nerve was identified and protected, and neurolysis was performed when the nerve was embedded in scar tissue. The fracture nonunion site was opened and explored (muscle interposition was found in 3 patients), and after the removal of any previously placed hardware (except in 1 patient, where we left the previous plate in place and added a second LCP plate), the nonunion site was identified and a thorough debridement was performed. All fibrous and scar tissue was removed from around the nonunion site, including the entire pseudocapsule, until punctate bleeding was seen at the bony ends (Paprika sign).[11] The medullary canal was opened using a drill, and the deformity was then corrected in all planes.

Excess autogenous iliac crest bone graft was harvested from the contralateral iliac crest so that it could be trimmed as necessary. The iliac crest graft was trimmed to enable it to snugly telescope into the fracture fragments across the fracture site. When a bone gap was present, the cancellous iliac crest bone graft was inserted into the gap, and the fracture was reduced with bone graft spanning the fracture (Fig. 1).

Osteosynthesis across the fracture site was achieved using a 4.5-mm narrow LCP plate and screws in compression mode to obtain cortex-to-cortex stability. Depending on the shape of the humerus, the plate was precontoured prior to being applied to match the humeral morphology. A second plate was added orthogonally to the first plate when there was concern about the stability of the single-plate construct (Fig. 1). In this study, double plates were applied in 3 patients, and in 1 patient, we retained a plate that was previously present and added a second plate. A single plate was applied in the other 3 patients. The remaining excess pieces of bone graft were packed longitudinally to bridge the fracture site. The wounds were closed in layers, and a sterile dressing was applied.

2.5. Postoperative management

Cephalosporin antibiotics were routinely given preoperatively and were continued for 24 hours postoperatively. A hinged plastic brace was applied to all patients for a period of 4 weeks after surgery. Supervised rehabilitation including gentle active and active-assisted range-of-motion exercises of the shoulder and elbow were started on the first postoperative day in all patients. Four weeks postoperatively, elbow and shoulder mobilization was initiated aggressively, while the lifting of weights with the operated limb was deferred for 3 months or until osseointegration or fracture healing was observed.[12]

2.6. Observation indicators

At follow-up, clinical and radiographic examinations were performed by a clinical researcher who did not take part in the treatment. The clinical evaluation consisted of an assessment of pain, instability, motility, dysfunction, and the movement of adjacent joints. The radiographic evaluation included anteroposterior and lateral images of the humerus, including an assessment of alignment, implant loosening or breakage, and the presence of bridging or healing callus across the nonunion site.[12] Intra- and postoperative complications were also documented. Fractures were considered united radiographically with the presence of 3 healed cortices, bridging callus formation, and crossing trabeculae on 2 orthogonal lateral radiographs.

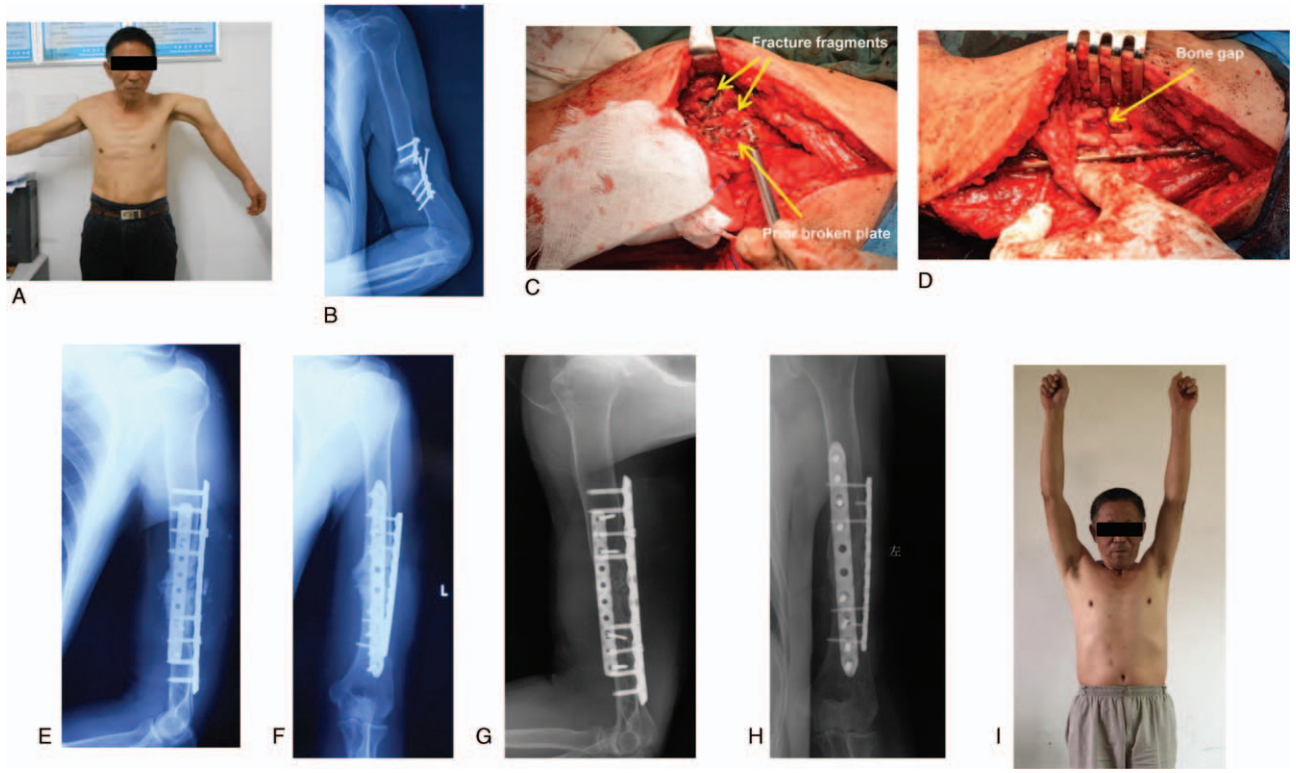

Figure 1. A 58-year-old farmer sustained a left humerus fracture caused by a steel pipe hit while building a house 19 years ago. He was treated nonoperatively with closed reduction and splinting. The fracture did not heal within 8 months after the injury, and open reduction and plate fixation with autogenous iliac crest bone grafting was performed. However, the humerus fracture site still did not unite, but he did not have any further operative intervention until he visited our institution for treatment. open reduction and internal fixation was performed, with 1 posterior and 1 lateral plate, combined with anterior iliac crest bone grafting. Twenty months following the surgery, although he had persistent ulnar nerve palsy, the patient had excellent clinical, functional, and radiographic results, including a return to his preinjury activity status. (A) The left arm before surgery with marked mobility and deformity. (B) Preoperative plain X-ray showing classic synovial pseudarthrosis nonunion of the left humerus. (C) Intraoperative photograph showing a broken plate and loose screws. (D) Intraoperative photograph showing a gap between the fragments was created for auto-iliac crest bone graft. (E, F) Postoperative radiographs showing satisfactory alignment with dual plates. (G, H) Anteroposterior and lateral radiographs demonstrating osseous union 20 months postoperatively. (I) Clinical photographs demonstrating restoration of range of motion and return to activities of daily living.

Shoulder function was evaluated preoperatively and at the most recent follow-up visit with the use of the Constant and Murley scale,[13] where excellent if the score is between 80 and 100 points; good if the score is between 60 and 79 points; fair if the score is between 40 and 59 points, and poor if the score is <40 points. The Mayo elbow performance index (MEPI) was used to evaluate elbow function,[14] where excellent if the score is between 90 and 100 points; good if the score is between 75 and 89 points; fair if the score is between 60 and 74 points, and poor if the score is <60 points. And pain was evaluated using the visual analog scale (VAS).

2.7. Statistical analysis

Statistical analysis was performed using SPSS version 17.0 software (SPSS Inc, Chicago, IL). Differences in the findings were analyzed by paired samples T tests, and $P < .05$ was considered statistically significant.

3. Results

3.1. Initial patient assessment

Our series included 6 male patients with an average age of 56.3 years (range, 49–62 years) and an average nonunion duration of 19.5 years (range, 10–31 years) (Table 1), and all were farmers with a low socioeconomic status. The mechanisms of initial injury included 1 fall, 3 traffic accidents, 1 steel pipe injury, and 1 machine injury. Four patients had involvement of the left humerus and in the other 2 the right humerus was affected. Four patients had fractures of the midshaft and 2 had fractures at the junction of the middle and distal thirds. The fractures were closed in all patients, and neurovascular injuries and radial nerve palsy were not detected preoperatively. The patients had mild to severe pain with a mean VAS of 5 points, and a limitation of activities of daily living. One patient (patient 4) had diabetes mellitus and 1 (patient 1) had an arrhythmia. Three (patients 1, 2, and 4) were smokers, and 3 patients (patients 2, 3, and 4) were alcohol abusers. The type of nonunion was classified by radiographic standards as being atrophic, hypertrophic, or synovial.[15] In this series, 4 patients were of synovial pseudarthrosis, 1 was atrophic, and 1 was hypertrophic.

3.2. Previous therapeutic interventions

All patients were initially managed in other institutions and 4 patients had already been unsuccessfully operated on elsewhere for their nonunion, with each having undergone internal fixation with autogenous bone grafting.

Table 1

Patient data.

Patient	Age, y	Gender	Type	Side	Site	Mechanism of injury	Smoker	Prior treatment	Nonunion duration, y	Complaint
1	62	Male	Synovial pseudarthrosis	Left	Middle Third	Same level fall	Yes	Two times plate	31	Pain + instability
2	58	Male	Synovial pseudarthrosis	Left	Middle Third	Steel pipe hit	Yes	Splint then plate	19	Pain + instability
3	54	Male	Synovial pseudarthrosis	Right	Distal Third	Traffic accident	No	plate	22	Pain + instability
4	58	Male	Hypertrophic	Left	Middle Third	Traffic accident	Yes	Two times plate	21	Pain
5	57	Male	Synovial pseudarthrosis	Right	Middle Third	Machine injury	No	plate	10	Pain + instability
6	49	Male	Atrophic	Left	Middle Third-Distal Third	Traffic accident	No	Plate then nail	14	Pain

3.3. Follow-up assessment of outcomes and interventions

In this study, acceptable reduction and secure fixation of the fracture fragments was accomplished in all patients. None of the patients of nonunion were due to infection. The mean duration of revision follow-up was 26 months (range, 16–36 months). All fractures had solid clinical and radiographic evidence of fracture union, and none of the implants had loosening or breakage at the final follow-up. Postoperative alignment was within 10° of anatomic in 4 patients, 1 patient had a 23° valgus angulation, and 1 patient had a posterior angulation of 12°. Mean humeral shortening was 2.8 cm (range, 0.5–5.5 cm) (Table 2).

At the final follow-up, the mean shoulder forward flexion was 141.7° (range, 100–165°). The mean Constant and Murley joint function score was 88.3 points (range, 83–94 points), which was significantly improved compared with preoperative scores ($P = .005$), and all 6 results were in the excellent range. For the elbow, the mean elbow mobility in flexion-extension was 136.7/5/0 (range, 130°–145° flexion; 0°–10° loss of extension). The mean MEPI was 96.7 points (range, 85–100 points) ($P = .001$), with 5 excellent results and 1 good result. The mean VAS score decreased from 5 points preoperatively (range, 2–7) to 0.7 points (range, 0–2) at follow-up, which was statistically significant ($P < .001$). Each patient was able to resume work and was highly satisfied with the treatment.

3.4. Complications

One patient (patient 3) developed a transient radial nerve palsy with thumb and index finger numbness postoperatively, which recovered spontaneously 2.5 months after surgery. One patient presented with palsy of the ulnar nerve, and surgical exploration and neurolysis 7 months after surgery by a neurosurgeon demonstrated that the nerve was in continuity. The ulnar nerve was transposed anteriorly, but the palsy persisted at final follow-up. Morbidity at the bone graft harvest site was minimal, with only 1 patient complaining of occasional discomfort.

4. Discussion

The nonunions included in this study had several common characteristics, including a longtime nonunion duration, pain caused by unstable implants, and patients with a low socioeconomic status and loss of faith in surgical treatment. In addition, 4 patients had already been unsuccessfully operated on for their nonunion. All of these factors may have increased the likelihood of failed union after surgical intervention. They believed they had no chance for a second surgery. Hence, treatment of these nonunions is challenging. During the intervention, after we corrected the deformities, we applied LCP fixation (3 single plates and 3 orthogonal double plates) and supplemented this with autogenous bone graft, and this provided us with adequate fixation for each patient. Treatment in this study was successful, all of the patients had solid union and good function. To our knowledge, there have been no published reports dealing specifically with the management and outcome of longstanding humeral shaft nonunions.

The outcomes of this study are similar to or better than those of other reports. A report by Otsuka et al[4] on the outcomes of 21 nonunions of the humeral shaft treated with compression plating and bone grafting showed that at an average of 42 months of follow-up, the average Constant score for the shoulder was 81.8 ± 15.4 and the average MEPI was 93.7 ± 5.6. All of the patients achieved a good or excellent outcome, and these values were very similar to our study (see Table 2). However, Bernard de Dompsure et al[8] reported the results of 21 patients with nonunion of the humeral diaphysis treated with ORIF using compression plates and screws with autologous bone graft enhancement. The mean shoulder elevation was 140°, the mean Constant score was 77, the mean elbow flexion–extension arc was 130/15/0, and the mean MEPI was 97. These values are comparable to those achieved in our study.

There are many factors affecting the healing of humeral shaft fractures and causing nonunion, including smoking, alcoholism,

Table 2

Patient outcomes.

Patient	Number of plates	Last follow-up, mo	VAS	Shoulder function (flexion)	Constant and Murley	Elbow function flexion/extension	Mayo	Final complaint	Malalignment	Humeral shortening, cm
1	2	28	1	155°	88	145°/ 10°	100	None	6°	2
2	2	27	2	165°	91	140°/ 0°	85	Ulnar never palsy	7°	2.5
3	1	18	0	150°	83	130°/0°	100	Radial nerve palsy	23°	5.5
4	2	16	0	150°	84	130°/10°	100	None	8°	0.5
5	1	36	1	100°	90	135°/0°	95	None	12°	2
6	1	31	0	130°	94	140°/10°	100	Iliac crest discomfort	4°	1.5

VAS = visual analog scale.

Figure 2. A 57-year-old man with a right humeral shaft fracture sustained 10 years ago. Failure of orthopedic treatment by acute internal plate fixation occurred. Final intervention was with locking compression plate fixation with autogenous bone grafting. (A) Preoperative plain X-ray showing a synovial pseudarthrosis nonunion with screw loosening. (B, C) Immediately after the final surgical repair. (D) Three years after surgery, with evidence of radiographic consolidation.

osteoporosis, unstable fixation, poor patient compliance, soft tissue devitalization, inadequate immobilization, fracture pattern (fracture line at the middle or middle third of the humerus, transverse, and comminuted fractures), and infections.[7,16] In this study, the main cause of nonunion was unstable fixation. Furthermore, 3 patients had a history of smoking, 3 patients were alcohol abuses, and 1 was noncompliant (went back to work 15 days after last surgery), and these factors may have been associated with nonunion. Various methods have been described for the management of humeral shaft nonunion; however, there is currently no consensus on the optimal operative treatment of humeral shaft nonunions.[5,17] Intramedullary nailing may reduce the risk of sepsis and radial nerve palsy, but nails are associated with a higher rate of reoperation because they provide less rotational control and axial stability.[18,19] ORIF with plating and bone grafting for humeral shaft nonunion may avoid the disadvantages of intramedullary nailing, and allows for more precise correction of the deformity and the ability to obtain absolute stability, and also allow the option of biologic augmentation.[9] Thus, union was achieved as expected. In a systematic review of 36 articles, Peters et al[7] found that plate fixation with autogenous bone grafting achieved high union rates (mean union rate of 98%) with relatively low complication rates in patients with humeral shaft nonunion. Konda et al[20] pointed out that a humeral shaft nonunion that occurs after initial operative fixation of a fracture is more resistant to achieving union compared with a nonunion that occurs after initial nonoperative treatment, and they recommended plate and screw fixation for humeral shaft nonunion even in recalcitrant patients that have undergone multiple prior surgeries. As stated previously, the main contributing factor in this series was unstable fixation. Based on the thought that the nonunions in this study united once thorough debridement was performed and stable fixation was achieved, we applied each patient with LCP fixation and auto bone graft. As we expected, at the final follow-up, all of the patients had solid union and good function, with the mean shoulder raw Constant joint function score being 88.3 points, and the mean MEPI being 96.7 points. Although 1 patient had persistent ulnar nerve palsy, all patients were satisfied with the treatment and all returned to work (Fig. 2).

The limitations of this study include its retrospective design and small sample size, and the fact that all of the patients were males. There was also a small age range (49–62 years). The objective of the present study was not to compare treatment outcomes of different implants for humeral diaphysis nonunions, but rather to report that it is valuable to use LCP fixation for longstanding humeral diaphysis nonunions. However, nonunions of the humeral diaphysis are not common, and despite the small sample size, this limitation did not influence the results, and results may be more convincing with larger samples in future studies. Moreover, we were not able to determine the exact timeline for union in each patient because most patients were reluctant to come to the hospital for regular follow-up. There was a mean 2.8 cm of humeral shortening from the osteotomies, so any reduction in bone length would have led to a secondary loss of triceps muscle tension.[21]

In this study, we found that the outcomes after LCP fixation associated with autogenous iliac crest bone grafting for longstanding humeral shaft nonunions were favorable. LCP fixation can achieve a high degree of cortex-to-cortex stability with compression of the bone segments and correction of the malalignment. Additionally, an autogenous graft with intimate contact with both fragments may facilitate neovascularization and migration of osteogenic cells, which can foster an environment conducive to bone healing.[16,22,23] Finally, it is important to provide longstanding humeral shaft nonunion patients with adequate encouragement, since our patients were extremely frustrated with their clinical course. We recommend LCP fixation associated with autogenous iliac crest bone grafting for longstanding humeral shaft nonunions. Future

studies should be larger and the long-term effects should be evaluated further.

5. Conclusion

This series demonstrated that plate fixation with autologous iliac crest bone grafting for the treatment of longstanding humeral shaft nonunion had satisfactory results with respect to bone healing and functional capacity. Therefore, if a patient's overall physical condition and economic circumstances allow for surgery and the surgeon is experienced, this surgical treatment is a worthwhile intervention in patients with longstanding humeral shaft nonunion.

Author contributions

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