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Research Article

An Outcome Analysis of Locking Versus Limited Contact Dynamic Compression Plate in Surgical Management of Shaft of Humerus Fracture - A Comparative, Longitudinal Study

Radha Krishna AM[1], Shivananda S[2], Jayaram BS[1] and Vijay Bharadwaj[3]*

[1]*Professor, Department of Orthopaedics, Kempe Gowda Institute of Medical Sciences and Research Centre, Bangalore*

[2]*Professor and Head, Department of Orthopaedics, Kempe Gowda Institute of Medical Sciences and Research Centre, Bangalore*

[3]*Postgraduate, Department of Orthopaedics, Kempe Gowda Institute of Medical Sciences and Research Centre, Bangalore*

***Corresponding Author:** Vijay Bharadwaj, Postgraduate, Department of Orthopaedics, Kempe Gowda Institute of Medical Sciences and Research Centre, Bangalore.

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Abstract

Background and Objectives: For managing humerus shaft fractures, limited contact dynamic compression plates (LC-DCP) were developed to limit contact between the bone and plate. Off late, a novel bio-friendly, locking compression plates (LCP) are hypothesized to be more suitable especially for osteoporotic bones. Current study was conducted to evaluate and compare clinical, functional and radiological outcomes and complications associated with them.

Methodology: This comparative longitudinal study conducted for a period of 18 months among subjects with fracture of humerus shaft. Subjects were assessed for 6-month follow-up. Functional outcomes were measured by Constant and Murley scoring system and Pain by using VAS score. Statistical analyses were performed using SPSS software. P value < 0.05 was considered statistically significant.

Result: W20 cases each managed by LCP and LCDCP respectively. Baseline details were statistically comparable (p > 0.05) between study groups. RTA was the commonest mode of injury. Commonest fracture pattern noted was transverse type (40%). Fracture union time was 18-24 weeks commonest among both study groups. Range of motion was 75% cases in both groups. Most patient had Constant and Murley Score between 71-85 indicating good outcome at final follow-up. 85% cases in both study groups had mild pain by VAS score at follow-up. Statistically all the patient outcome parameters were noted to be comparable between study groups (p > 0.05).

Conclusion: The Results were statistically comparable between both study groups, indicating that results from both Plates are equivalent and can be adopted to manage shaft of humerus fractures. Both the Plates were noted to be safe.

Keywords: Humerus; Fracture; Diaphyseal Fractures; Limited Contact Dynamic; Compression Plates (LC-DCP); Locking Compression Plates (LCP)

Introduction

Humerus fractures are known to occur as a result of trauma (high or low energy) or pathologic fractures mostly due to metastatic disease. The fracture of mid shaft of humerus accounts for 3.0% of all fractures and commonly occurs due to a direct blow to the upper arm [1]. Sporting activities, working accidents, fall from a height, violence, and bone pathology account for less than 10% of humeral shaft fractures and pathologic and open fractures of the humeral shaft are uncommon and account for 6% to 8% and 2% to 5% of all diaphyseal humeral fractures, respectively [2]. With the rise in aging population, the incidence of these fractures has also

been increasing [3]. Such fractures might result in severely reduced quality of daily activities and additional consumption of medical resources which has to be addressed [4].

Treating such fractures has been the subject of debate from long time. Though, conservative treatment as popularized by Sarmiento in 1977 was considered to be the method of choice for managing humerus shaft fractures, an operative treatment is considered to be best, nowadays with both compression plating and intramedullary nailing to improve functional outcomes [3,5]. With improved surgical techniques and the socioeconomic environment, there is always a chance of choosing the treatment options that can offer a faster recovery and earlier return to normal activities [2]. The open reduction and internal fixation (ORIF) are indicated in case of open fractures, vascular injury requiring repair, brachial plexus injury, floating elbow (ipsilateral forearm fracture), and compartment syndrome including polytrauma, bilateral humerus fractures, pathologic fractures, and burns or soft tissue injury precluding bracing, the relative indications [1]. The plates are one of the common implants used in case of open reduction and internal fixation [1]. These bone plates act by transmitting the forces from one end of a bone to the other, bypassing and hence protect the area of fractures and also by holding the fracture ends together throughout the healing process by maintaining the proper alignment of the fragments. A plate which is applied under tension produces static compression at a fracture site and is a static compression plate. However, plates which can transfer or modify functional physiological forces into compressive forces at the fracture site are dynamic compression plates. Importantly in dynamic compression plating (DCP), the large contact surface of plate and bone interferes with cortical perfusion leading to cortical porosis and possible re-fractures [6]. Keeping these factors in mind, the limited contact DCP (LC-DCP) was developed in order to limit contact between the bone and plate to reduce the interference with cortical perfusion but could address the issue only partially [6].

The locking compression plates (LCP) are further advanced in comparison to LCDCP as locking plates follow the bio-mechanical principle of internal fixator and the plate and bone friction is not required and the stability is maintained at the angular-stable screw-plate interface. LCP aims at minimal surgical damage to the blood supply, maintenance of optimal bone structure near the implant, improved healing in the critical zone, minimal damage to bone lining after plate removal with reduced risk of re-fracture.

Even though the use of locking plates in fixing diaphyseal osteoporotic bones has become commoner in clinical practice, the literatures comparing the difference in the outcomes of locking plates vis-a-vis LC-DCP are less in our study setting to our knowledge. Hence the current study was conducted to compare the usefulness of locking plates in the management of humeral diaphysis fractures indicated with ORIF in terms of clinical, functional and radiological outcomes and also the complications in comparison with LC-DCP among the adults [6].

Material and Methods

Patient enrolment

This comparative and longitudinal study conducted in the duration of 18 months. Subjects presented with fractures shaft of humerus at the hospital were screened for the study. Skeletally mature patients of age more than 18 years irrespective of the gender who presented with fresh simple fractures, fresh type 1 Gustilo-Anderson compound fractures, displaced fractures irrespective of the radial nerve involvement and willing to give consent for the procedures were considered for the study. The exclusion criteria included: patients who presented with pathological fractures, malunited fractures and infected fractures, fractures more than 3 weeks old, those who were medically unfit for surgery and also the fractures which were associated with injuries of ipsilateral shoulder, forearm and elbow.

Sample size

Considering 3% prevalence of humeral shaft fractures [1] with 95% confidence interval and absolute precision (L) as 7.5%, total sample size of 20 per group was calculated using the formula n = z2(pq/L2), where, z = 1.96 at 95% confidence interval, p = estimated prevalence (3.0%), q = 100-p (97.0%) and L = permissible error (8.0%). The total sample size was noted to be 40, which was divided equally among the two groups i.e., locking compression plate group (LCP) and limited contact – dynamic compression plate (LC-DCP) group to compare the outcomes.

Surgical procedure

After valid consent all patients were operated under general anesthesia, with the patient placed in the lateral decubitus position, using the posterior approach. The radial nerve was explored and protected and fracture site was dissected to eliminate hematoma

and soft tissue interjecting between the fragments. The fracture fragments were reduced and plate osteosynthesis was done with either LCP or LC-DCP, depending upon the patient's study group. Wound closure was in layers and postoperative antibiotics and analgesics were started. Suture removal was typically done on 12-14th day and elbow movement was started as early as possible depending on the compliance of the patient.

Study data collection

All data were recorded in the semi-structured questionnaire consisting of three parts, part-1 consisted of socio-demographic details, part-2 consisted of details on the complaints, complete history of injury and investigations and part-3 included data on functional outcomes viz., pain, range of movement, fracture union and complications through Constant and Murley scoring system and pain was also assessed using VAS scores.

Statistical analysis

All the categorical variables were expressed in proportions and continuous variables were expressed in means and standard deviation or medians and interquantile ranges. Independent t- test/ Mann-whitney U test was used to assess the difference in the Constant and Murley scores and VAS scores and improvement in the mean/median scores during the follow up will be done using repeated measures ANOVA or Wilcoxon signed rank test. Chi-square test and/ or fisher's exact tests were used to compare the difference in the proportions of complications among the two treatment modalities. Statistical analyses were performed using SPSS software version 24.0. A *P*-value of < 0.05 was considered statistically significant.

Results

A total of 40 cases of shaft of humerus fracture were enrolled in the study, of which 20 were managed by Locking Compression Plate (LCP) and 20 patients were managed by Limited Contact Dynamic Compression Plate (LCDCP). The age distribution was statistically comparable (p > 0.05) between study groups. Majority in LCP group were females (70%) while majority in LCDCP group were male patients (70%). Overall, 23 patients (57.5%) in study suffered from some kind of comorbidity. In LCP group, 11 patients each had DM and/or HTN, 1 patient had history of asthma. In the LCDCP group, 6 patients had DM, two had HTN while one had other comorbidity (Table 1).

	LCP group (n = 20)	LCDCP group (n = 20)	P value
Age group distribution			
18-30 years	3 (15%)	7 (35%)	0.17
31-43 years	7 (35%)	3 (15%)	
44-55 years	4 (20%)	7 (35%)	
> 55 years	6 (30%)	3 (15%)	
Gender distribution			
Male	6 (30%)	14 (70%)	0.02*
Female	14 (70%)	6 (30%)	
Comorbidities			
Nil	7 (35%)	10 (50%)	0.38
DM	6 (30%)	6 (30%)	
HTN	5 (25%)	2 (10%)	
Asthma	1 (5%)	1 (5%)	
Others	1 (5%)	1 (6.67%)	

Table 1: Demographic and baseline details of enrolled patients.

P < 0.05 considered significant by Chi-square test.

Majority of cases in both the LCP (55%) and the LCDCP (65%) groups suffered from right sided injury. Majority cases in LCP group suffered from injury because of fall from height (55%), while RTA was the commonest nature of injury in LCDCP group. Overall, RTA was the commonest mode of injury (60%). 45% in LCP group while 90% in the LCDCP group suffered from direct injury. Associated injuries was noted in 35% of cases overall, radial nerve injuries being common injuries in 20% of LCP group cases and 15% of LCDCP group cases respectively. Commonest fracture pattern noted was transverse type (40%), spiral type (27.5%) and comminute fractures (20%). The fracture details of both study groups have been described in detail in table 2 below.

The time of surgery following admission was most commonly 0-2 days in both the LCP group (50%) and in the LCDCP group (75%). Hospital stay was commonly noted for 1 week (60% in LCP group and 40% in LCDCP group). In LCDCP group, 40% patients also had 1-2 weeks' hospital stay. Statistically the hospital stay was comparable between study groups (p > 0.05).

75% patients in LCP group and 80% patients in the LCDCP group had a time-to-fracture-union of 18-24 weeks. 13 patients (85%) in LCDCP group and 10 patients (65%) in LCP group had mild pain at 6-month follow-up. None of the patients in the study groups suf-

	LCP group (n = 20)	LCDCP group (n = 20)	P value
Side of injury			
Left	9 (45%)	7 (35%)	0.74
Right	11 (55%)	13 (65%)	
Nature of injury			
RTA	9 (45%)	15 (75%)	0.07
Fall from height	11 (55%)	4 (20%)	
Trivial injury	0	1 (5%)	
Mechanism of Injury			
Direct	9 (45%)	18 (90%)	0.01*
Indirect	11 (55%)	2 (10%)	
Duration since injury			
< 1 week	20 (100%)	18 (90%)	0.46
> 1 week	0	2 (10%)	
Associated injuries			
Nil	12 (60%)	14 (70%)	0.25
Radial nerve injury	4 (20%)	3 (15%)	
Head injury	0	0	
Chest injury	0	2 (10%)	
Other limb injuries	4 (20%)	1 (5%)	
Fracture pattern			
Transverse	5 (25%)	11 (55%)	0.1
Oblique	3 (15%)	0	
Comminuted	5 (25%)	3 (15%)	
Spiral	5 (25%)	6 (30%)	
Compound	2 (10%)	0	

Table 2: Fracture details of enrolled patients.

P < 0.05 considered significant by Chi-square test.

fered from any deformity after surgery. The range of motion was very good in 25% cases in both groups, while it was good in 75% in both groups. Statistically all the patient outcome parameters were noted to be comparable between study groups (p > 0.05) (Table 4).

All patients in both the study groups had Constant and Murley Score between 71-85 indicating good outcome at final follow-up. Statistically the scoring status was comparable between study groups (p > 0.05). (Figure 1)

	LCP group (n = 20)	LCDCP group (n = 20)	P value
Time of surgery following admission			
0-2 days	10 (50%)	15 (75%)	0.26
3-5 days	6 (30%)	3 (15%)	
6-8 days	4 (20%)	2 (10%)	
Hospital stay			
1 week	12 (60%)	8 (40%)	0.41
1-2 weeks	6 (30%)	8 (40%)	
> 2 weeks	2 (10%)	4 (20%)	

Table 3: Fracture management details of enrolled patients.

P < 0.05 considered significant by Chi-square test.

	LCP group (n = 20)	LCDCP group(n = 20)	P value
Fracture union in weeks			
16-18 weeks	1 (5%)	0	0.59
18-24 weeks	15 (75%)	16 (80%)	
> 24 weeks	4 (20%)	4 (20%)	
Pain at 6 months follow-up			
No pain	7 (35%)	3 (15%)	0.27
Mild	13 (65%)	17 (85%)	
Deformity			
Absent	15 (100%)	15 (100%)	1
Present	0	0	
Range of movement			
Very good	5 (25%)	5 (25%)	1
Good	15 (75%)	15 (75%)	

Table 4: Patient outcome details of enrolled patients.

P < 0.05 considered significant by Chi-square test.

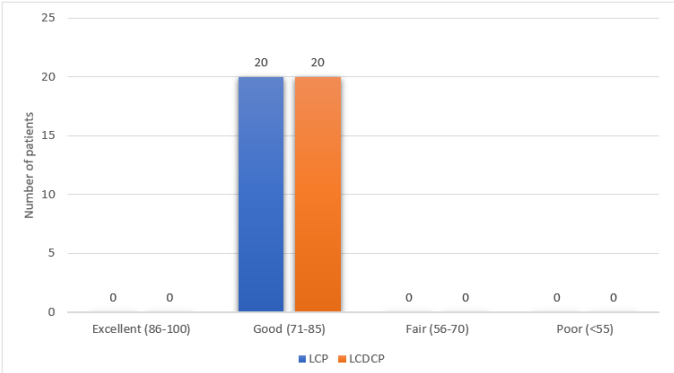

Figure 1: Constant and Murley Scoring in study groups.

85% cases in both study groups had mild pain, while 15% cases in each group had moderate grade of pain by VAS score at follow-up. None of the patients suffered from severe grade of pain by VAS score. Statistically the VAS Score status was comparable between study groups ($p > 0.05$) (Figure 2).

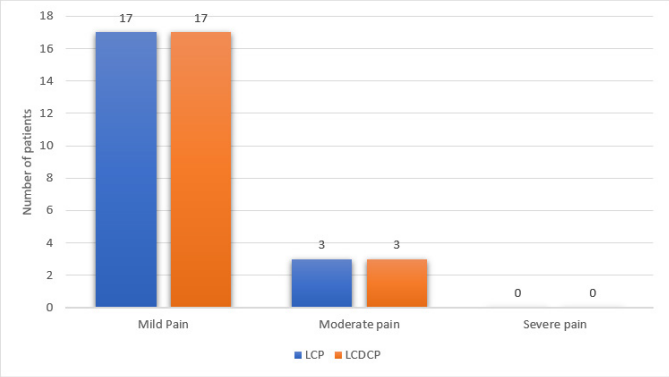

Figure 2: VAS Score status in study groups.

39 of the 40 enrolled cases suffered from no complications. 1 patient in LCP group suffered from radial nerve injury. Statistically the complication rate was comparable between study groups ($p > 0.05$) (Table 5).

Complications	LCP group (n = 20)	LCDCP group (n = 20)
Nil	19 (95%)	20 (100%)
Radial nerve injury	1 (5%)	0
P value	0.9, considered NOT significant by Chi-square test	

Table 5: Complications noted in study groups.

Discussion

Management of shaft of humerus fractures has been discussed by orthopaedic surgeons from decades, and has also been considered challenging in most cases. Plate osteosynthesis remains the standard of surgical treatment [7]. Plate fixation has been found to have high union rates but needs extensive dissection along with soft tissue stripping [8]. Nevertheless, open reduction and internal fixation (ORIF) with plating has benefits of stable fixation, direct visualization as well as protection of the radial nerve [9]. Locking plates may have a combination of holes which allow placement of both locking as well as traditional non-locking screws (so called "combi" plates). Many authors have showed the superiority of locking plates over dynamic compression plates in different cadaveric long-bone models [10]. The LCP is further innovative than the LCDCP as locking plates follow the bio-mechanical principle of internal fixator and do not need friction between the bone and the plate. Stability is preserved at the angular-stable screw-plate interface. Cortical porosis under plates is a crucial factor of weak fracture healing as well as re-fracture [11]. It is intended to lead to minimal surgical damage to vasculature, maintenance of optimal bone structure adjacent to the implant, better healing in the critical zone, negligible damage to bone lining following plate removal with decreased risk of re-fracture. The locking by LCP has been mentioned to minimize the compressive forces exerted by the plate on the bone. This means that the plate does not need to touch bone surface at all [12]. For non-comminated and simple diaphyseal fractures in osteoporotic bone needing an ORIF, locking plates offer the benefit of augmented pull-out resistance of the locking head screws in comparison with that of conventional screws [13]. Thus, for these fractures, locking plates can be applied based on the compression principle via eccentric placement of screws in the dynamic compression unit of the combi hole or by the utilization of a compression device after early placement of one locking head screw on the opposite side of the fracture [14]. Though both the LCP and the LCDCP plates seem to have promising effect on humerus shaft fracture outcomes, literature search revealed very few clinical studies published comparing locked plate and limited-contact dynamic compression plate fixation of humerus shaft fractures. The aim of this study is to evaluate whether a difference in plate design leads to better outcome in managing a specific chosen group of humeral shaft fractures.

In present study, 20 cases each were managed by LCP and LCDCP respectively. The age distribution was statistically comparable ($p > 0.05$) between study groups. The study had overall near-equal distribution amongst age groups, and the other baseline features were also mostly comparable. Overall, the comorbidity status was also statistically comparable between two groups ($p < 0.05$). Table 6 below gives a tabular representation of the demographic details in similar studies.

Majority of cases in both the study groups suffered from right sided injury. Overall, RTA was the commonest mode of injury in the study (60%), and majority cases suffered from direct injury (67.5%). Associated injuries was noted in 35% of cases overall,

Study	LCP group	LCDCP group
Age details		
Singh., *et al.* [6]	37.6 ± 10.8 years (22-64 years)	36.8 ± 8.9 years (18-65 years)
Shen., *et al.* [15]	43.3 ± 19.5 years (18-78 years)	36.8 ± 10.6 years (20-60 years)
Khalid., *et al.* [16]	40 ± 12.3 years	38.73 ± 13.06 years
Patel., *et al.* [17]	33.13 years	34.17 years
Gender distribution		
Singh., *et al.* [6].	Males: 68.18%, Females: 31.82%	Males: 71.56%, Females: 28.44%
Shen., *et al.* [15]	Males: 69.23%, Females: 30.77%	Males: 58.82%, Females: 41.18%
Khalid., *et al.* [16]	Males: 66.67%, Females: 33.33%	Males: 73.3%, Females: 26.7%

Table 6: Demographic details in similar studies.

radial nerve injuries being common injuries in both study groups. Commonest fracture pattern noted overall was transverse type (40%). Other identical studies had similar fracture findings. In the study by Singh., *et al.* 63.67% cases suffered from right sided humerus fracture, similar to the number noted in our study. In addition, mechanism of injury most commonly noted was RTA in 45.75%, similar to the most common mechanism in our study. In the study by Shen., *et al*. 20 patients had right sided fracture while 23 had left sided humerus fracture [15]. Just like our study, RTA was commonest cause of injury noted in more than half cases. In the study the mean time interval from injury to surgery was 5.8 ± 2.6 days (range 2-13 days) in LCDCP group while it was 5.8 ± 3.0 days (range 2-14 days) in the LCP group. In the study by Patel., *et al*. most common cause of fracture was RTA in 24 (80%) cases [17].

The time of surgery following admission was most commonly 0-2 days in both the study groups. Hospital stay was commonly noted for 1 week in both the LCP and LCDCP groups. The time-to-fracture-union of 18-24 weeks was the commonest noted in both study groups. None of the patients in the study groups suffered from any deformity after surgery. The range of motion was very good in 25% cases in both groups, while it was good in 75% in both groups indicating identical effects of the surgeries on movements. All patients in both the study groups had Constant and Murley Score between 71-85 indicating good outcome at final follow-up. 85% cases in both study groups had mild pain, while 15% cases in each group had moderate grade of pain by VAS score at follow-up. Statistically all the patient outcome parameters were noted to be comparable between study groups ($p > 0.05$). In addition, only one patient suffered from a complication in study, in LCP group (radial nerve injury). However, this was not a significant finding ($p > 0.05$).

The functional outcomes were comparable in other similar studies as well. In the study by Singh., *et al*. there was no significant difference found between the two groups in terms of primary outcome measures [6]. According to Rodriguez-Merchan criteria, comparison of functional outcomes of both groups showed insignificant difference ($p = 0.48$). There was no significant difference found between the two groups regarding mean ULCA score ($p = 0.34$) and mean MEPI sore ($p = 0.54$). In terms of complications, no significant difference was found between the two groups. In the study by Shen., *et al*. mean time of fracture union was 16.77 ± 6.01 weeks in LCDCP group and 14.59 ± 5.73 weeks in LCP group ($p > 0.05$). Seven (26.9 %) patients had postoperative complications in LCDCP group and 3 (17.6 %) in LCP group ($p > 0.05$) [15]. The mean UCLA End-Result score in LCDCP group was 34.31 ± 1.26 points and 33.12 ± 2.76 points in LCP group ($p > 0.05$). The mean MEPI was 100.00 ± 0.00 points in LCDCP group and 97.35 ± 7.52 points in LCP group ($p > 0.05$). The authors of that study concluded that there were no significant differences between the outcomes of these two types of implant. In the study by Patel., *et al*. the mean mobilization time in the LCP group was 3 days and the LCDCP group was 2.73 days. (p-value = 0.356), which was comparable. The mean time of union in the LCP group was 19.00 weeks and the LCDCP group was 16.57 weeks. (p-value = .151), which was comparable [17]. The Mean UCLA score for the LCP group was 31.20 and the LCDCP group was 30.40 (p-value = .186), which was again comparable. The Mean MEPI score in the LCP group was 84.33 and in the LCDCP group was 88.00 (p-value = .204), statistically comparable. The UCLA score was Excellent in 13.3% (2 patients) and good in 80.0% (12 patients) in the LCP group (Total 93.3%) and Excellent in 20% (3 patients) and good in 73.3% (11 patients) in the LCDCP group. (Total 93.3%). The MEPI score was Excellent in 26.7% (4 patients) and good in 60.0% (9 patients) in the LCP group (Total 86.7%) and Excellent in 40% (6 patients) and good in 53.3% (8 patients) in the LCDCP group (Total 93.3%). There were 2 patients had radial nerve palsy and 1 patient had superficial soft tissue infection in the Group A. There was 1 patient had radial nerve

palsy and 1 patient had superficial soft tissue infection in the Group B. There was 1 case of non-union in each group of the LCP and the LCDCP. Though most other studies showed comparable outcomes between LCP and LCDCP like our study, the study by Khalid., et al. had different findings [16]. Functional outcomes were significantly better with DCP in that study with cancellous bone graft as compared to LCP with cancellous bone graft in all age groups ($p \leq .004$), genders ($p \leq .012$), educational ($p \leq .049$) and economic status ($p \leq .003$) and BMI ($p \leq 0.049$) based on Modified Constant and Murley score.

Case 1: Xray at 6th,12th and 24th week with range of motion after 24th week.

Case 2: Xray at 6th,12th and 24th week with range of motion after 24th week.

Case 3: Xray at 6th,12th and 24th week with range of motion after 24th weeks.

Case 4: Xray at 6th,12th and 24th week with range of motion after 24th week.

Our study had a few limitations. The sample size was limited and the study was done at only one study center. Future studies with bigger sample size and conducted at multiple centres can help in validation of our study findings.

Conclusion

The surgical and functional outcomes were found to be statistically comparable between LCP and LCDCP study groups, indicating that results from both surgeries are equivalent and they can be adopted to manage shaft of humerus fractures. Both the procedures were noted to be safe. Fracture fixation with good compression is more important than plate selection.

Conflict of Interest

The authors show no conflict of interest regarding the article or anything.

Case 5: Xray at 6th, 12th and 24thweek with range of motion after 24th week.

Informed Consent

Informed consent was obtained from all the study subjects individually for this study.

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