Salter-Harris II Fractures of the Distal Tibia: Does Surgical Management Reduce the Risk of Premature Physeal Closure?

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Introduction: Premature physeal closure (PPC) is a common complication resulting from the management of a displaced Salter-Harris II (SH II) fracture of the distal tibia. The purpose of this study was to evaluate our institution's treatment approach to assess PPC and complication rates of fractures treated both surgically and nonsurgically.

Methods: We performed a retrospective review of all patients presenting with a displaced SH II fracture between 2004 and 2010. Initial treatment was closed reduction in the emergency department. Further treatment and subsequent categorization was based on amount of residual displacement. Patients with <2 mm of postreduction displacement were treated with a non–weight-bearing long-leg cast (LLC; group 1), patients with residual displacement between 2 and 4 mm were treated with one of 2 approaches based on surgeon preference: either LLC (group 2) or open reduction and internal fixation (ORIF) with removal of any interposed tissue (group 3). Patients with >4 mm of residual displacement were treated with ORIF (group 4). Follow-up radiographs were performed for a minimum of 6 months. If there was clinical concern about PPC, computed tomography imaging was performed to assess for a bony bar.

Results: In total, 96 patients with a mean age of 12.6 years at presentation were included in the study. Among the 14 patients with <2 mm of postreduction displacement, 29% had a PPC and 7% had to undergo a subsequent procedure (epiphsyiodesis, osteotomy, etc.). Of the 33 patients with 2 to 4 mm of displacement who were treated with a LLC, 33% had a PPC and 15% had to undergo a subsequent procedure. Of the 11 patients with 2 to 4 mm of displacement treated with ORIF 46% had a PPC and 18% had a second procedure. Finally, 38 patients with >4 mm of displacement treated with ORIF had a PPC rate of 55% and 23% had a subsequent procedure. No statistical differences in PPC ($P = 0.19$) or subsequent surgeries ($P = 0.57$) were observed between groups. Among those with 2 to 4 mm of postreduction displacement, patient age ($P = 0.36$), sex ($P = 0.39$), mechanism of injury ($P = 0.13$), time to fracture management ($P = 0.51$), amount of initial displacement ($P = 0.34$), number of reduction attempts ($P = 0.43$), and operative treatment ($P = 0.47$) did not significantly influence PPC.

Conclusions: Patients with displaced SH II distal tibia fractures pose a challenging problem for the treating physician with a high rate of PPC (43% overall). Although surgical fixation with anatomic reduction and removal of interposed tissue may be necessary to improve joint alignment, it does not reduce the incidence of PPC and may increase the need for subsequent surgeries.

Key Words: tibia fracture, Salter-Harris II, premature physeal closure

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Fractures involving the distal tibia physis occur frequently in children. Physeal injuries of the distal tibia are more common in older pediatric patients, typically occurring close to skeletal maturity. This is especially true in the setting of Tillaux and Triplane fractures and Salter-Harris II (SH II) fractures. Within the spectrum of physeal fractures, SH II fractures are the most common, accounting for 40% of all pediatric distal tibia fractures.[1,2] Premature physeal closure (PPC) is associated with these fractures, and long-term complications of PPC include altered joint mechanics, extremity malalignment, and leg length discrepancy. The actual rate of premature physeal arrest following these injuries is unknown. Although some studies have indicated physeal arrest rates between 2% and 5% following these types of fractures, recent studies by Barmada and colleagues, have reported an increased rate of PPC of 36% and 40%, respectively.[3–7]

To reduce the rate of PPC, surgical reduction and fixation has been recommended in the treatment of fractures with residual displacement >3 mm, and in those patients with more than 2 years of growth.[6,7] The rationale for surgery focused on removing entrapped periosteum, with the goal of achieving an anatomic reduction, thus, minimizing the chance of PPC.[6,8] Ross and Zionts[9] demonstrated that physeal fractures involving disruption of the periosteum in a rabbit model resulted in PPC. To date, Barmada and colleagues performed the only study examining this relationship in humans. They found that in

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those patients with a residual gap >2 mm following closed reduction had disrupted periosteum that was entrapped within the fracture site. Of these, 60% developed PPC compared with 17% of patients with a gap of <2 mm. This translated to a 3.5 times greater risk of developing PPC in patients with a residual gap of >2 mm.[6]

At our institution, a systematic approach in the management of SH II fractures of the distal tibia has been implemented. All acute displaced fractures were reduced in the emergency department under conscious sedation. Fractures with <2 mm of residual displacement were treated nonoperatively, whereas patients with >4 mm of residual displacement were treated surgically. Patients with 2 to 4 mm of residual displacement in either the coronal or sagittal planes were treated either nonoperatively or operatively, based on surgeon preference. The purpose of this study was to assess PPC rates and complications based on treatment. We hypothesized that an anatomic reduction would minimize the chance of PPC and the need for subsequent operative interventions.

METHODS

A retrospective review of patients treated for a SH II fracture of the distal tibia at our institution between 2004 and 2010 was performed. Inclusion criteria were as follows: presentation within 7 days of initial injury, open distal tibia physis confirmed with radiograph, and initial displacement >2 mm requiring reduction. Patients with <6 months of follow-up were excluded. Each patient was treated by one of 8 fellowship trained pediatric orthopaedists. All patients at our institution with displaced distal tibia fractures undergo an initial closed reduction. Patients received subsequent treatment based on the amount of postreduction fracture displacement. Those with <2 mm displacement were treated with a non–weight-bearing long-leg cast (LLC). Patients with postreduction displacement of 2 to 4 mm were treated with one of 2 approaches based on the surgeon's preference: no further attempts at reduction and definitive treatment with a non–weight-bearing LLC, or open reduction and internal fixation (ORIF) with removal of any interposed tissue. Patients with >4 mm of postreduction displacement were treated with ORIF.

All patients were placed into a LLC for 4 weeks at the time of definitive treatment (surgery or closed reduction). At 4 weeks, patients were transitioned to short-leg casts and remained non–weight-bearing for an additional 2 weeks. For those treated surgically with 0.062-inch Kirschner wires, the pins were removed 4 weeks postoperatively. For those treated with screws, implants were not routinely removed unless symptomatic; if performed, this surgery was documented as a subsequent procedure.

Charts were reviewed and the following variables were collected for each patient: age, sex, side of injury, mechanism of injury, presence of concurrent fibula fracture, amount of initial displacement before reduction, amount of postreduction displacement (measured in millimeters as the largest amount of displacement between the epiphysis and metaphysis on radiograph), and occurrence of PPC. Mechanism of injury was classified as either abduction or supination external rotation based on the greatest distance measured on the anterioposterior (AP) or lateral radiograph, respectively.[10] The physis was radiographically evaluated at all follow-up appointments. Bilateral AP and lateral radiographs were used to study the distal tibia physis. If there was any clinical suspicion of PPC, a computed tomography scan was obtained to further investigate the presence of a physeal bar. Any clinically significant complication, including postoperative infection, leg-length discrepancy, or angular deformity was documented. In addition, any need for subsequent surgery, such as bony bar excision, epiphysiodesis, or implant removal was recorded.

Patients were categorized by amount of residual displacement and treatment rendered. Four comparison groups were created: group 1 consisted of those with <2 mm of displacement treated with a LLC, group 2 contained patients with 2 to 4 mm of displacement treated with a LLC, group 3 was comprised of patients with 2 to 4 mm of displacement treated with ORIF, and group 4 included patients with >4 mm of displacement treated with ORIF. Descriptive statistics including means and frequencies were calculated for each of the examined variables. Further analysis included comparisons between all 4 treatment groups, and a stratified analysis of patients based on amount of residual displacement [<2 mm (group 1), 2 to 4 mm (groups 2 and 3), and >4 mm (group 4)]. χ^2 tests were performed for categorical dependent variables and analysis of variance or student t tests were used to compare continuous dependent variables, as appropriate. Data were analyzed using PASW Statistics Version 18.0 (SPSS Inc., Chicago, IL). A P-value of 0.05 or less was considered statistically significant.

RESULTS

A total of 96 patients met the inclusion criteria for this study; group 1 consisted of 14 patients, group 2 contained 33 patients, group 3 was comprised of 11 patients, and group 4 included 38 patients. The study sample and their respective treatment categories are shown in Figure 1. Among all participants, 20 were female and 76 were male with a mean age of 12.6 years at the time of injury. Comparisons of all patients across treatment categories are displayed in Table 1. Age, side of injury, presence of a fibula fracture, and amount of initial displacement did not significantly differ among the 4 groups. We found no significant relationship between initial displacement and postreduction displacement ($r = 0.17$, $P = 0.16$); however, patients with abduction type injuries were less likely to have greater residual displacement when compared with their supination external rotation (SER) counterparts ($P = 0.012$). In addition, significantly more surgical interventions were performed in patients with abduction type injuries than supination external rotation type injuries ($P = 0.01$).

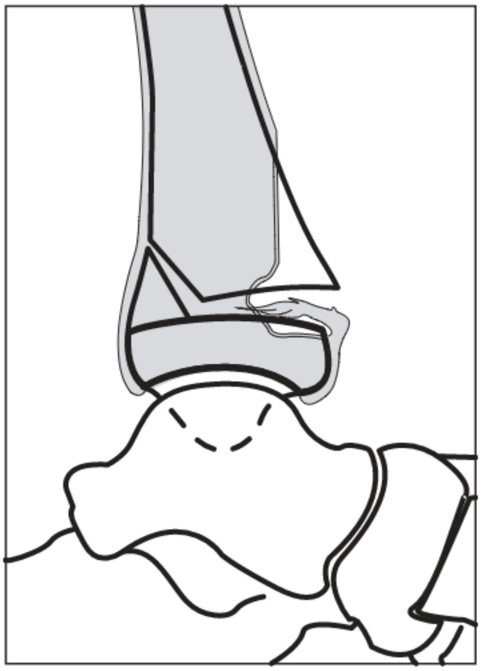

FIGURE 1. Schematic diagram illustrating interposed periosteum within the fracture site of a Salter-Harris II distal tibia fracture.

The course of treatment and respective PPC outcomes were assessed between the 4 groups, as depicted in Figure 2. PPC rates were 28.6%, 33.3%, 45.5%, and 53.3%, respectively, between groups 1 through 4. There were no statistically significant differences in the rate of PPC between treatment groups ($P = 0.19$). In those patients who progressed to PPC, the average length between time of presentation and time to diagnosis was 7.4 months (range, 2 to 27 mo).

Variables associated with PPC were evaluated among each of the stratified treatment groups. As presented in Table 2, when comparing only those patients with 2 to 4 mm of postreduction displacement (regardless of nonoperative or operative treatment), there were no significant associations between PPC rate and patient age ($P = 0.36$), sex ($P = 0.39$), mechanism of injury ($P = 0.13$), amount of initial displacement ($P = 0.34$), or operative treatment ($P = 0.47$). Within group 1, there were also no significant associations between the examined variables and the occurrence of PPC. Further analysis of PPC of patients in group 4 indicated that older patients ($P = 0.008$) and patients with greater initial displacement ($P = 0.03$) had increased rates of PPC.

In most cases, PPC was identified early on in our series; therefore, few patients developed an angular deformity or fibular overgrowth. In total, we identified 1 case of angular deformity > 10 degrees. Within our total patient population, 16 patients underwent additional procedures, which were as follows: 14 required epiphysiodesis, 2 required hardware removal, and 1 required irrigation and debridement secondary to osteomyelitis; no osteotomies were necessary. In those patients treated surgically, no statistical difference in outcome was observed between fixation achieved through screws or k-wires ($P = 0.48$). The need for subsequent surgery was evaluated collectively for all 96 patients in the 4 treatment groups and the results are shown in Figure 2. Subsequent surgical interventions rates were 7.1% in group 1, 15.2% in group 2, 18.2% in group 3, and 23.7% in group 4. No statistical difference in the rate of subsequent procedures was found between the groups ($P = 0.57$). However, the total number of surgical procedures performed per patient was statistically significant between the 4 groups, with an average of 0.07 surgeries performed per patient in group 1, 0.15 surgeries per patient in group 2, 1.18 surgeries performed per patient in group 3, and 1.24 surgeries per patient in group 4 ($P < 0.001$; Figs. 3–5).

TABLE 1. Characteristics of All Patients Treated for Displaced Salter-Harris II Distal Tibia Fractures According to Treatment Group* (N = 96)

	Mean ± SD or n (%)				
Variables	**Group 1 (n = 14)**	**Group 2 (n = 33)**	**Group 3 (n = 11)**	**Group 4 (n = 38)**	***P***
Age (y)	12.4 ± 2.4	12.9 ± 2.0	12.5 ± 1.1	12.4 ± 2.1	0.74
Sex					0.05
Male	7 (50)	27 (81.8)	10 (90.9)	32 (84.2)	
Female	7 (50)	6 (18.2)	1 (9.1)	6 (15.8)	
Injured side					0.24
Right	10 (71.4)	23 (69.7)	4 (36.4)	23 (60.5)	
Left	4 (28.6)	10 (30.3)	7 (63.6)	15 (39.5)	
Mechanism of injury					**0.01**
Supination external rotation	11 (78.6)	27 (81.1)	7 (63.6)	18 (47.4)	
Abduction	3 (21.4)	6 (18.2)	4 (36.4)	20 (52.6)	
Fibula fracture	8 (57.1)	15 (45.5)	8 (72.2)	29 (76.3)	0.05
Amount of initial displacement (mm)	9.0 ± 5.9	8.7 ± 4.4	10.9 ± 4.8	10.0 ± 5.0	0.54

*Treatment groups were categorized as follows: group 1, < 2 mm displacement treated nonoperatively; group 2, 2 to 4 mm displacement treated nonoperatively; group 3, 2 to 4 mm displacement treated operatively; group 4, > 4 mm displacement treated operatively. Bold value indicates significance.

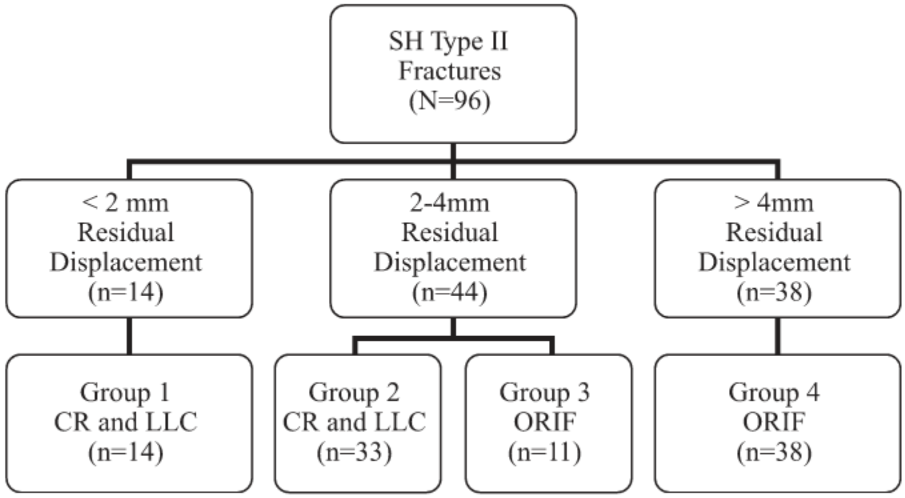

FIGURE 2. Treatment categories of patients with displaced Salter-Harris (SH) type II distal tibia fractures. LLC indicates long-leg cast; ORIF, open reduction and internal fixation. CR indicates closed reduction.

DISCUSSION

The optimal treatment of SH II fractures of the distal tibia is controversial. Although these injuries have classically been considered uncomplicated, with PPC rates reportedly as low as 2% they have proven to be more problematic than initially believed.[3,4] Previous studies at our institution indicated a PPC rate of 36% to 40%, for both SH I and II fractures. More recently, Leary et al[11] studied 124 SH fractures, 40 of which were type II, and reported a PPC rate of 25% in their SH II cohort. The current study validates these findings with an overall PPC rate of 42.7%. Our reported rate may be higher than previously published given that we are only addressing displaced type II fractures that require, at minimum, a closed reduction.

TABLE 2. Variables Associated With Premature Physeal Closure (PPC) Among Patients Treated Both Nonoperatively and Operatively for Displaced Salter-Harris II Distal Tibia Fractures With 2 to 4 mm Postreduction Displacement (Groups 2 and 3)* (N = 44)

	Mean ± SD or n (%)		
Variables	**No PPC (n = 28)**	**PPC (n = 16)**	***P***
Age (y)	12.6 ± 2.0	13.1 ± 1.2	0.36
Sex			0.39
Male	22 (78.6)	15 (93.8)	
Female	6 (21.4)	1 (6.2)	
Injured side			0.21
Right	15 (53.6)	12 (75.0)	
Left	13 (46.4)	4 (25.0)	
Mechanism of injury			0.13
Supination external rotation	24 (85.7)	10 (62.5)	
Abduction	4 (14.3)	6 (37.5)	
Fibula fracture	15 (53.6)	8 (50.0)	0.82
Amount of initial displacement (mm)	8.8 ± 4.2	10.3 ± 5.1	0.34
Compartment syndrome	0	1 (6.2)	0.36
Operative treatment (group 3*)	6 (21.4)	5 (31.3)	0.47
Time to treatment (d)	2.2 ± 3.3	1.6 ± 2.2	0.51
No. reduction attempts	1.3 ± 0.5	1.4 ± 0.7	0.43

*Treatment groups were categorized as follows: group 1, < 2 mm displacement treated nonoperatively; group 2, 2 to 4 mm displacement treated nonoperatively; group 3, 2 to 4 mm displacement treated operatively; group 4, > 4 mm displacement treated operatively.

Other institutions have examined the relationship between mechanism of injury and PPC. We classified mechanism of injury based on the greatest amount of displacement measured on plain film in the AP view, which corresponded with a SER type injury, or lateral view, which correlated with an abduction-type injury. Rohmiller et al[7] documented a greater rate of PPC following abduction injuries (54%) versus those patients who sustained an SER mechanism of injury (35%), though it was not found to be statistically significant. The results of the current study were similar to Rohmiller's with closure rates of 58% for abduction fractures and 35% for SER fractures, but our results were found to be statistically significant.

In the current study, patients with an abduction-type injury were found to have a significantly higher rate of surgical intervention as compared with those with SER injuries ($P = 0.01$). The literature has documented the relationship between postreduction displacement and mechanism of injury, and found that abduction type injuries are more likely associated with a greater degree of postreduction displacement as compared with their SER counterparts.[7] It is unclear whether these abduction type injuries are associated with more periosteum being entrapped within the fracture site, or whether the initial damage to the physis alters the contours of the growth plate making an anatomic reduction more difficult to achieve.[12]

The results of our study showed that older patients within group 4 were more likely to have a PPC

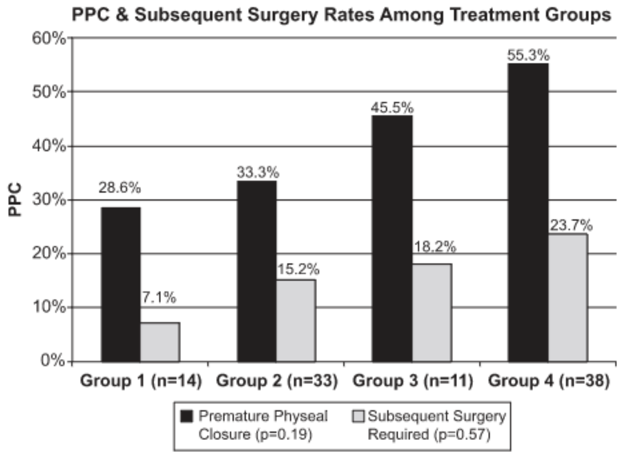

FIGURE 3. Premature physeal closure (PPC) and subsequent surgery rates among Salter-Harris type II distal tibia fractures treatment categories (treatment groups were categorized as follows: group 1, <2 mm displacement treated nonoperatively; group 2, 2 to 4 mm displacement treated nonoperatively; group 3, 2 to 4 mm displacement treated operatively; group 4, >4 mm displacement treated operatively).

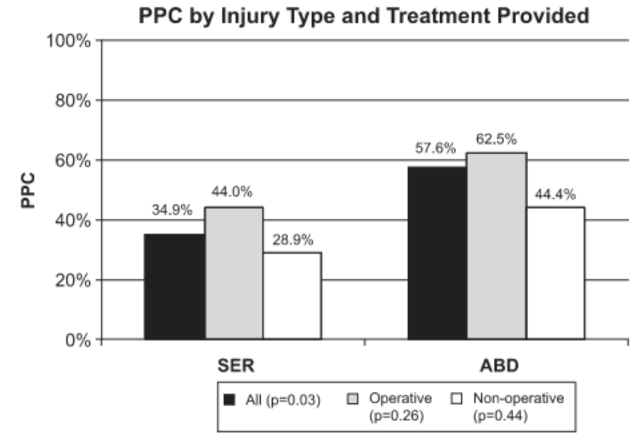

FIGURE 4. Premature physeal closure (PPC) according to type of injury, supination external rotation (SER) or abduction, and treatment approach.

($P = 0.01$), though no significant association was found between PPC and the development of a clinically significant deformity. In cases where PPC of the distal tibia was identified, the tibia either partially or completely closed before the fibula, as opposed to simultaneous closure observed in cases where physiological closure was observed. Arrest after a traumatic injury to the distal tibia physis has been observed at the same location where initial physiological closure occurs, in the anteromedial portion of the growth plate known as Poland hump or Kump bump.[13,14] Ecklund and Jaramillo[15] demonstrated that the majority (60%) of pathologic closure occurs initially at this site. Historically, 3 to 5 mm of growth per year has been attributed to the distal tibia physis.[16,17] Given that this segment of the physis is responsible for 43% of the growth of the distal tibia and 15% to 25% of overall leg length, injuries to this site have the potential to result in significant angular or length disturbances.[14,16,18] In this series, if a patient with significant growth left was noted to have a PPC, an epiphysiodesis was performed. Fortunately, the majority of our patient population had minimal skeletal growth left. Therefore, despite premature closure of the growth plate, there were no significant associated clinical sequela such as leg-length discrepancy or angular deformity. Although adolescent patients nearing skeletal maturity are unlikely to have significant deformity due to PPC as observed in group 4, younger patients who sustain this injury need to be followed closely for the development of a physeal bar, as it may lead to clinically significant deformities of the distal tibia.

Despite evidence demonstrating anatomic reduction and surgical fixation as the best approach to reestablish

FIGURE 5. A 9-year-old girl with a supination external rotation type Salter-Harris II fracture of the distal tibia. Postreduction lateral radiograph showed 3 mm of residual displacement. The patient underwent open fixation with removal of interposed periosteum from the fracture site. Six months postoperatively the patient developed a premature physeal closure and she required bilateral distal tibia and fibula epiphysiodeses. ORIF indicates open reduction and internal fixation.

physiological alignment, it may lead to further complication and subsequent surgery, as demonstrated by our findings.[19] In addition, we discovered that those treated operatively were not found to have a significantly decreased rate of PPC; rather, ORIF was observed to have an overall increased rate, though not significantly greater than those treated conservatively. In addition, patients treated initially with surgery to remove the entrapped periosteum (groups 3 and 4) underwent a significantly greater number of total surgeries compared with those treated nonsurgically adding to overall cost of care with no clear benefit.

The rate of PPC following distal tibia physeal fractures is alarmingly high, and the most commonly practiced acute surgical intervention (ORIF) does not seem to provide much benefit in reducing the rate of PPC when compared with closed reduction and casting. As we look to future treatment options, there may be support for prophylactic interposition fat grafting of the fracture site in order to reduce the incidence of PPC.[20] A single small case series from Australia (3 patients) described the effectiveness of interposition fat grafting at preventing bony bridge formation in juvenile patients with a distal tibia physeal fracture.[21] On the basis of this group's results, they have advocated this technique as the definitive management of acute physeal injuries of the distal tibia.

Fortunately, the majority of closures occur within 12 months, though some with follow-up <12 months may have been missed. With that said, we still identified a very high closure rate that is clinically relevant with important surgical implications. As the focus of this study was to look at fractures treated surgically versus nonsurgically and the follow-up between groups was equivalent, we did not feel that this biased our data either toward surgery or nonoperative treatment.

We recommend all displaced SH II fractures of the distal tibia be treated with closed reduction and nonsurgical treatment unless a gross deformity exists. Families should be counseled to the high risk of PPC. We recommend each patient receive close follow-up of a minimum of 12 months, with repeat radiographs or computed tomography imaging to assess for the presence of a bony bar that may indicate surgical intervention to maximize the likelihood of anatomic ankle joint alignment.

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