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Original Research

Outcomes of distal femoral fractures treated with minimally invasive plate osteosynthesis versus open reduction internal fixation with combined locking plate and interfragmentary screws

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A B S T R A C T

Purpose: Fractures of the distal femur remain challenging to treat, and numerous fixation methods are designed to promote stability and fracture healing. Locking plate constructs have recently become the mainstream fixation method, but debate exists on whether to use locking plates alone or to augment them with interfragmentary screws. This article compares outcomes of distal femur fractures treated with a single locking plate alone versus those treated with a locking plate and interfragmentary screws.

Methods: We retrospectively reviewed 57 patients treated for distal femur fractures from 2010 to 2013. Patients were divided into two groups: Those treated with a locking plate alone utilizing the minimally invasive plate osteosynthesis (MIPO) technique and those treated with combination of a locking plate and interfragmentary screws using an open technique. Postoperative outcomes were obtained via a manual chart review. Fracture healing and callus indices were evaluated from radiographs.

Results: 9 patients required revision surgery in the locking plate alone group (6 for persistent nonunion and 3 for varus deformity). Only two patients in the combination group required revisions (both for nonunion). Average time to full weight bearing was 19.54 weeks in the locking plate group versus 14.57 weeks in the combination group ($p = 0.004$). At the time of full weight bearing, frontal (1.15 versus 1.11, $p = 0.004$) and sagittal (1.22 versus 1.15, $P = 0.008$) callus indices were both significantly greater in the locking plate group.

Conclusions: In this study, the combination of a locking plate and interfragmentary screws achieved suitable stability and a faster time to full weight bearing than using a locking plate alone. Surgeons should consider combining a locking plate with interfragmentary screws as an effective method for fixation of distal femur fractures, particularly in cases when plate fixation alone fails to provide adequate fracture stability.

1. Introduction

In the field of orthopaedic trauma surgery, fractures of the distal femur are complex injuries that can be difficult to manage. Fixations of distal femur fractures have been shown to be associated with difficulties in fracture reduction, higher rates of fracture fixation failures with progressive angulation, delayed unions, and nonunions [1–5]. Common deformities in distal femur fractures include the shortening, flexion, and external rotation of the proximal fragments and the extension of the distal fragments. These issues are compounded by the presence of powerful muscles such as the gastrocnemius and the adductors, which insert on and exert unilateral forces on the distal femur [6,7].

In recent years, locking plates have been increasingly adopted as an alternative to traditional implants, such as angle blade plates, dynamic condyle screws, and intramedullary nails [8,9]. These locking constructs have been shown to provide better anatomic fitness, preserve blood supply, and facilitate fracture reduction and interfragmentary fracture compression [9,10]. However, fixation applications using plate constructs have frequently exhibited an easy loss of fixation of the distal femoral fragment, which may lead to progressive varus angulation and fixation failure [11–13]. This issue is particularly prevalent in the osteoporotic population [14,15]. Other common adverse events include infections, decreased range of motion, malunions, and nonunions [1,4]. Patients with these complications often require further surgery [16,17].

Before the development of locking constructs, interfragmentary screws were widely used in the fracture reduction and fixation process. The goal of treatment with interfragmentary screws is to increase the stiffness and stability of the fracture fragments and limit

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interfragmentary movement, which together provide a more stable environment for fracture fixation and healing. This advantage seems to conflict with the principle of locking plates, which allows for adequate interfragmentary movement to achieve secondary fracture union. However, as locking plates alone are sometimes associated with complications in distal femur fractures, surgeons may elect to use a combination of locking plate and interfragmentary screws to achieve adequate fixation.

The purpose of this study is to compare postoperative outcomes in patients with distal femur fractures treated with only a locking plate versus those who were treated with a locking plate and interfragmentary screws. We hypothesize that patients treated with both a locking plate and interfragmentary screws achieve better stability and have a faster time to bony union and full weight bearing capacity.

2. Methods

This is a single-center, retrospective study conducted on patients who sustained a fracture of the distal femur from January 2010 to June 2013 at a tertiary medical center. Inclusion criterion was the presence of a distal meta-diaphyseal extra-articular fracture of the femur (AO classification 33-A1, A2, A3) treated with locking plate fixation by orthopaedic trauma surgeons. Patients were excluded if they sustained open, multiple, or intra-articular fractures, or if they underwent revision surgery for fracture nonunion or periprosthetic fractures. Fractures were coded according to the AO/Orthopaedic Trauma Association (AO/OTA) fracture classification system. Patients were divided into two cohorts: Those who were treated with only a locking plate and those who were treated with a plate and interfragmentary fixation screws. This study was approved by Institutional Review Board of Tri-Service General Hospital (TSGHIRB No. 2-107-05-012). The work has been reported in line with the STROCSS criteria [18].

The surgical procedure is detailed below. Under anesthesia, patients were placed in a supine position on a radiolucent table. A round cushion or sheets were placed under the distal femur to compensate for secondary recurvatum and the entire leg was prepared to allow proximal extension for surgical exposure. The standard anterolateral approach to the distal femur was performed with a curvilinear incision from 3 to 6 cm proximal to the tibial tubercle to the mid-lateral aspect of the distal femur. In the plate-only group, fracture reduction was aided by free-hand traction to correct alignment in the coronal plane. Under fluoroscopy guidance, alignment and rotation were restored, and the fracture was provisionally stabilized using Kirschner wires. In the locking plate only group, a standard method for putting the plate on the lateral surface of the distal femur using the minimally invasive plate osteosynthesis (MIPO) technique was followed. In the group with interfragmentary screws, a reduction clamp or forceps was used to stabilize the fracture site to achieve appropriate alignment and rotation. The fracture was provisionally stabilized using positional screws, and then the plate was inserted and fixed.

For simple and noncomminuted fractures (AO type 33A-1 and 33A-2), partial weight bearing with assisted devices was allowed as soon as possible as tolerated by the patient. However, for complex and comminuted fractures (AO type 33A-3), delayed weight bearing was indicated for 4–6 weeks after surgery, depending on reduction quality and stability. Regular X-rays were obtained on day 2 and then at 4, 8, 12, 16, 24, and 48 weeks and upon achieving full weight bearing after surgery. These patients were reevaluated at monthly intervals. AP and lateral plain films of pre-operative and post-operative X-rays were obtained to analyze fracture healing and the complications associated with the loss of reduction and fracture nonunion.

Time to full weight bearing was obtained from the medical records and regular visits. Fracture healing with callus formation was evaluated from anteroposterior and lateral radiographs obtained post-surgery. Fracture union was defined as the callus bridging of at least 2 of the 3 cortices visible on the AP and lateral radiographs combined with resolution of pain at the fracture site during full load bearing.

The callus index was determined using a measurement method described previously by Gardner, Hardy, Evans and Kenwright [19]. This method calculates the quotient of the width of the thickest part of the callus formation and the width of the bone at the same site, as described in the formula below.

2.1. Callux index = combined width of the bone and callus/width of bone

Complications were defined as fixation failures, a loss of reduction, implant breakage, infections, nonunions, and the need for revision surgery. Loss of reduction was defined as a change in varus alignment of $\geq 5^{\circ}$ compared to the initial post-operative alignment, whereas a change of $< 5^{\circ}$ was considered to be within the measurement variation [20,21]. Nonunion was defined as failure of fracture union at 9-month follow-up with no progression of callus formation on three sequential monthly radiographs [22,23].

2.2. Statistical analysis

The clinical characteristics of the two fixation types were compared using a *t*-test for continuous variables and a chi-squared test for categorical variables. A *t*-test was also used to compare both the time until fracture healing and the callus index. Statistical analyses were carried out with the IBM Statistical Product and Service Solutions (SPSS) for Windows, Version 22.0 (IBM Corp., Armonk, NY, USA), and $p < 0.05$ was considered significant for all analyses.

3. Results

92 patients (ages 19–92 years) with distal femur fractures who were treated with a lateral distal femur LCP were reviewed. 32 patients failed to meet study criteria and three had less than 2 years' follow-up, leaving a final cohort of 57 patients. 29/57 fractures were fixed using only a distal femur locking plate, and 28/57 fractures used interfragmentary screws in addition to a locking plate.

In the group treated with a locking plate only, nine patients in the locking plate group required revision surgeries. Six developed persistent nonunion requiring a bone graft and three developed varus deformity. Comparatively, two patients in the combined locking plate and interfragmentary screw group required revision surgery. Both of these patients underwent revision for nonunion and showed satisfactory healing post-revision. Demographics and features of internal fixation for the remaining 46 patients who did not require revisions are summarized in Table 1. Average time to weight bearing in all patients who did not require revisions was 16.74 weeks (range, 10–36.29 weeks). In the locking plate only group, the average time to full weight bearing was 19.54 weeks (range 12.14–36.29 weeks). Those who were in the combination group had an average time of 14.57 weeks to achieve full weight bearing status (range 10–27.14 weeks) ($p = 0.004$) (Fig. 1).

When comparing the callus index at the time of full weight bearing, the mean frontal callus index was 1.15 (1.06–1.33) for patients with plate-only fixation and 1.11 (1.05–1.19) for those who also received interfragmentary screw fixation ($p = 0.004$) (Fig. 2). The mean sagittal callus index was 1.22 (1.04–1.38) for patients with plate-only fixation and 1.15 (1.05–1.35) for those who also received interfragmentary screw fixation ($p = 0.008$) (Fig. 3). The patterns of callus formation revealed that the amount of callus formed in the sagittal plane was greater than that in the frontal plane (Table 2). The results also showed less callus formation on the lateral cortex of the distal femur, immediately adjacent to the plate.

4. Discussion

Fractures of the distal femur present many challenges for treatment, with numerous fixation methods having been designed to improve

Table 1
Characteristics and features of internal fixation in groups of single locking plate fixation and combination fixation.

	Single locking plate	Combined interfragmentary screws	*P*
Age (Mean ± SD)	62.70 ± 15.3	61.38 ± 17.5	0.791[a]
Sex			0.482[b]
Male	5 (25)	9 (35)	
Female	15 (75)	17 (65)	
Fracture side			0.855[b]
R	11 (55)	15 (48)	
L	9 (45)	11 (42)	
AO fracture type			0.703[b]
33-A1	5 (25)	9 (34)	
33-A2	10 (50)	10 (36)	
33-A3	5 (25)	7 (30)	
Length of locking plate (mm)	297.5	301	0.289[a]
Number of proximal locking screws	3.55	3.53	0.469[a]
Number of distal locking screws	6.1	6.12	0.435[a]
Union time (wks)	19.54	14.19	0.004[a*]

*: $P < 0.05$.
[a] T test.
[b] $\chi 2$ test.

stability and promote healing. Locking plate constructs provide better stability in the osteoporotic distal femur and have become the mainstream fixation method. One of the advantages of locking plates is that they can be used as a rigid design in a manner similar to conventional plates by offering primary bone healing [10] or in a less rigid manner by increasing the bridging span over the fracture site [9,24–27]. However, recent studies have demonstrated several complications that may still be prevalent in distal femur fractures despite treatment with locking plates [16,17,28]. Therefore, we questioned whether additional interfragmentary screws could provide better stability and fracture healing for the treatment of distal femur fractures than the use of a locking plate alone.

We found that patients treated with interfragmentary screws in addition to a plate required less time to achieve full weight bearing. This result showed that the use of interfragmentary screws might provide more stability to the fracture site and could decrease the time to full weight bearing. Figs. 4 and 5 show a series of X-rays that highlight the differences in bony union between similar distal femur fractures treated without and with interfragmentary screws. Although it is believed that locking plates can allow adequate interfragmentary movement and thus promote secondary bone healing [20], a more rigid fixation method may be required for the distal femur, which is subjected to powerful muscle contractions occurring in several directions.

Despite an improved clinical outcome, postoperative radiographic studies show that the combined plate and interfragmentary screw fixation group had significantly less callus formation in the frontal and sagittal planes. Several studies have suggested that flexible fixation increases callus formation [29–31]. The stability and flexibility of the fixed implants influence interfragmentary movement. In a previous study, interfragmentary movement was required to stimulate callus formation in fracture consolidation [30,32–34]. In this study, although less callus formation was observed in the combination fixation group, the patients in this group exhibited faster bone healing and required less time for full weight bearing. Our results show that differences in callus indices may not necessarily correlate with improved clinical and functional status, and that increased rigidity of the fixation may play a larger role in promoting healing in distal femoral fractures. Furthermore, delayed union or hypertrophic nonunion might result from insufficient mechanical stability, which may be associated with large callus formation around the fracture site [35,36].

While increased rigidity may play a large role in improved clinical outcomes following distal femur fractures, it is worth noting that two patients in the combined fixation group exhibited persistent nonunions over the fracture site. After removing the interfragmentary screws and combined with allogenous bone grafting, fracture union was noted in the following months. It seems that in some cases, fixation that might be too rigid allowed less interfragmentary movement and resulted in the

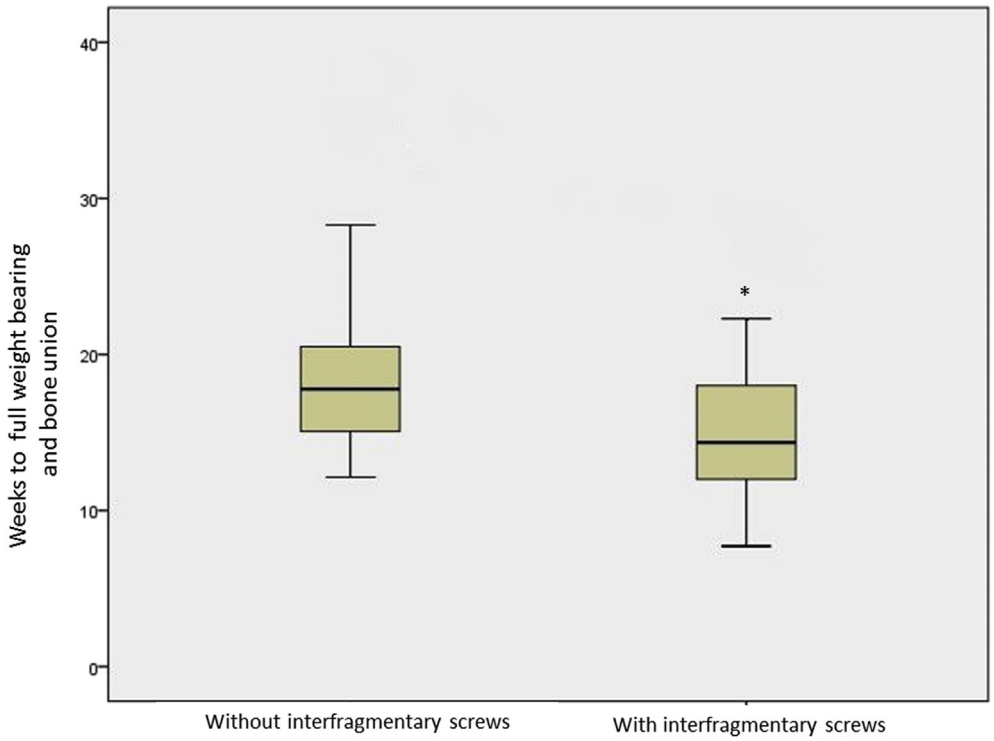

Fig. 1. Comparison of the union time with full weight bearing for the treatment of distal femur fractures with or without interfragmentary screws (p = 0.004).

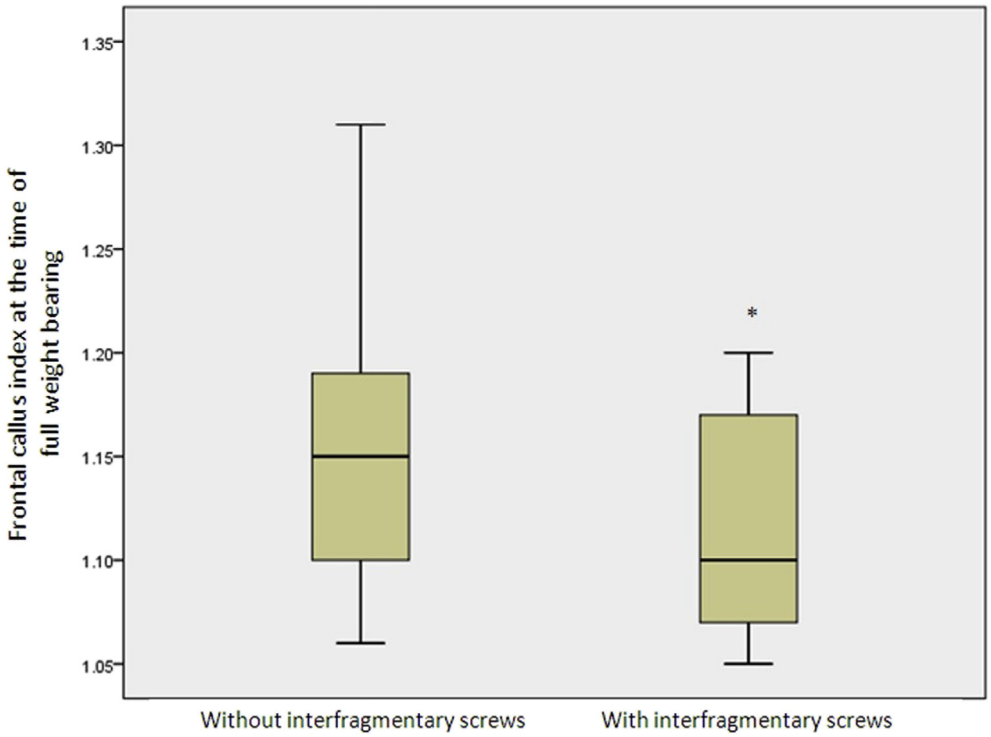

Fig. 2. Comparison of the frontal callus index at the time of full weight bearing for the treatment of distal femur fractures with or without interfragmentary screws (p = 0.004).

complication of nonunion.

Rigid fixation of fractures using interfragmentary screws through the open method is contrary to the principle of the MIPO technique, which as aims to facilitate callus formation through indirect bone healing. The interfragmentary screw fixation technique was previously considered to inhibit callus induction due to the rigid fixation and decreased interfragmentary motion, thereby resulting in delayed bony union. However, in this study, the use of interfragmentary screws resulted in significantly faster fracture healing and a more rapid return to full weight bearing, albeit with a lower callus index. Horn et al. presented the same result in the treatment of distal tibia fractures [37]. Their study revealed that interfragmentary lag screws led to faster

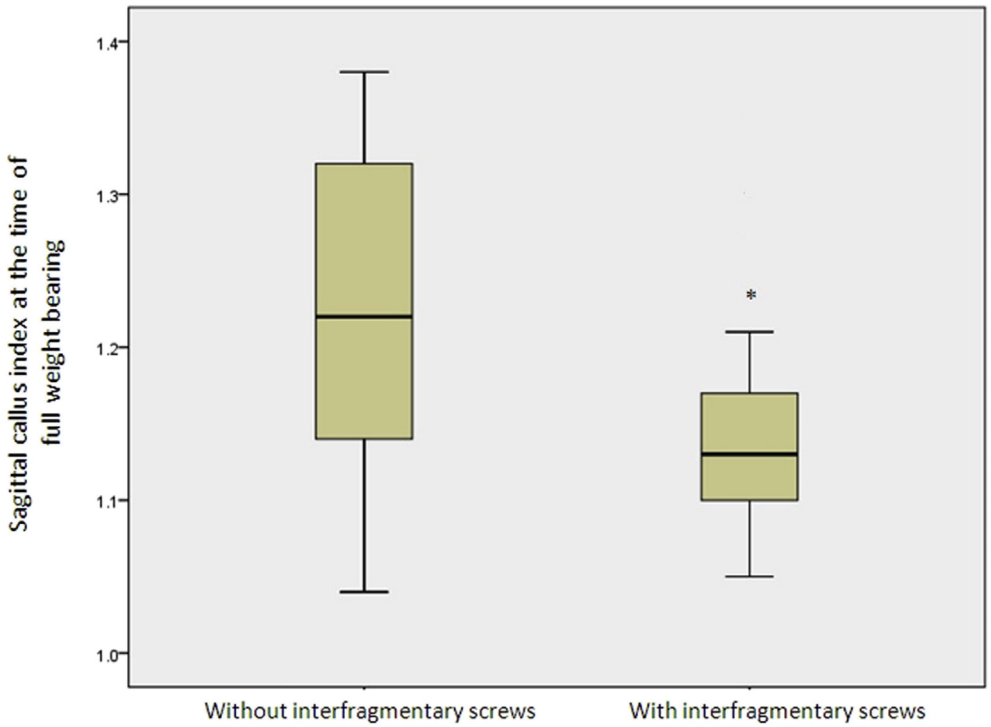

Fig. 3. Comparison of the sagittal callus index at the time of full weight bearing for the treatment of distal femur fractures with or without interfragmentary screws (p = 0.008).

Table 2
Callus index comparison in frontal and sagittal view.

	Frontal Callus index		*P* value	Sagittal Callus index		*P* value
	Single locking plate	Combined interfragmentary screws		Single locking plate	Combined interfragmentary screws	
6 weeks	1.062	1.063	0.466	1.076	1.066	0.133
12 weeks	1.117	1.111	0.426	1.141	1.117	0.117
18 weeks	1.179	1.116	0.038*	1.211	1.155	0.033*
24 weeks	1.18	1.123	0.003*	1.234	1.168	0.017*

1. Fractures with single plate fixation were healed at 19.54 weeks with a frontal callus index of 1.15 and sagittal index of 1.22; fractures with interfragmentary screws were healed at 14.57 weeks, showing a frontal callus index of 1.11 and sagittal index of 1.15.
2. *: $P < 0.05$.

Fig. 4. A 63-year-old male with a distal femur fracture (AO classification: 33-A2) received an operation with locking plate fixation without interfragmentary screw fixation. X-rays taken before and after the surgery and after 24 weeks show fracture nonunion.

Fig. 5. A 67-year-old male with a similar distal femur fracture pattern as in Fig. 4 who also received interfragmentary screw fixation. The series of X-ray evaluations taken before and after surgery and after 16 weeks show progressive bony union.

fracture healing, but callus formation was significantly reduced in patients with screw fixation.

This study has several limitations. First, this study is retrospective and includes with all of its inherent limitations. Second, the sample size is relatively small. Third, a number of different surgeons operated on our patient cohort and may have differing intraoperative techniques and postoperative management strategies. Fourth, the status of the healing fracture was only evaluated using X-rays, without further CT examination, which may have resulted in missed small defects within the fracture site. Finally, the placement of interfragmentary screws requires a more invasive, open technique and thus we were unable to perform MIPO on the combination group. Despite this, the combination group still had a better postsurgical outcome than the plate only group.

5. Conclusion

In this study, we found that additional fixation using interfragmentary screws in addition to a locking plate could achieve suitable stability and faster fracture healing in cases of distal femur fracture. Surgeons should consider combining a locking plate with interfragmentary screws as an effective method for fixation of distal femur fractures, particularly in cases when plate fixation alone fails to provide adequate fracture stability.

6. Data statement

A total of 92 distal femur fractures treated with a lateral distal femur LCP were reviewed. Finally, 57 patients met the study criteria and enrolled in this study. During the operation, 29/57 fractures were fixed using a distal femur locking plate alone, and 28/57 fractures were fixed using interfragmentary screws to provide additional stability.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Ethical approval

The Institutional Review Board of Tri-Service General Hospital approved this study (TSGHIRB No. 2-107-05-012) and the committee waived the need for written informed consent.

Conflicts of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Author contribution

None.

Research registration number

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Guarantor

None.

CRediT authorship contribution statement

Sheng-Hao Wang: Data curation, Formal analysis, Writing - original draft. **Chia-Chun Wu:** Data curation, Formal analysis. **William T. Li:** Writing - review & editing. **Hsain-Chung Shen:** Methodology, Supervision. **Leou-Chyr Lin:** Supervision, Validation. **Ru-Yu Pan:** Writing - review & editing.

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The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ijsu.2019.03.019.

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