

Original Research Article

A comparative study of the effect of early versus late dynamization of external fixator in the treatment of compound fracture of tibia: a non-randomized controlled trial

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ABSTRACT

Background: Dynamization is commonly employed to enhance fracture healing following stabilization with external fixators or intramedullary nails. However, the optimal timing of dynamization remains controversial, with limited consensus in clinical practice. The aim was to compare the radiological and functional outcomes of early versus late dynamization in patients with tibial fractures treated using external fixation and to determine the optimal timing for dynamization.

Methods: This prospective comparative study included 36 patients with open tibial fractures managed with external fixation. Patients were equally divided into two groups: group I (early dynamization, initiated at 2-4 weeks postoperatively) and group II (late dynamization, initiated at or after 4 weeks). Patients were followed up for fracture union, time to union, complications, pain, range of motion, need for secondary procedures, and functional outcome using the Baird and Jackson scoring system. Statistical analysis was performed to compare outcomes between the two groups.

Results: Fracture union was achieved in 94.4% of patients in the early dynamization group compared to 72.2% in the late dynamization group. The mean time to union was significantly shorter in group I (12.65 ± 5.49 weeks) than in group II (18.46 ± 4.61 weeks; $p=0.005$). Complication rates, including pin tract infection and limb shortening, were lower in the early dynamization group. Functional outcomes were favorable in both groups; however, excellent Baird and Jackson scores were more frequent in the early dynamization group. Pain relief and restoration of joint range of motion were achieved earlier in patients undergoing early dynamization.

Conclusions: Early dynamization within four weeks of surgery results in faster fracture union and better functional outcomes compared to late dynamization. Early dynamization should be considered the preferred strategy in the management of tibial fractures treated with external fixation.

Keywords: Tibial fracture, Dynamization, Early dynamization, External fixation, Fracture union, Functional outcome

INTRODUCTION

Fracture healing is a complex, highly coordinated biological process involving the interaction of multiple cell types within a tightly regulated environment of chemical mediators, growth factors, and mechanical stimuli. An optimal balance between biological activity and mechanical stability is essential for successful bone regeneration.¹

Dynamization refers to the deliberate reduction in fixation stiffness to permit controlled interfragmentary motion (IFM), thereby creating a more favourable mechanical milieu for bone healing.² Experimental and clinical studies have demonstrated that dynamization enhances fracture healing in patients treated with both intramedullary nails and external fixators. Although the precise cellular mechanisms underlying mechanotransduction- the

conversion of mechanical signals into biochemical responses- are not yet fully elucidated.³

MSCs and endothelial progenitor cells are the principal cellular contributors to fracture healing. MSCs, derived from bone marrow and periosteum, support repair through direct differentiation into osteoblasts and chondrocytes, as well as through paracrine secretion of osteogenic and angiogenic growth factors such as bone morphogenetic proteins (BMPs) and vascular endothelial growth factor (VEGF).⁴

A major unresolved issue is the optimal timing of dynamization. Several studies report that early dynamization- typically within the first four weeks- results in faster fracture union and improved functional outcomes. Conversely, other authors advocate late dynamization, citing better union rates and reduced complications.

Experimental studies in tibial fracture models have produced conflicting findings, with some demonstrating enhanced healing following early dynamization, while others show delayed remodelling or no significant benefit. Clinical evidence remains similarly divided, highlighting the need for further investigation.^{4,5}

Compound fractures of the tibia are particularly suitable for studying the effects of dynamization, as they are commonly treated with external fixators that can be easily adjusted without additional surgical intervention. Moreover, external fixation is frequently employed as a definitive treatment modality in these injuries.

Given the ongoing controversy regarding the timing of dynamization, the present study aimed to compare the effects of early versus late dynamization of external fixation in the management of compound tibial fractures, with particular emphasis on fracture union and clinical outcomes.

Aims and objectives

The primary objective of this study was to compare the effect of early versus late dynamization of external fixation in the management of compound tibial fractures, with respect to time to fracture union and functional outcome.

METHODS

Study design

It was a hospital-based, non-randomized controlled interventional study.

Study setting

The study was conducted in the department of orthopedics, Regional Institute of Medical Sciences (RIMS), Imphal, India.

Study population

Patients presenting with compound fractures of the tibia to the outpatient department and emergency services (casualty) of the department of orthopedics, RIMS, Imphal, during the study period were assessed for eligibility.

Inclusion criteria

Patients aged 14-60 years. Gustilo-Anderson grade II and IIIA open fractures of the tibia Fracture patterns suitable for dynamization, including: transverse fractures, short oblique shaft fractures, butterfly fragment involving <25% of cortical circumference. Patients medically fit to undergo anesthesia and surgical intervention

Exclusion criteria

Patients with conditions known to impair fracture healing, such as: peripheral vascular disease, malignancy under active treatment, long-term steroid therapy. Patients unwilling to provide informed consent.

Study duration

The study was conducted from September 2022 to March 2024. Protocol approval was obtained between May and August 2022. Data analysis and manuscript preparation were completed by June 2024.

Sample size calculation

The sample size was calculated using the formula for comparison of two means:

$$n = \frac{(u + v)^2 \times (S_1^2 + S_2^2)}{(m_1 - m_2)^2}$$

Where,

u=0.84 (power of 80%); v=1.96 ($\alpha=0.05$)

Taking into consideration the review conducted by Schultz et al of early and late dynamization of external fixator in the treatment of compound tibial fracture in which both comparison in term of time of union.²

We take,

$S_1 = 2$ (SD of early dynamization group)

$S_2 = 2.1$ (SD of late dynamization group)

$m_1 = 16$ weeks (mean union time in early group)

$m_2 = 14$ weeks (mean union time in late group)

The calculated sample size was 16 patients per group. After accounting for a 10% anticipated dropout rate, the final sample size was 18 patients per group, resulting in a total of 36 patients.

Sampling method and group allocation

Patients fulfilling the eligibility criteria were recruited using convenience sampling. Group allocation was based on patient preference after counselling regarding both treatment strategies: group I (early dynamization): dynamization performed before 4 weeks. Group II (late dynamization): dynamization performed after 4 weeks.

Data collection

Data were collected using a pretested, structured proforma, which included: sociodemographic details, mechanism and characteristics of injury, clinical examination findings, radiological and laboratory investigations, follow-up clinical and radiographic assessments.

Both primary and secondary data sources were utilized, including departmental medical records and follow-up reports.

Operative technique

All patients underwent external fixation under spinal, general, or regional anesthesia. The procedure was performed with the patient in the supine position on a radiolucent table. Debridement was done in usual fashion.

Schanz pins (4.5 mm) were inserted percutaneously through the anteromedial surface of the tibia, ensuring optimal pin trajectory for proximal and distal fragments. Pins were connected using two tubular rods and clamps to achieve stable fixation.

Postoperative management

Broad-spectrum intravenous antibiotics (third-generation cephalosporins) were administered for 3 days. postoperative radiographs were obtained. Pin-tract care was performed on alternate days using antiseptic dressings.

Intervention: dynamization

Dynamization was achieved by loosening the AO universal clamp attached to the tubular rod on one side of the fracture fragment.

Early dynamization performed between 2 and ≤ 4 weeks postoperatively. Late dynamization performed after 4 weeks postoperatively.

Partial weight-bearing was initiated post-dynamization based on patient tolerance.

Follow-up and outcome assessment

Patients were followed clinically and radiographically at 2, 6, 10, and 14 weeks, and thereafter until fracture union.

Functional outcomes were assessed using the Baird and Jackson scoring system.

External fixators were removed upon evidence of clinical and radiological union, followed by application of a patellar tendon-bearing brace for 4-6 weeks.

Criteria for fracture union

Fracture union was defined by: Obliteration of the fracture gap in at least three cortices on two orthogonal radiographic views. Cortical continuity with visible callus formation. Absence of clinical mobility at the fracture site.

Statistical analysis

Data were analyzed using IBM SPSS Statistics version 21. Continuous variables were expressed as mean $\pm$ standard deviation. Categorical variables were expressed as frequencies and percentages. Independent t-test was used to compare mean union time and age between groups. Chi-square test or Fisher's exact test was used for categorical variables.

A p value <0.05 was considered statistically significant.

Ethical considerations

Ethical clearance was obtained from the research ethics board, RIMS, Imphal. Written informed consent was obtained from all participants. Confidentiality was maintained using unique identification codes, and participation was entirely voluntary.

RESULTS

A total of 36 patients with compound fractures of the tibia were included in the study. Of these, 18 patients underwent external fixation with early dynamization (group I) and 18 patients underwent external fixation with late dynamization (group II), resulting in equal distribution between the two groups.

Demographic profile

The study population was predominantly male, with 32 males (88.9%) and 4 females (11.1%). The mean age of the entire cohort was 39.25 ± 14.46 years (range: 18-60 years). Majority of the affected patients were males (89%) while 11% were females. The most commonly affected age group was 18-30 years (36.1%), followed by 51-60 years (30.5%).

On the basis of religion, 69% were Hindus, followed by 28% Christians and only 3% were Muslims. Regarding occupation, students (36.1%) constituted the largest group, followed by businessmen (33.3%), while daily wage workers and unemployed individuals each accounted for 13.9% of cases. Married individuals comprised 61.1% of the study population.

Injury characteristics

All patients (100%) sustained injuries due to road traffic accidents. According to the Gustilo-Anderson classification, 23 patients (63.9%) had grade IIIA fractures and 13 patients (36.1%) had grade II fractures.

The left tibia was involved in 66.7% of cases, while the right tibia was affected in 33.3%. The middle third of the tibial shaft was the most commonly involved site (63.9%), followed by the upper third (22.2%) and distal third (13.9%).

Table 1: Complications (n=36).

Complications	Number of patients, N (%)		
	Group I (18)	Group II (18)	Total (36)
Pin tract infection	1 (5.6)	3 (16.7)	4 (11.1)
Shortening	1 (5.6)	1 (5.6)	2 (5.6)
Residual deformity	0 (0)	0 (0)	0 (0)

Table 2: Mean union time (n=30).

Type of intervention	Number of patients	Mean±standard deviation union time in weeks	P value
Early dynamization	17	12.65±5.49	0.005
Late dynamization	13	18.46±4.61	

Table 4: Range of motion at ankle joint (n=36).

Range of motion at ankle joint	Number of patients, N (%)		
	Group I	Group II	Total
Full	17 (94.4)	16 (89.9)	33 (91.7)
Mild restriction	1 (5.6)	2 (11.1)	3 (8.3)
Complete restriction	0 (0)	0 (0)	0 (0)
Total	18 (100)	18 (100)	36 (100)

Table 4: Further treatment after non-union sign (n=36).

Further treatment	Number of patients, N (%)			P value
	Group I	Group II	Total	
IM nailing	1 (5.6)	4 (22.2)	5 (13.9)	0.177
Ilizarov	0 (0)	1 (5.6)	1 (2.8)	
Nil	17 (94.4)	13 (72.2)	30 (83.3)	

Table 5: Baird and Jackson scoring system (36).

Range of motion at adjacent joint knee and ankle	Number of patients, N (%)		
	Group I (18)	Group II (18)	Total (36)
Excellent	16 (88.9)	15 (83.3)	31 (86.1)
Good	2 (11.1)	2 (11.1)	4 (11.1)
Fair	0 (0)	1 (5.6)	1 (2.8)
Poor	18 (100)	18 (100)	36 (100)

Comparison between study groups

The mean age in group I was 36.22±12.94 years, while in group II it was 42.28±15.60 years; this difference was not statistically significant (p=0.214).

Baseline demographic variables such as gender and marital status, as well as injury characteristics including grade of injury, side of fracture, and site of fracture, were

comparable between the two groups, with no statistically significant differences (Table 5).

Fracture union

Overall fracture union was achieved in 30 patients (83.3%). Group I: union in 17 patients (94.4%). Group II: union in 13 patients (72.2%)

Although the union rate was higher in the early dynamization group, the difference did not reach statistical significance ($p=0.073$).

Mean union time

Among patients who achieved union ($n=30$), the mean time to union was significantly shorter in the early dynamization group: group I: 12.65 ± 5.49 weeks. group II: 18.46 ± 4.61 weeks

This difference was statistically significant ($p=0.005$), indicating faster fracture healing with early dynamization.

Complications

Complications were minimal in both groups. Pin tract infection occurred in 4 patients (11.1%), with a higher incidence in group II (3 cases) compared to group I (1 case). Tibial shortening was observed in 2 patients (5.6%), one in each group. No residual deformity was noted in any patient at final follow-up.

Pain assessment

At the end of follow-up, 34 patients (94.4%) reported significant improvement or absence of pain. Mild pain persisted in 2 patients (5.6%), both belonging to group II. No patient reported moderate or severe pain.

Range of motion

Full ankle joint range of motion was achieved in 33 patients (91.7%). Mild restriction was observed in 3 patients (8.3%), more commonly in group II. All patients in both groups maintained full range of motion at the knee joint.

Further treatment

Among patients with non-union ($n=6$), intramedullary nailing was performed in 5 patients (13.9%), predominantly in group II. Ilizarov fixation was required in one patient (2.8%), also from group II. The need for further surgical intervention did not show a statistically significant association with the type of dynamization ($p=0.177$).

Functional outcome

Functional assessment using the Baird and Jackson scoring system demonstrated excellent outcomes in the majority of patients: excellent: 31 patients (86.1%), good: 4 patients (11.1%), fair: 1 patient (2.8%), poor: none.

Excellent outcomes were slightly higher in group I (88.9%) compared to group II (83.3%), though overall functional results were favorable in both groups.

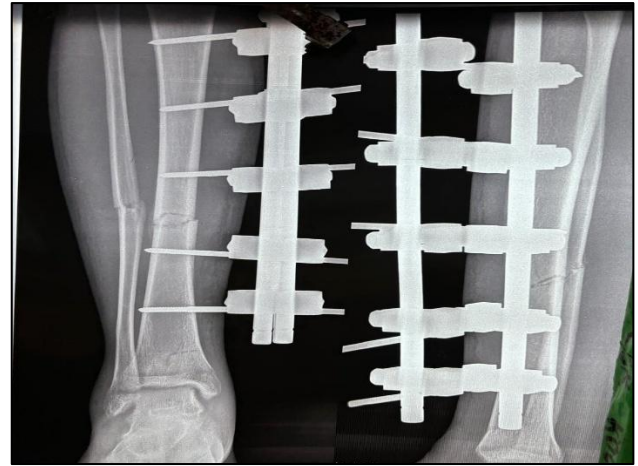


Figure 1: Radiological picture showing correction of displacement with external fixation.



Figure 2: Clinical photograph showing a healthy post-operative wound.



Figure 3: Radiological evidence of union with callus formation: A) after early dynamization (9 weeks); B) after late dynamization (11 weeks).

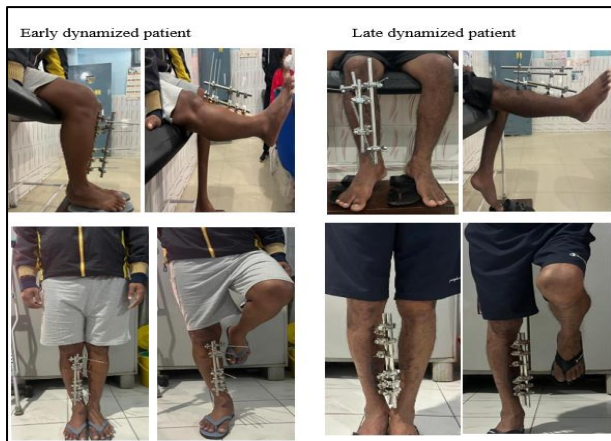


Figure 4: Clinical photograph showing range of motion of adjacent joint and weight bearing on affected limb without difficulty after fracture union with an external fixator.

DISCUSSION

Dynamization is a well-recognized strategy to enhance fracture healing following stabilization with either intramedullary nails or external fixators. By allowing controlled axial micromotion at the fracture site, dynamization promotes callus formation and progression toward union. However, the optimal timing for dynamization remains controversial, largely due to incomplete understanding of the underlying mechano-transduction mechanisms involved in fracture healing.^{2,6}

Previous experimental and clinical studies have reported conflicting results regarding the ideal timing of dynamization. As summarized in Table 1, both animal and human studies have evaluated early and late dynamization protocols. The extrapolation of animal data to human fracture healing is limited, as the physiology and healing dynamics of smaller animals differ significantly from those of humans. In most animal studies, early dynamization was initiated within the first or second postoperative week, while late dynamization was performed between 3 and 4 weeks.⁷⁻¹⁰ The outcomes of these studies have been inconsistent, reflecting the complexity of mechanical and biological interactions during fracture repair.

In clinical studies, early dynamization has generally been initiated between 2 and 4 weeks postoperatively, while late dynamization has been performed between 4 and 6 weeks.¹¹⁻¹³ Overall, clinical evidence appears to favor early dynamization. The present study was designed to further clarify the impact of dynamization timing on fracture union and functional outcomes in tibial fractures managed with external fixation.

Demographic and injury characteristics

The majority of patients belonged to the 18-30 years age group (36.1%). The mean age was comparable between the

early and late dynamization groups, indicating that age was unlikely to confound the outcome differences observed. Similar age distributions have been reported by Foxworthy et al, who observed a mean age of 32 years (range: 13-84 years), and by Perumal et al, who reported a mean age of 35.92 years (range: 16-63 years).^{5,14} These findings suggest that tibial fractures commonly occur in young and middle-aged adults, likely due to higher exposure to road traffic injuries.

In the present study, early dynamization was initiated at 2 weeks and always before 4 weeks postoperatively, whereas late dynamization was performed at or after 4 weeks.

Complications and functional outcomes

Pin tract infection occurred in four patients (11.1%), with a higher incidence in the late dynamization group. Limb shortening was minimal, with no patient exhibiting shortening greater than 2.5 cm. Mild pain was reported only by two patients in the late dynamization group, while all patients in the early dynamization group were pain-free at final follow-up. The majority of patients in both groups achieved full range of motion at the knee and ankle joints, with only three patients demonstrating mild ankle restriction.

Timing of dynamization and fracture union

The optimal timing for transitioning from rigid to flexible fixation remains a subject of debate.¹ In the present study, a higher union rate was observed in the early dynamization group (94.4%) compared to the late dynamization group (72.2%). Additionally, the mean time to union was significantly shorter in the early dynamization group (12.65 ± 5.49 weeks) than in the late dynamization group (18.46 ± 4.61 weeks). These findings indicate that early dynamization promotes faster fracture healing.

Comparable results have been reported in previous clinical studies. Foxworthy et al demonstrated that dynamization performed before 4 weeks resulted in quicker healing compared to late dynamization.⁵ Kulshrestha et al observed improved early functional outcomes following dynamization at 3 weeks in fractures of the radius.¹⁵ Barquet et al reported higher union rates, shorter healing times, and reduced need for bone grafting with early axial compression dynamization and early weight bearing.¹⁶

Conversely, some studies have reported favourable outcomes with late dynamization. Noordeen et al found shorter healing times in the late dynamization group (4-6 weeks) compared to early dynamization, although their protocol involved leaving the fixator unlocked from the time of application, which differs from the staged approach used in the present study.¹⁷ Claes et al reported inferior healing parameters with very early axial dynamization initiated one week postoperatively, suggesting that excessive early motion may impair early

callus mineralization.¹¹ Singh et al initiated dynamization at 4-6 weeks and reported union times similar to those observed in the late dynamization group of the present study.¹⁸

Evidence from animal studies

Animal studies provide insight into the biological mechanisms underlying dynamization. Larsson et al demonstrated improved torsional stiffness and more uniform periosteal callus formation following axial dynamization at one week in a canine tibial fracture model.¹⁹ Similar findings were reported by Egger et al and Goodship et al, who suggested that improved fracture gap reduction rather than direct biological stimulation may

account for enhanced healing.^{20,21} Takeda et al, using a rat tibial fracture model, showed that early mechanical stimulation enhanced hematoma formation and chondrogenesis, although prolonged cartilage presence could delay callus maturation.²²

Early dynamization during the first or second postoperative week has been shown to influence mesenchymal stem cell differentiation toward a chondrogenic phenotype, potentially resulting in lower-quality early callus.¹¹ However, this does not necessarily compromise final fracture union. Schultz et al. reported optimal histological outcomes when dynamization was initiated at 3-4 weeks.²

Table 1: Summary of animal study of early dynamization.

Authors	Year	Animal	Bone (unilateral/ bilateral)	Amount of gap	Time of starting dynamization	End point of study	Finding
Larsson et al ¹⁹	2001	Canine	B/L Tibia bone one side was dynamized and other side was not dynamized	2 mm (external fixation)	1 Week	12 Weeks	Early axial dynamization enhanced callus formation, remodeling and provide higher mechanical stiffness
Egger et al ²⁰	1993	Canine	B/L Tibia bone, one side was dynamized and other side was not dynamized	2 mm (external fixation)	1-4 week	9 Weeks	Improved healing on dynamized side probably due to closer gap rather than effect on healing
Goodship and Kenwright ²¹	1985	Bovine	Tibia bone group 2 was dynamized and group 1 was not dynamized	3 mm (external fixation)	1 Week	12 Weeks	Torsional stiffness and healing better in dynamized group
Bottlang et al ²³	2011	Bovine	Tibia bone dynamized with the help FCL (far cortical locking) and other was fixed with LCP (locking compression plate) without dynamization	3 mm	0 week	9 Weeks	FCL actively Promotes fracture healing compared to LCP
Claes et al ¹¹	2009	Rat	Femur bone one group was dynamized and other was not dynamized	1 mm (External fixator)	1 week	5 weeks	No benefit of early dynamization
Aro et al ²⁴	1990	Canine	B/L tibial bone one group dynamised and other was not dynamised	800micro metre (External fixator)	15 days (2weeks +1day)	12 weeks	Callus distribution more on dynamized group

This prospective comparative study ensured systematic data collection and comparison of early and late dynamization in a comparable patient population. Uniform surgical techniques and follow-up procedures may also have increased the reliability of the findings. The use of validated functional and radiological outcome measures may increase the validity of the findings. The clinical relevance and applicability of the findings are significant.

The limitations of the present study need to be kept in mind while interpreting the results. The sample size of the study was relatively small with only 36 patients. The non-randomized study design with allocation of the study group according to patient preference may induce a selection bias. The study was performed at a single center and the results may not be generalized for the larger population and different clinical settings. The study had a short duration of follow-up, and hence the long-term results such as late complications and functional recovery could not be evaluated. Some of the confounding factors such as nutritional status and patient compliance with the rehabilitation protocol and minor variations in the surgical technique could not be completely controlled for in the study. The study did not include severe fractures such as Gustilo-Anderson grade II B and II C fractures

CONCLUSION

In conclusion, early dynamization following external fixation of tibial fractures is associated with superior radiological and functional outcomes when compared with late dynamization. Patients who underwent early dynamization demonstrated a higher rate of fracture union, a significantly shorter time to union, earlier progression to weight bearing, and better restoration of joint range of motion. The findings of this study suggest that the optimal timing for dynamization is within four weeks of surgery. Although the present study was conducted using external fixators, these results may be extrapolated to intramedullary nailing, as the biological mechanisms of fracture healing and the response to controlled mechanical stimulation are fundamentally similar across fixation methods.

We know that no callus is formed if the strain is less than 2%.so mechanical stimulation is needed for callus formation. Osteoblast does not have the capacity to divide. Osteoblast has to come from osteoprogenitor cells. Differentiation of osteoprogenitors cells start within days of fracture. Best time for mechanical stimulation will be during the process of differentiation, not when the osteoprogenitors cell is differentiated to another lineage like fibroblast. This theoretical knowledge also supports the finding of this study. So that the timing of starting mechanical stimulation i.e. dynamization will be best if it is started in day.

Based on the findings of the present study, early dynamization within a period of 2 to 4 weeks of external fixation is recommended in the management of compound

tibial fractures as it resulted in faster fracture union, relief of pain, and functional outcome in comparison to late dynamization. The timing of dynamization needs to be individualized depending on the fracture pattern, stability of fixation, soft tissue status, and patient condition. Early initiation of controlled partial weight-bearing after dynamization may also contribute to fracture healing by promoting beneficial interfragmentary micromotion. Adherence to pin tract care practices and regular follow-up is critical in preventing complications such as infection and ensuring optimal results in these patients. The importance of considering a standardized approach for dynamization practices in orthopaedic settings needs to be explored and implemented for better patient care. Larger multicentric studies in the form of a randomized controlled trial with a longer follow-up period are needed to validate these findings and draw a consensus on clinical guidelines in the management of compound tibial fractures.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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