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Temporary spanning external fixator versus splintage prior to delayed internal fixation of high grade tibial plateau fractures

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Abstract
Background: Peri-articular knee fractures of the proximal tibia are known as tibial plateau fractures. The presentation is typically determined by the mechanism of injury, which is either low-energy trauma or very high-energy trauma. This investigation was designed to evaluate the effectiveness of acute spanning external fixation versus splintage in the early management of closed high-grade tibial plateau fractures prior to delayed definitive osteosynthesis in terms of soft tissue healing, time for surgery, quality of reduction, and cost on the health system.
Methods: This prospective randomized investigation was conducted on 40 patients who had closed high grade tibial plateau fractures. In one of the two equal groups, 20 patients were enrolled: A Group (Splintage above the knee): included patients who underwent temporary above knee splintage in flexion 15 to 20 degrees and admitted in a above knee splintage till definitve fixation.
Group B (N=20) (Spanning external fixator)**:** included 20 patients who were prepared for a knee spanning external fixator on admission as first stage management till delayed definitive fixation.
Results: Spanning external fixator group had significantly shorter interval between applying the external fixator or the splintage till undergoing to internal fixation, operative time and total hospital stay compared to splintage above knee group ($P<0.05$). In comparison to the Splintage above knee group, the Rasmussen radiological score in the Spanning external fixator group was significantly higher (P=0.041).
Conclusions: Spanning external fixator exhibited higher efficacy compared to splintage above knee in high grade tibial plateau fractures with shorter time of soft tissue healing, shorter operative internal fixation time indicating easier operation, shorter hospital stay, and better quality of reduction.

Keywords: Temporary spanning, external fixator, splintage, delayed; internal fixation, high grade; tibial plateau fractures.

Introduction
Tibial plateau fractures are collectively referred to as peri-articular knee fractures of the proximal tibia. It is predominantly associated with either very high-energy trauma (which is typically experienced by younger men) or low energy trauma (which is typically experienced by geriatric women, as a fragility fracture), the presentation is contingent upon the mechanism of injury [1]. The vector of force, the amount of energy and the quality of bone determine the shape and type of fracture [2].
The soft tissue condition, fracture type, and geometryof the fracture all contribute to the management plan of tibial plateau fractures. The Schatzker classification points to that, I-II-III categories are not typically associated with high energy trauma [3], the soft tissue injury is usually mild so, it's treated by primary definitive management. However, Schatzker categories IV, V, and VI are generally associated with high-energy trauma, which is known to cause more severe soft tissue injuries. In order to perform internal osteosynthesis with high energy fractures, it is imperative to wait for the local conditions to improve. And soft tissue envelop healing [4].
Anatomic reduction of the articular surface with stable fixation is the standard treatment for tibial plateau fractures, which enables the early recuperation of range of motion. Additionally, it is essential to prevent ligamentous laxity in order to prevent knee instability later on [5].

Patients and Methods

This prospective randomized research was conducted from DEC 2023 to DEC 2024 on 40 patients with closed tibial plateau fractures who were admitted to the Orthopedic Department of Benha University Hospitals.

Patients submitted informed consent in writing. Ethics Committee of Benha University's Faculty of Medicine authorized the investigation (Approval code: MS 34-11-2023).

The study included patients who were admitted with tibial plateau fractures of Schatzker categories IV, V, and VI (high-grade fractures), with closed fractures exclusively, and skeletally mature patients. Patients aged 65 years or older, those with neurovascular injury, open fractures, pathological fractures, significant pre-existing degenerative joint disease, and severe systemic illness (active cancer or chemotherapy, renal failure, or other serious comorbidities that impede surgery or rehabilitation) were excluded. Furthermore, Patients with Schatzker type I, II, or III tibial plateau fractures were excluded.

Randomization

A 1:1 ratio was used to randomize forty patients into two categories. In order to designate the research patients to one of the two groups, they were provided with opaque sealed envelopes that contained sequential numbers:

Group A (N=20) (Splintage above knee group): included patients who underwent temporary above knee splintage in flexion 15 to 20 degrees on admission.

Group B (N=20) (Spanning external fixator)**:** included patients who were prepared for a spanning external fixator on admission.

Demographic data including age, sex, residence, occupation, marital status, education, and any comorbidities (hypertension (HTN), diabetes mellitus (DM), and special habits such as smoking) were collected from all patients. In addition, the primary evaluation focused on life threatening conditions as the majority of the patients come with high energy trauma then a limb threatening conditions.all of our patents were encompassed with a general examination that included measurements of weight, height, body mass index (BMI), temperature, systolic and diastolic blood pressure, and a thorough history of any prior trauma or operations. The vascular status and neurological examination were documented. A radiographic knee series and CT scan of the knee was obtained, a compartment syndrome and neurovascular injury were ruled out. The Schatzker classification system was employed to identify and document the fracture pattern. The soft tissue envelope that encircles the fracture was also evaluated. Laboratory investigations was conducted including complete blood count (CBC) & Blood grouping, prothrombin time, concentration and INR, liver enzymes, virus antigen tests, kidney function test and random blood sugar (RBS).

Radiological investigations

The standard evaluation for knee trauma involves a radiographic examination that includes an anterior-posterior (AP), lateral, and AP view in the plateau plane (10-15-degree caudal view) which reveale the knee joint and the metaphyseal -upper diaphyseal part of the tiba. However to further identify the geometry of the fracture, a CT scan of the knee was achieved. this gives an idea about the comminution, posterior extention of the fracture and the main block fragment to build and reconstruct upon.

The 1st group

Temporary above knee back slab in flexion 15 to 20 degrees was done, this group admitted in above knee splintage was repeatedly examined every 24 hours to check the soft tissue status. This included cutting the splint and expose the skin, checking the distal pulse and the local soft tissue at the injured area.

The 2nd group

1st stage operation: We prepared patients for the emergency operating room to administer a uniplanar external fixator. This fixator consists of two or three Schanz pins in the femur shaft from the lateral or anterolateral aspect, as well as two or three Schanz pins in the anterior aspect of the middle and distal tibial shaft. This fixator circumvents the knee joint and the injured-fractured part. General or spinal anesthesia may be administered according to the general status of the patient and anathesiologist consultation. The fracture fragments and limb were grossly aligned using a C-arm fluoroscopy to accomplish successful distraction. Fragments were occasionally elevated using a 3 mm K wire to alleviate excessive depression. The fracture was disimpacted through rotatory motion and traction. In order to obtain images of the preliminary reduced fracture without interference, the connector rods were positioned external to the fracture. Knee flexion was maintained at 15-20 degrees while the fixator was tightened with maximal manual distraction.

Image 1: Tibial plateau fracture Sch type VI with a primary spaning external fixator.

Follow up of both groups until the definitive treatment:

The vascular status was reassessed to rule out compartment syndrome, and DVT prophylaxis was started from day 1 in the hospital. On the second day of the injury, blister formation was typically observed on the soft tissue that was injured and usually persisted till the seventh to eighth day or more according to the srverity of soft tissue injury. The delicate tissue was taken into account. Measures to prevent pin tract infection are taken in consideration for the group in external fixator. The soft tissue was reassessed every 24 hours in the external fixator group and also every 24 h in the splintage group. When it healed and appeared good, the decision of definitive management plating was taken and the patient was prepared to the next operation list.

Image 2: A Clinical photo of 2 patients. A patient with tibial plateau fracture in the group of spanning external fixator and the other in the splintage group showing subsidence of edema, ecchymosis and skin bullae, the wrinkle sgin appeared in both of them and they become ready for the definitive plating.

2nd stage operation

For definitive treatment of the fracture, both groups underwent internal fixation and open reduction. Schatzker types V and VI were subjected to stable robust double plating, while Schatzker types IV were subjected to medial plating via cancellous screws and locked plate. Bone graft was used according to the case, if there is a big gap after reduction and restoring the joint line. Usually under spinal anesthesia, the patient was prepared with a tourniquet and then draped in the supine position.

Image 3: Spinal anathesia is established and the patient is prepared in the supine position

The group in the external fixator underwent removal of the fixator first then re-draping and preparing was established for the definitive fixation. Direct lateral approach, direct medial approach, posterolateral or posteromedial approaches according to the geometry of the fracture. At the end of the operation, suction drain is inserted before wound closure, splintage of the knee was considered in the 1st two weeks or until removal of the sutures to ensure rest of the soft tissue and decrease post-operative pain and edema.

Image 4: Operative assessment

Operative assessment

Each patient underwent surgery under spinal anesthesia, with the exception of polytraumatized patients, who were administered a combination of general and epidural anesthesia according to the decision of the anasthesia staff. The patients were positioned supine on the fracture table and were under the control of the image intensifier (C-Arm). Approaches utilized were lateral, medial, posterolateral or posteromedial approaches according to the fracture type and geometry. With the external fixation group, the reduction was accomplished more easily through traction, regaining alignment length, and rotation and the reonstructing the jont line by elevating the depressed fragment using an osteotom.The two plateaus were compressed to each other's by using a Spanish clamp through the main fragments.

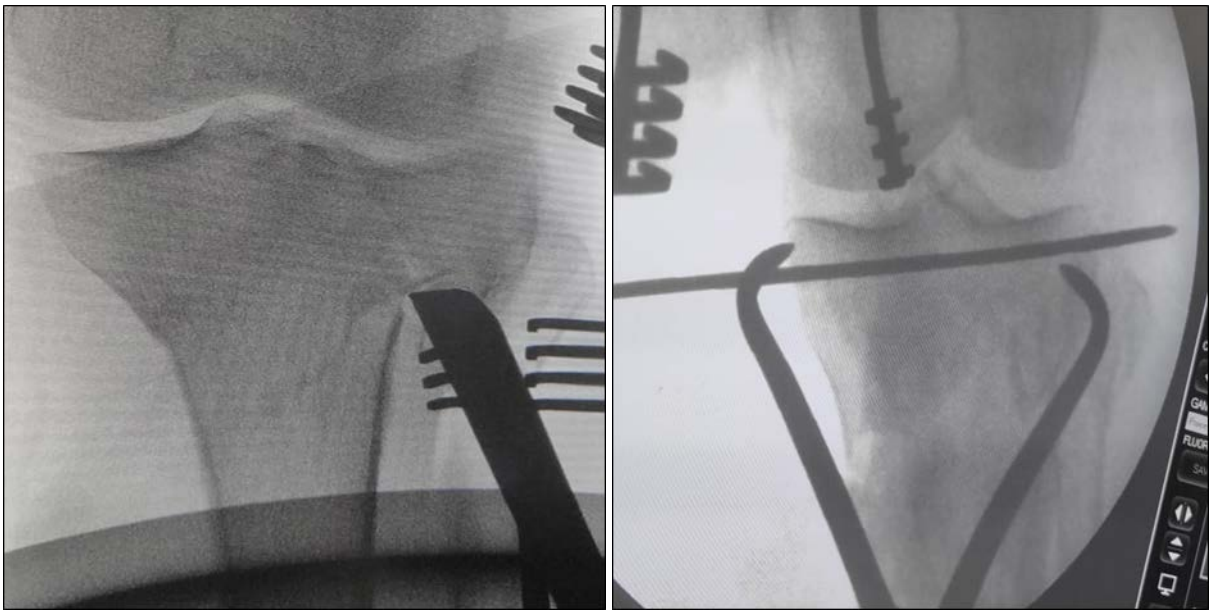


Image 5: Using an osteotom to elevate the depressed fragment and a Spanish clamp to compress the tow plateaus to restore the width

Any particular depression was elevated by an osteotomy and bone graft would be utilized if the gap was too wide. Autogenous bone graft from the iliac crest was the choice. The plateaus were secured by cancellous screws or multiple K. wires parallel to the joint line prior to the insertion of the plates, which were guided under the C-Arm. For Schatzker Type IV, through either a direct medial approach or a posteromedial approach, a medial locked plate was inserted. In order to stabilize the plateaus and the metaphyseal-diaphyseal portion of Schatzker types V and VI, lateral and medial plates wrer inserted on both lateral and medial sides respectively. Unfrequently, a unilateral plate on the medial or lateral side only if the fracture was in place and the screws were engaging the fragment from the other side with good purchase. Ultimately, Fixation was verified in both AP and lateral views under fluoroscopic image guidance. Subsequently, the limb was reassessed for alignment prior to wound closure.

Postoperative care and follow-up

Passive knee range-of-motion exercises were initiated on the second day following the operationa fter removing the suction drain and as the patient tolerate while the dressing was being applied. Removal of the stiches was done on the day 15th post operative. The use of orthotics or assistance was employed to progressively increase weight bearing from six to twelve weeks post operative, beginning with toe-touch at six weeks.

Image 6: Clinical photo of a patient with assisted tip toeing 1.5 month postoperative

Full weight bearing was permitted when guarantee of radiographic union at 12 weeks after the fracture had fully united and the callus had appeared on the radiographs. Clinical observation and X-ray film and clinical examinations were conducted on all patients at 3, and 6 months postoperatively. In order to ascertain the position of the bone plate, the tibial plateau varus angle (TPA), the posterior slope angle (PA), and the progression of fracture union, standard AP and lateral radiographs were employed. The Rasmussen index was employed to assess radiological and clinical outcomes six months post operative.

In this evaluation, the Rasmussen radiological score was implemented to assess the quality of the reduction. Furthermore, the Rasmussen clinical-functional score was implemented to assess the knee joint's functionality six months postoperatively. It was rated as excellent (≥ 27 points), good (20-26 points), fair (10-19 points), and poor (6-9 points).based on the functional score.

Case Presentation

Case 1

48 years' male- manual worker fall on the ground from 1.5 meters. Figure 1

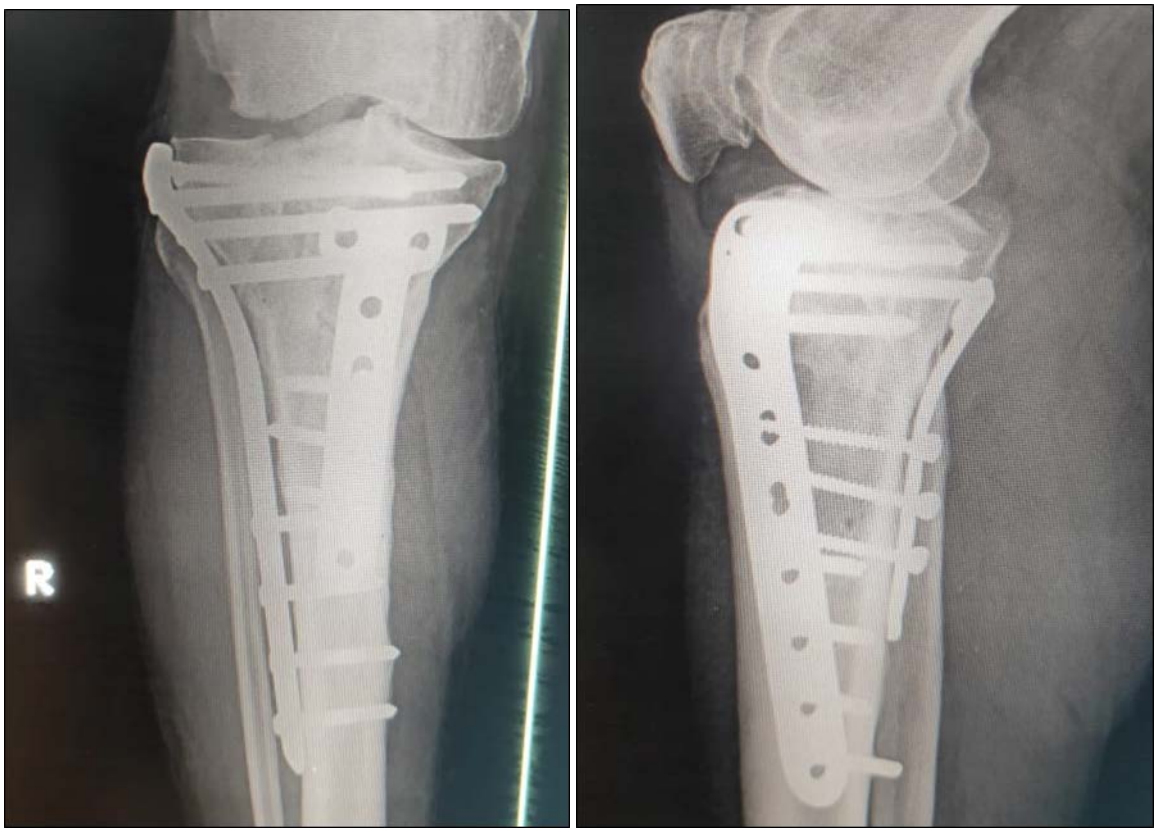
A **B** **C**

D

E

F

G



H **I**

J

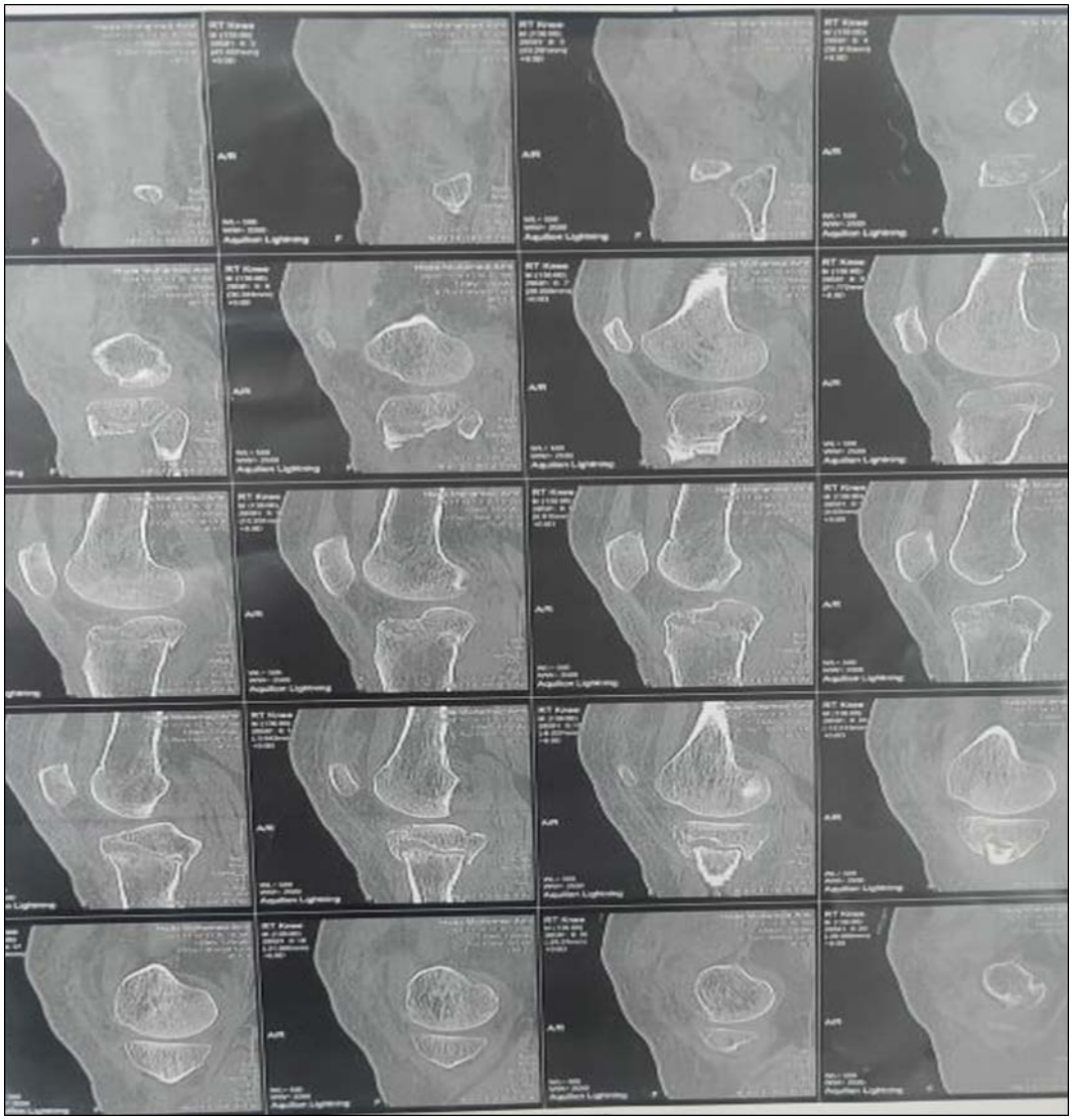
Fig 1: A-B: x-ray on admission antroposterior and lateral views, C: CT axial cuts, D: CT coronal cuts, E: CT Sagittal cuts, F: post-operative X-rays anteroposterior and lateral views, G: 1M follow up X-rays, -I: 6M follow up X-rays, M: clinical photos of knee range of motion-extension and flexion at 6m follow up.

Case 2

Female 49 years no comorbidities - sustained a motorbike accident. Figure 2

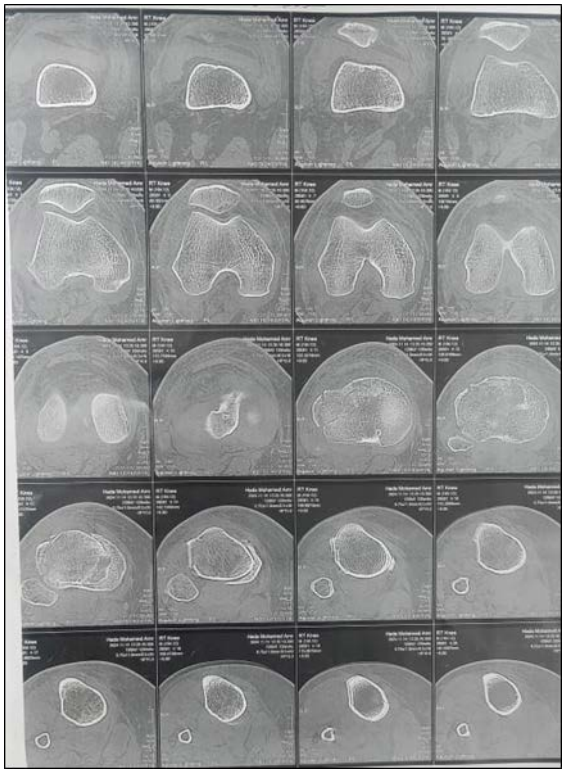
A

B **C** **D**



E

F



G

H

I

Fig 2: A: x-rays preoperative anteroposterior and lateral views. B -C: skin condition after 3 days of admission on above knee splintage. D: skin condition after 7 days of admission. E: CT sagittal cuts. F: CT 3d. G: CT axial cuts. H: CT coronal cuts. I : postoperative x-rays anteroposterior and lateral views. L: clinical photo postoperative showing the suction drain. M: follow up x-rays after 6 months.

Case 3

51 years' male was assaulted by others, he is diabetic and hypertensive. He used to smoke one pack every day.

Image 7: A clinical photo when the patient came to ER showng the deformed swollen limb.

Image 8: Moderate to severe edema indicating high energy trauma

Image 9: Within 15 hours after trauma he developed skin bullae and the edema increased in size and tension.

Soon, He was prepared for emergency operating room to implement a spanning external fixator.

Image 10: Preoperative x-ray anteroposterior and lateral views, on the left side Post external fixator application, the alignment restored, traction and joint spanning were done.

Image 10: Clinical photo 12 days after ex fix application showng subsidence of edema and skin ballae.

Now, he is ready for definitive treatment plan but, he developed low grade fever and CRP was 48 despite good pin sites with low grade infection

Image 11: 3 tibial pins with good insertion sites on the left and 3 femoral pins with low grade infection at the middle and proximal pins. But the knee joint was hot and tender, we suspect septic knee and go for detriment and suction drain was inserted. He underwent another session of lavage the next other day and after 5 days CRP decreased so, we go for plating under coverage of culture specific antibiotic.

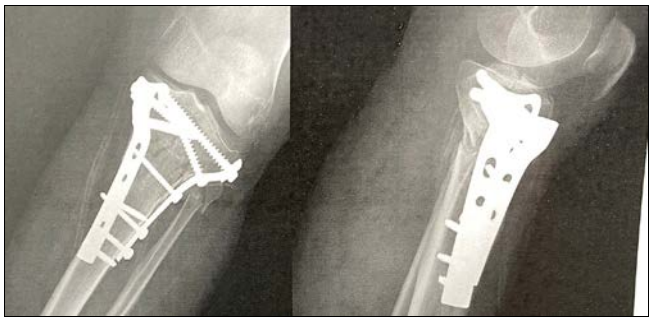


Image 12: Postoperative x-ray. Anteroposterior and lateral views.

Results

Demographics (Age, sex, weight, height, BMI, and smoking), prevalence of comorbidities (HTN and DM), the affected side and mechanism of injury were insignificantly different between both groups. Table 1

Schatzker type of tibial plateau fractures was insignificantly different between both groups. Spanning external fixator group had significantly shorter time of soft tissue healing (interval between applying the external fixator till undergoing to internal fixation), operative time of internal fixation and total hospital stay compared to above knee splintage group ($P<0.05$). Table 2

The prevalence of complications was insignificantly different between both groups. Compared to the Splintage above knee group,

Rasmussen radiological score was significantly higher in the Spanning external fixator group (P=0.041) Table 3

Discussion: Tibial plateau fractures are more than a fractured bone injury, it should be considered as a wide injury spectrum

of bone and soft tissue. Soft-tissue compromise, neurovascular damage, compartment syndrome, ligamentous and meniscal tears, are all complex injuries that pose a significant challenge for even the most experienced orthopedic trauma surgeons. However, the optimal therapeutic approach remains a topic of debate [7]

However, the prevalence of comorbidities was not substantially different between the two groups in the study, the mechanism of injury, the afflicted side, or complicated injury did not differ significantly between the two groups.

In line with us, Buyukkuscu *et al.* [8]. In the initial treatment of ankle fracture-dislocations, they compared the efficacy, functional outcome, and complication frequency of splinting and external fixation. Smoking frequency, comorbidities, fracture type, afflicted side, fracture fragment ratio, and age were not significantly different between the two groups. However, Gerlach *et al.* [9].discovered that the ex-fix group was biased toward the affected side, smoking, and osteoporosis ($p < 0.047$).

From our results, spanning external fixator group had significantly shorter operative time in delayed internal fixaton session compared to splintage above knee group ($P<0.001$), by about 15-29 minutes.

In line with us, Buyukkuscu *et al.* [8].asserted that the external fixator group experienced a reduced time of surgery.

Spanning external fixator group had significantly shorter total hospital stay compared to splintage above knee group ($P<0.001$).

The follow up duration was insignificantly different between both groups in our study which was in alignment with Gerlach *et al.* [9], as they found insignificant difference in follow up between plaster cast group and external fixator group.

Both results of shorter operative time and hospital stay can be explained and confirmed by Mukhopadhyay *et al.* [10]. Illusterated by their demonstration, the spanning external fixator provides an additional advantage over splinting by enabling the visualization of the soft tissue and compartment assessment during the transition interval of soft tissue follow up by examinton and assessment before definitive management. The soft tissue was reassessed every 24 hours in the spanning external fixator group and also every 24 h in the splintage group, making the spanning external fixator group easier in soft tissue reassessment and less time consuming because of bared skin.

Spanning external fixator group had significantly shorter time of soft tissue healing compared to splintage above knee group ($P<0.001$ and 0.004 respectively).

Rudran *et al.* [4], advocated for the necessity of splintage above the knee and recommended that soft tissue compartments of the leg should be serially examined for a minimum of 24 hours following the injury. In addition, they recommended that the preponderance of tibial plateau fractures should be splinted in an above-the-knee cast or brace during the initial management phase.

In our study, the prevalence of complications such as infection metal failure or loss of reduction were insignificantly different between both groups.

In a similar vein, a previous study with a slightly similar study hypothesis and concept revealed that 25 cases (19.7%) experienced a loss of reduction, and 19 (15.0%) were converted to ex-fix. The rates of epidermal necrosis (ex-fix: 7.4% vs. cast: 6.5%) and surgical site infections (ex-fix: 11.1% vs. cast: 4.6%) were not significantly different between the respective groups but this study was on patients with fracture dislocation ankle [9].

In disagreement, Wawrose *et al.* [11]. The objective of this comparative study was to ascertain the efficacy of immediate external fixation as a substitute for splinting and the prevalence of complications associated with closed reduction and splinting of unstable ankle fracture-dislocations, Discovered that splintage immobilization was associated with an elevated risk of complications, such as re-dislocation and epidermal necrosis, in ankle fracture-dislocations, in contrast to a temporizing external fixator. In cases that were temporized with a splint, the rate of redislocation and the rate of cutaneous necrosis development were statistically higher than those who used an external fixator. In contrast to a temporizing external fixator, the authors found that fracture-dislocations that were not treated with acute open reduction internal fixation, splint immobilization, were associated with a higher risk of complications, including re-dislocation and cutaneous necrosis. This discrepancy may be due to the fact that the authors evaluated ankle fracture-dislocations, which are not included in our inclusion criteria.

In difference with our insignificant results, Buyukkuscu *et al.* [8] stated that the splintage group exhibited a higher incidence of skin complication and reduction loss in comparison to the external fixator group. The inclusion of patients with deteriorating soft tissue conditions or open fractures may be the cause of this discrepancy.

The fnantial cost of the splintage above the knee group was significantly less than that of the spanning external fixator group (P=0.022). as the splint is considered as a low cost resources. This point makes the developing countries with limited resources and a primary care centers with limted resources prefer splintage above knee as it had lower cost and especially as our results showed that both techniques had comparable safety. However, spanning external fixator had better efficacy and other adventagous properities, but splintage above knee still works.

A previous study by Ristiniemi *et al.* [12]**.** Proved the significance of cost assessment by illustrating that primary hospital costs only account for an average of 13% of the total economic burden caused by injuries, with the primary burden being caused by indirect costs and loss of working days.

Spanning external fixator group had significantly better quality of reduction and Rasmussen radiological score compared to splintage above knee group (P=0.038 and 0.018 respectively).

The preferable effect of external fixator in reduction quality gives better Rasmussen radiological score that was confirmed by Wu *et al.* [13]. This finding strongly supports the effectiveness of external fixation. However, they compared a definitive hyprid external fixator to internal fixations, which differs from our approach. Additionally, they stated that the fractures were adequately reduced using both surgical treatments, which reinforces the superior quality of external fixation in obtaing good reduction.

We also can suggest sending the patient home with the external fixator and organising the follow up visit within 5 to 7 days according to the severity of injury and the condition of soft tissue, despite that patient is educated how to take care of the external fixator to decrease the incidence of pin tract infection this for sure will decrease the financial burden

The current study had certain limitations as relatively small sample size and short follow up period which may contribute to relatively less reliable results and the need of more variable measurement and more statistical analysis methods.

Table 1: Demographics, comorbidities and general examination of the studied groups

		Splintage above knee group (N=20)	Spanning external fixator group (N=20)	P value
Age (years)		48.05±8.81	47.65±7.58	0.878
Sex	Male	15 (75%)	17 (85%)	0.518
	Female	5(25%)	3 (15%)	
Weight (kg)		74±11.17	75.4±7.51	0.644
Height (m)		1.7±0.04	1.7±0.04	0.112
BMI (kg/m^2)		26.2±4.06	27.3±2.99	0.307
Smoking		3 (15%)	4 (45%)	0.677
Comorbidities	HTN	7 (35%)	8 (40%)	0.744
	DM	5 (25%)	7 (35%)	0.490
Affected side	Right	10 (50%)	8 (40%)	0.525
	Left	10 (50%)	12 (60%)	
Mechanism of injury	Fall from height	9 (45%)	6 (30%)	0.572
	Road accident	10 (50%)	12 (60%)	
	Sport injury	1 (5%)	2 (10%)	

Data presented as mean ±SD or frequency (%), BMI: Body mass index. HTN: Hypertension, DM: Diabetes mellitus. * Significant as P-value ≤ 0.05.

Table 2: Schatzker classification of tibial plateau fractures, operative time, hospital stay and follow-up duration of the studied groups

		Splintage above knee group (N=20)	Spanning external fixator group (N=20)	P value
Schatzker type	IV	2 (10%)	1 (5%)	0.550
	V	5 (25%)	8 (40%)	
	VI	13 (85%)	11(55%)	
The interval between applying the external fixator or the splintage till undergoing to internal fixation (days)		18.25±1.11	9.35±1.72	<0.001*
Operative time (min)		82.45±12.97	63.50±10.06	<0.001*
Hospital stays (days)		11.90±4.24	7.30±2.00	<0.001*

*Statistically different as P-value ≤ 0.05.

Table 3: Complications and rasmussen radiological score of the studied groups

			Splintage above knee group (N=20)	Spanning external fixator group (N=20)	P value
Complications	Infection	Superficial	2(10%)	2 (10%)	0.641
		Deep	0(0%)	1 (5%)	
	Metal failure or loss of reduction		1 (5%)	0 (0%)	
	Joint stiffness		1 (5%)	0 (0%)	
	No		14 (70%)	18 (90%)	
Rasmussen radiological score			14.00±2.36	15.50±2.12	0.041*

*Statistically different as P-value ≤ 0.05

AP	Anterior- posterior
BMI	Body mass index
CBC	Complete blood count
DM	Diabetes mellitus
HTN	Hypertension
RBS	Random blood sugar

Conclusions

Spanning external fixator as a primary management exhibited higher efficacy and advantageous properities compared to splintage above knee in high grade tibial plateau fractures specially schatezker types V & VI with shorter time of soft tissue healing, shorter operative internal fixation time, shorter total hospital stay, and better quality of reduction. However, the safety of both techniques was comparable with insignificant complications, but splintage above knee had lower cost, thus it was be affordable for the countries and facilities with limited resources. So, splintage was an economical and affordable technique but with lower efficacy and longer definitive operation and hospitalization time.

Therefore, spanning external fixator is recommended for a high efficacy as first stage management before delayed definitive osteosynthesis of closed high grade tibial plateau fractures regarding the soft tissue, time for definitive surgery, quality of reduction and total hospital stay and In order to obtain more significant results, it is advisable to incorporate a larger sample size and a lengthier follow-up period.

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Conflict of Interest: Nil

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