EXTERNALIZED METAPHYSEAL LOCKED PLATING OF COMPLEX PROXIMALTIBIAL FRACTURES. CLINICAL AND BIOMECHANICAL OUTCOMES.

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ABSTRACT

Objective: The study aimed to evaluate the outcomes of using a metaphyseal distal femur locking plate as a definitive external fixator for treating complex multifragmentary proximal tibial fractures based on analysis of clinical results and biomechanical experimental Finite Element study. *Methods:*An ipsilateral LISS DF plate was used as an external fixator in 7 high energy multifragmentary proximal metaphyseal tibial fractures with simple intrarticular involvement in 7 patients. The mean follow-up was 22 months (range, 14 - 48 months). Moreover, static axial compression tests were performed to evaluate the strength of the fixation technique by assessing stiffness of the contruct,interfragmentari motions and strain at the fracture site. *Results:* The mean fracture healing time was 23.7 weeks (range, 18 - 32 weeks). At 4 weeks postoperatively and at the final follow-up, the average Hospital for Special Surgery(HSS) knee score was 86 (range, 72 - 93) and 96 (range, 88 - 100), respectively, and the American Orthopaedic Foot and Ankle Society(AOFAS) score was 92 (range, 84 - 100) and 99 (range, 95 - 100), respectively. Based on FE analysis, construct stiffness was 655 N/mm (IC-1), 197 N/mm (IC-2) and 128 N/mm (IC-3). Interfragmentary motions under partial weightbearing were 0.31 mm (IC-1), 1.09 mm (IC-2) and 1.74 mm (IC-3), whereas under full weight-bearing were 0.97 mm (IC-1), 3.50 mm (IC-2) and 5.56 mm (IC-3) respectively. The corresponding longitudinal strains at the fracture site under partial weightbearing were 1.55%(IC-1),5.45%(IC-2)and 8.70%(IC-3).*Conclusions:* The clinical outcomes confirmed that definitive externalized locked plating could be an effective alternative treatment option in selected cases with complex proximal tibial fractures after obtaining an appropriate fracture reduction.The static axial loading of a virtual biomechanical model with simulated thin and thick soft tissue envelope, seems to ensure favorable conditions for callus formation with longitudinal strains at the fracture site not exceeding 10%, thus providing an adequate relative stability for indirect bone healing under early partial weightbearing.

Keywords: *External Locked Plating, Tibia, Fracture, Multiple Trauma,Finite Element Analysis.*

Introduction

Unstable proximal tibial fractures caused by high-energy trauma are usually accompanied by severe soft tissue injury [1, 2]. In such cases, direct internal fixation, without considering soft tissue wrap condition, can elevate infection risk and may eventually lead to amputation. Usually external fixation is recommended for staged or provisional fixation until soft tissue recovery, which is subsequently converted into internal fixation to complete bone healing [3]. External fixators are designed to provide sufficient interfragmentary motion to stimulate secondary bone healing by callus formation [4]. An appropriate range of interfragmentary motion is crucial for indirect callus formation. However, traditional external fixator constructs (bar and half-pin, ring, and hybrid designs, hexapods etc.) are often bulky, uncomfortable, inconvenient, and difficult to ambulate. Walking with lower limb fixator frame is awkward [5-10]. A lot of studies discuss the benefits of the application of an external locking plate as an external fixator for muptifragmentary tibial injury have been demonstrated [5-8]. Recently, more surgeons have reported similar experiences with satisfactory results [9-12].

However, the supercutaneous application of locking plates as a definitive monolateral external fixators remains uncommon and not widely acknowledged. Moreover, the reduced stiffness of the external locking plate and the amount of interfragmentary motions pose a concern about the adequate fracture healing process. Recent papers describe fixation stability with extracutaneous/supercutaneous locked palting but clinical recommendations on its practical use in reducing implant failure risk remain to be defined. The study aims to determine wether one-staged external locked plate fixation could provide sufficient stability and maintain fracture fixation until bone healing. Virtual 3D model and biomechanical assesment with Finite Element Analysis (FEA) were performed to test the stability of externalized distal femur metaphyseal locking plate (LISS DF) application for treatment of unstable proximal tibial fractures. For that purpose we conducted a prospective observational study to evaluate the functional outcomes, fracture healing time and complications to demonstrate a rational, noninferior surgical approach for treatment of these challenging fractures.

Materials and methods

Patients : Between April 2013 and December 2018, a total of 20 patients with complex tibial fractures were treated at our institution using the described technique. Seven patients (six men and one woman) average age, 53 years (ranging, 22 to 70 years) with 7 high energy multifragmentary proximal tibial fractures, from this cohort were included in current study. Three of the patients sustained a multiple trauma and were classified as borderline according to ISS scoring system and two of them were with an ipslatreal multifraglemtary femur fracture classified type IIa (Floating Knee Injury) according to Fraser et al. (1978) [6]. Three of them were Gustilo and Anderson, typeII [13]. In addition, the fractures were classified according to the AO Foundation and Orthopaedic Trauma Association (AO/OTA) and AO soft tissue classi-fication (Table 1) [14].The fractures were caused by falls from heights of > 1,2m (n = 2) and traffic accidents (n = 5). All seven fractures were evaluated radiographically and clinically. The radiographic evaluation was done using antero-posterior and lateral postoperative radiographs as well as antero-posterior and lateral weightbearing radiographs taken at the time of healing and at the most recent follow-up. Time to union, nonunion, malunion, leg length discrepancies, range of motion for the knee and ankle, deep infection and reasons for external plate fixation were evaluated. Union was defined as the time when a bridging callus was identified on two orthogonal radiographs and the fracture site was painless during one month of full weight bearing [5, 7]. Delayed union was defined as bone healing that occurred without additional surgery but with a healing time that exceeded double the normal healing time of 3 months. Nonunion was defined as deficient bone healing requiring additional surgical measures such as cancellous bone grafting or revision osteosynthesis. Malunion was defined as bone healing with an axial deviation in any direction exceeding 5° or 1 cm of leg-length discrepancy. Deep infection was defined as infection involving tissue below the muscular fascia [8]. When the fracture site was at the proximal tibia extending to the metadiaphyseal junction (tibial shaft), the fracture classification was determined according to its center [14]. All patients' knee and ankle range of motion were measured by completing two validated and reliable clinical outcome score systems, i.e.the Hospital for Special Surgery (HHS) knee score and American Orthopaedic Foot and Ankle Society (AOFAS) ankle score at 4 weeks postoperatively and at the final follow-up [15,16]. The study was approved by the institutional review board, and informed consent was obtained from each patient.Fig.1(A-F-J).

Fig.1. A - 50y.m, Multiple Trauma, Unstable, B - preop. x-ray – Floating knee injury, C – Indirect reduction and fixation under C-arm control, D - post op.x-rays, E - 3rd Post op.day, F – bone union(24weeks) and plate removal, H – J – final x-ray , clinical appearance and ROM,range of motion.

Table 1. Patient demographics.

Case	Age/ gender	Mechanism	Gustilo Grade	AO Soft Tissue	AO/OTA classification	Other fracture	General condition	Associated injury
1	M/50	MCA	II	-	41C2.2	Ipsilatral NOF; diaphysis;serial ribs	Unstable	Intracranial hemorrhage
2	M/54	MVA	II	-	41C2.2	Pelvis;Open calcaneus	Borderline	Hemopneumothorax
3	F/66	FALL	II	-	41C2.3	Ribs	Borderline	
4	M/70	FALL	-	IO2	41C2.2		Stable	
5	M/22	MVA	-	IO4	41C2.2	Ipsilatral complex femur	Unstable	Hemopneumothorax
6	M/65	MVA	-	IO2	41C2.2	Contra lateral distal tibia/43A3.1	Stable	
7	M/47	FALL	-	IO3	41C2.2		Stable	

Mechanism: MVA - motor vehicle accident; MCA - motorcycle accident; IO - open skin lesion; NOF - femoral neck fracture.

Finite Element Study

Virtual 3D Computer Modeling

Based on serial computed tomography (CT) scan images including the contours of the cortical and cancellous bone of a right tibia of 48 years-old male donor, a finite element model of an unstable proximal tibia fracture was developed to compare the stability of one internal and two different externalized plate fixations. The geometry of the bone/plate construct was developed using computer-aided design (CAD) software (Solid-Works 2009, Dassault Systemes, Waltham, MA, USA) based on the Distal Femur Less Invasive Stabilization System (LISS DF plate) provided by many companies such as Synthes (Oberdorf, Switzerland), Smith & Nephew (Memphis, TN, USA), DePuy (Warsaw, IN, USA), Zimmer (Warsaw, IN, USA), and "Mahe Medical GmbH Germany.A 2cm osteotomy gap was made, located 5cm distally to the proximal articular surface(the tibial plateau) to simulate a multifragmentary proximal metaphyseal fracture with simple intra articular involvement according to AO/OTA 41C2.2 fracture type (Arbeitsge - meinschaft fur Osteosynthesefragen/Orthopedic Trauma Association), and virtually stabilized with an eleven holes ipsilateral stainless steel LISS DF plate. Three implant configurations (IC) with different plate elevations were modelled and virtually tested biomechanically: IC-1 with 2mm elevation (standard internal plate fixation); IC-2 with 22mm elevation (external plate fixation with thin soft tissue simulation); IC-3 with 32mm elevation (external plate fixation with thick soft tissue simulation).In the short proximal segment we applied four locking head(LH) screws with a shorter anterior screw for increased plate elevation. Distaly four bicortical LH screws and one monocortical LH screw at the last plate hole (Fig.2).

Fig.2. Three groups with different plate offset (plate /bone elevation) and screw configuration.

IC-1 IC-2 IC-3

After alignment of the tibia and bone/plate system in the CAD environment, the entire solid model was imported into a commercial FEA package (ANSYS Workbench 12.0, ANSYS Inc. Canonsburg PA, USA). All materials were assumed to be linear elastic and isotropic with values adopted from the available literature [28]. The material properties of the models were completed using the software MIMICS 10.0 (Materialise, Belgium). The plate and screws were made of stainless steel. The diameter of the LH screw was 5 mm. To conserve computing time, the geometry of the screw was simplified to a cylinder (D = 5 mm) matching the geometry of the proximal tibia. In addition, the plate/screw and screw/bone interface were bonded to simulate locking and contact with friction (a static friction coefficient of 0.95) between bone and screw to mimic threads and bicortical purchasing (Fig 3a). For the LISS DF plate The Young’s modulus was set to 110 GPa, and the Poisson’s ratio to 0.3. Plate and screws were modeled as a homogeneous (stainless steel) structure. Bone material elastic properties were considered inhomogeneous based on BMD (bone mineral density) values from the CT scan. Axial loading of 25kg (250N) for simulating partial weightbearing (PWB) and 80kg (800N) for simulating full weightbearing (FWB) were applied to the tibial plateau and distributed at a ratio of 80%/20% on the medial/lateral condyles to evaluate the biomechanical performance of the entire construct[29]. The distal end of the tibia was fixed in all degrees to prevent rigid body motions during the analysis. Distal articular surface was constrained to a control point (a hinge joint simulated) thus only frontal axis rotation allowed. Parameters of interest were construct stiffness (the resulting displacement of the applied force measured at the most lateral point of the articular surface - the red circle, (Fig.3b), IFM (interfragmentary motion - the change of the osteotomy gap width at the lateral side measured in millimeters - the blue arrow, (Fig.3b) and longitudinal strain (the deformation of bone and implant calculated in percentage by dividing the IFM to fracture gap width) at the fracture site. Interfragmentary displacement of the fracture site was recorded to calculate the axial stiffness of the construct (Fig.3b).

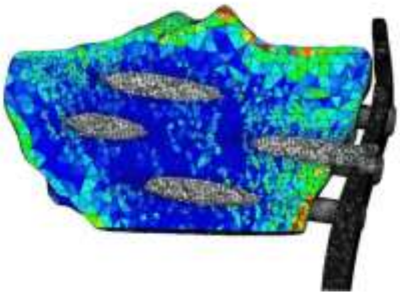

Fig.3.a) Screw/bone interface model. Fig.3.b) Parameters of interest.

Results

Clinical and functional outcomes:

All patients were followed up for a mean period of 22 months (range, 14 - 48 months), and the mean time between admission and external locked plate fixation was 2.86 days (range, 0 - 11days). The mean duration of surgery was 33 minutes (range, 20 - 45 minutes), the mean radiologic exposition time was 21seconds (range, 13 - 27 seconds). The mean fracture healing time was 23.7 weeks (range, 18 - 32 weeks). According to the HSS knee scoring system and AOFAS ankle scoring system the mean HSS score was 86 (range, 72 - 93) and 96 (range, 88 - 100), and the mean AOFAS score was 92 (range, 84 - 100) and 99 (range, 95 - 100) at 4 weeks postoperatively and final follow up (Table 2.a).

Table 2.a) Patients` outcomes.

Mean final range of motion	
Knee ROM(extension-flexion)	2° (0 - 7°) to 121°(50 - 145°)
Ankle ROM (dorsiflexion-plantar flexion)	19°(15 - 20°) to 37°(20 - 45°)
HSS score: 4 weeks/final	86 (72 - 93) / 96 (88 - 100)
AOFAS: 4 weeks/final	92 (84-100) / 99 (95 - 100)
Complications	
	Delayed/non-union: 1/0
	Deep infection: 0
	Malunion (>5°varus): 1
	Shortening (>1 cm): 1
	Screw broken: 0
	Screw loosening: 4 screws in 2 cases
	Plate broken: 0

All fractures healed in an acceptable position with callus formation (Fig1.H-J). After unrestricted four weeks walking with full weight-bearing, all patients underwent uneventful plate removal in outpatients' facilities within a couple of minutes. Pain assessment during plate removal was done using visual analogue score (VAS). The average VAS score was 2.5 points (range, 1 - 5). Delayed union of the proximal fracture occurred in one patient and screws loosening occurred in two patients. One patient had limb length discrepancy of more than 1.5 cm and 7 degrees varus, because of early uncontrolled full weight-bearing. At the most recent follow-up, the mean range of motion at the knee was 2° extension to 121° flexion and the mean ankle range of motion was 19° dorsal flexion to 37° plantar flexion. There were no cases of deep infection. Minor screw tract infection occurred in two patients and resolved after oral antibiotic therapy. We had four screw loosening in two patients, but no screw breakage and external plate fixator disintegration occurred at all. Five patients had excellent functional results and were walking freely at the final follow-up, one patient (54M) was lost to follow-up for 6 months but finished with a good final functional result. One patient (66F) was bedridden for 3 months and developed a 35 degrees extension knee contracture and had a fair final result. All patients refused a second-stage internal fixation. No pedicle neither free flaps were used in our case series. The mean final range of motion (ROM) of the knee and ankle, complications, functional HHS knee and AOFAS ankle scores at 4 weeks and at the final follow up were shown in Table 2.b.

Table 2. b) Final results.

Case	Follow up (months)	Bone union (weeks)	Surgery duration (min)	Ro-Time (sec)	Final ROM (degree)		Complica tion	Functional outcome	Externalized plate fixation consent
					Knee E and F	Ankle D-P			
1	48	28	35	21	0-140	20-38	-	Excellent	Agreed
2	19	22	33	27	7-115	20-35	7°varus; >10mm LLD	Good	Agreed
3	17	22	35	22	0-55	15-20	SSI	Fair	Agreed
4	16	18	20	13	0-125	20-35	screw loosening(one)	Excellent	Agreed
5	14	26	27	15	0-145	20-45	screw loosening(three)	Excellent	Agreed
6	19	24	30	23	5-125	20-45	-	Excellent	Agreed
7	15	20	45	19	0-140	20-38	-	Excellent	Agreed

ROM - Range of Motion; E - extension; F - flexion; D - dorsal flexion; P - plantar flexion.

Biomechanical FEA Results:

Construct stiffness under partial (PWB) and full (FWB)weightbearing was 655 N/mm (IC-1), 197 N/mm (IC-2) and 128 N/mm (IC-3). Interfragmentary motions under PWB were 0.31 mm (IC-1), 1.09 mm (IC-2) and 1.74 mm (IC-3), whereas under FWB were 0.97 mm (IC-1), 3.50 mm (IC-2) and 5.56 mm (IC-3). The corresponding longitudinal strains at the fracture site under partial weightbearing were 1.55%(IC-1), 5.45%(IC-2) and 8.70%(IC-3).The internal fixation model (IC-1) had the highest axial stiffness results. Construct stiffness decreased while the plate/bone offset increased among two external fixation models (IC-2 to IC-3). Axial stiffness was reduced by 75% for the IC-2 and 80 % for the IC-3 respectively. Furthermore, the amplitude of IFM under PWB was in the range of 1.05mm, respectively, compared to internal fixation model (IC-1) (Table 3).

Table 3. Results under PWB, Axial Loading with 250N.

Group	Stiffness (N/mm)	IFM(mm) PWB(250N)	Strain at Fracture Site(%)
IFP	654.80	0.31	**1.55%**
EFP-22	197.08	1.09	**5.45%**
EFP-32	127.56	1.74	**8.70%**

(IFM, Inter Fragmentary Motion)

Disscusion

Exteranalized locked plating for definitive one–staged fixation is well-suited to treating patients with high-energy tibial trauma or those who require longer periods of external fixation due to soft tissue injury or short stature[5, 7, 8]. Multiple trauma patients usually require staged approach which prolong the time before definitive internal fixation can be performed. Kloen et al. were the first to describe the use of a locked compression plate as external fixation and coined the term *supercutaneous* plating [11]. The metaphyseal LISS DF plate, which is designed for unstable and osteoporrhotic distal femur fractures was used to fix both closed with severely damaged soft tissue envelope and open multi fragmentary proximal metaphyseal tibial fractures. We decided to use this alternative treatment option to manage these challenging fractures, by placing in an antegrade manner an ipsilateral LISS DF plate as a definitive monolateral external fixator. It is thicker and with a shape that relatively matches the medial aspect of the proximal tibia, thus suitable for the selected purpose. The design of the plate was appropriate for stabilizing short metaphyseal segments, several metaphyseal screw holes can be chosen depending on the fracture pattern. The plate was placed on the anteromedial aspect of the tibia, with its broad end close to the knee joint, because we found that the contour of the plate matched to the shape of the lower leg. The broad cluster end of the LISS DF plate offered a greater versatility for screws placement as it had 7 holes which gave more precise modulation in obtaining an optimal bone purchasing in the shorter proximal segment. The plate-bone distance was selected to be 22mm in patients with thin soft tissue envelope and 32 mm in patients with thick soft tissue envelope. In our clinical study, long locked plates with 9 to 11 holes were used. All screws were bicortical. All these features increased both the axial and torsional stability [22].The mean fracture healing time was 23.7 weeks (range, 18 to 32 weeks). Ensuring appropriate reduction before application of the external locking plate was crucial, because the plate position could not be modified once locked screws are in place [5-12]. High degree of Anatomical reduction and stable fixation of the intra articular fracture according to AO paradigm could be attributed to the use of a mini open technique through traumatic wound or short incision, whereby the articular fractures were stabilized using a limited internal fixation with 3.5-mm or 2.7mm cannulated screws under C-arm image intensifier. Moreover, the metaphysis and diaphysis were essential in restoring correct length and axial and rotational alignment. After achieved stable anatomical fracture reduction of the articular block, then reattached to the diaphysis with the external locked bridge plating provided relative stability until secondary callus formation gained. Regarding the plate position, some reports recommended plate placement on the medial or anteromedial aspect of the tibia in closed tibial fractures ,therefore, the plate can be placed close to the skin and bone and clearly palpated, facilitating fast healing, with less risk of neurovascular injuries and without compromised motility of muscle [9, 10]. In addition, anatomical reduction of articular fracture is more easily achieved using this approach [5-8]. In contrast to the tibial locking plate, the femoral LISS plate is thicker and the diameter of screws are larger, which effected the stability of fixation. The anteromedial aspect of the tibia is not covered by bulky muscles and important neurovascular structures, hence, the surface can be clearly palpated and facilitating fast and accurate screw insertion with less risk of neurovascular iatrogenic damage. In our study, the mean surgical duration was 33 minutes. The fixation did not cross the knee or ankle joint and rehabilitation could be started early. Therefore, the patients obtained excellent knee/ankle motion and functional recovery. Because of its low profile, the externalized locked plate was easily concealed under regular clothing and did not interfere much with ambulation and daily activities [5-10]. Seven unstable proximal tibial fractures (six male patients with AO/OTA41 C2.2 and one female patient with 41C2.3) were enrolled in our study.The articular anatomical reduction quality was crucial to determine whether the external locking plate could be used; external locking plate could be used to stabilize extra-articular or simple articular fractures. In some AO/OTA41C2.3 fractures, anatomical reduction of the articular block was difficult, especially in severely comminuted fractures [10].The metaphyseal locking plate was successfully used as a provisional or definitive external fixator for severe open tibial fractures [5-8]. However, externalized locked palting is not a standard treatment technique, and whether the external locking plate provides appropriate stability to maintain reduction until fracture healing is still a concern. Moreover, insufficient stiffness of external fixation would lead to unstable and delayed fracture healing, while excessive stiffness may also cause delayed healing or non-union, especially in open fractures. Although internal locked plate fixation is well accepted in clinical treatment, numerous researches reported that its relatively high stiffness might hinder secondary bone healing and result in deficient callus formation or delayed union and nonunion [17-21]. Based on the biomechanical and clinical results of this study, the external locked plating fixation provided sufficient structural stiffness for callus formation.

Bottlang et al. addressed the theory of far cortical locking (FCL), which demonstrated that a flexible fixation would promote secondary bone healing while maintaining sufficient construct stiffness. In their serial biochemical study, they showed that FCL constructs function as true internal fixators by replicating the biomechanical behaviour and biologic healing response of external fixators and may be advisable for stiffness reduction in periarticular plating constructs thus promoting fracture healing by callus formation [22]. Ahmad et al. observed that locking plate /bone interface with 5 mm offset (elevation from bone) had inferior performance in the mechanical properties characterized by decrease in axial stiffness and torsional rigidity of the construct and recommended an optimal plate bone offset of 2 mm[23]. In the virtual biomechanical FE model, under static axial loading with 250N simulating partial weight bearing, the stiffness of construct decreased with 70% in IC-2 with 22mm offset (plate/bone distance) simulating thin soft tissue envelope and by 80% in IC-3 with 32mm offset, simulating thick soft tissue envelope, compared to IC-1 with 2mm offset (standard internal fixation). In addition, decreased construct stiffness in our clical series might be acceptable with mean offset of 18mm (range,14 - 32mm) and as a result we achieved secondary bone healing with callus formation in all present clinical cases.

Carter and coworkers used FE modelling to test Pauwels' hypothesised relationship between mechanical loading and tissue differentiation (Blenman et al., 1989; Carter et al., 1988, 1998) and stated that the size of the fracture gap is essential for bone healing process to begin[24]. Bone fragments with a small gap (≤ 0.5 mm) undergo 'gap healing' – here the gap size is too big for osteoclasts to cross, thus osteoblasts work from one end of the fracture and deposit lamellar bone layer by layer until the gap is bridged[25]. All other mechanical environments favoured differentiation of fibrous connective tissue or fibro-cartilage[26]. According to Perren's theory, strain at the fracture site above100% results in non-union. In the range between 10% and 100% granulation and fibrous tissue formation is expected though between 2% and 10% cartilage formation and enchondral ossification are the substratum of indirect bone healing and secondary callus formation; whereas less than 2% provides a primary bone healing [27]. In the presented 3D model of unstable proximal tibial fracture externally fixed with LISS plate, the values of tibial displacement measured on the lateral side of the virtual 2cm fracture gap presented with inerframentary montions (IFM) under partial weightbearing were 0.31 mm (IC-1), 1.09 mm (IC-2) and 1.74 mm (IC-3), whereas under full weightbearing were 0.97 mm (IC-1), 3.50 mm (IC-2) and 5.56 mm (IC-3). IFM amplitude under PWB was in the range of 1.03mm and the corresponding longitudinal strains at the fracture site was 1.55% (IC-1), 5.45% (IC-2), 8.70% (IC-3), thus a callus formation via indirect bone heeling was the expected result. In our study all fractures healed with indirect callus formation.

Consequently, no deep infection developed because of screw/pin tract infection. In addition, no plate broke, however, four screw loosenings in two cases were observed though reducing the stiffness of the externalized plate, did not affect the overall the locking plate/bone construct. This phenomenon may be similar to the effect of dynamization of a static interlocking nail on fracture healing [30]. We observed one case (54M) with 7 degrees of varus malunion and LLD of more than 1.5cm at the final follow-up, which could be primarily attributed to an early uncontrolled FWB. We did not observed a secondary loss of reduction due to externalized locked plating technique. Our study has several limitations, including small patient number and lack of a control group. The use LISS DF plate(originally designed for internal fixation of the unstable and/or osteoporrhotic distal femur fractures), as definitive external fixator is also controversial, though there are several advantages of external locked plating in complex proximal tibial fracture treatment [32]. It is minimal invasive, time-saving, simple and friendly to the soft tissues and blood supply. This makes the technique appropriate for definitive damage control in borderline and unstable patients with life-threatening multiple trauma injuries and/or short sature. The externalized locking plating cannot replace the Ilizarov ring fixator or the hybrid external fixator in simultaneously fracture treatment limb deformity with substantial soft tissue damage and bone defects [33]. Externalized plates do not interfere with the radiographic evaluation of bone union and can be used as an alternative method when suitable external fixators are unavailable. This study demonstrated that to guarantee a successful external plate fixation in multifragmentary metaphyseal junctional tibial fractures the plate/bone distance should be 32 mm or less. The low profile plate can be concealed under stockings and it is aesthetically acceptable. It is easy to remove the hardware after fracture healing.Traditional and approved surgical treatment of a complex proximal tibial fracture is the internal fixation. In our study, the indication for definitive external plate fixation was expanded to include both closed and open fractures.

In conclusion: In carefully selected cases of complex proximal metaphyseal fractures of the tibia, definitive one-staged externalized locked plating appears to be a safe and reliable alternative treatment technique with a few complications and very good outcomes. From biomechanics point of view, externalized locked plating of unstable proximal tibia fractures with simulated thin and thick soft tissue environment seems to ensure favorable conditions for callus formation with longitudinal strains at the fracture site not exceeding 10%, thus providing appropriate relative stability for secondary bone healing under early partial weight-bearing.

More biomechanical studies and prospective clinical trials are required to evaluate the validity of locking plates as definite external fixators for the treatment of these challenging injuries.

CONFLICT OF INTEREST

No potential conflict of interest.

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