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JINJ 7002 No. of Pages 5
ARTICLE IN PRESS
Injury, Int. J. Care Injured xxx (2016) xxx–xxx
Contents lists available at ScienceDirect
Injury
journal homepage: www.elsevier.com/locate/injury

Metaphyseal locking plate as an external fixator for open tibial fracture: Clinical outcomes and biomechanical assessment

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ARTICLE INFO

Keywords:
Locking plate
External fixator
Open tibial fracture
Biomechanical assessment

ABSTRACT

Objective: This study aimed to evaluate the outcome of using a metaphyseal locking plate as a definitive external fixator for treating open tibial fractures based on biomechanical experiments and analysis of clinical results.
Methods: A metaphyseal locking plate was used as an external fixator in 54 open tibial fractures in 52 patients. The mean follow-up was 38 months (range, 20–52 months). Moreover, static axial compression and torsional tests were performed to evaluate the strength of the fixation techniques.
Results: The average fracture healing time was 34.5 weeks (range, 12–78 weeks). At 4 weeks postoperatively and at the final follow-up, the average Hospital for Special Surgery knee score was 85 (range, 81–100) and 94 (range, 88–100), respectively, and the American Orthopaedic Foot and Ankle Society score was 88 (range, 80–100) and 96 (range, 90–100), respectively. Based on the static test result, the axial stiffness was significantly different among groups ($p = 0.002$), whereas the torsional stiffness showed no significant difference ($p = 0.068$).
Conclusions: Clinical outcomes show that the use of locking plate as a definitive external fixator is an alternative choice for tibial fractures after obtaining appropriate fracture reduction. However, external locked plating constructs were not as strong as standard locked plating constructs. Therefore, the use of external locked plating constructs as a definitive treatment warrants further biomechanical study for construct strength improvement.

Introduction

Open tibial fractures caused by high-energy trauma are usually accompanied by severe soft tissue damage [1,2]. In such cases, direct internal fixation, without considering soft tissue damage, can elevate infection risk and may eventually lead to amputation. Clinically, external fixation is recommended for definitive or provisional fixation until soft tissue recovery, which is subsequently substituted by 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 callus formation and bone healing. However, traditional external fixator constructs (bar and half-pin, ring, and hybrid designs) are often bulky, uncomfortable, and inconvenient, and ambulating with a lower limb fixator frame is awkward [5–10].

The benefits of the application of an external locking plate as an external fixator for open tibial injury have been demonstrated [5–8]. Recently, other surgeons have reported similar experiences with satisfactory results [9–12]. However, the use of locking plates as external fixators remains an off-label treatment that is not generally acknowledged. Moreover, insufficient stiffness of the external locking plate poses a concern. Literature describing fixation stability using this technique is limited; thus, clinical recommendations on its practical use in reducing implant failure risk remain to be determined.

This study aims to determine whether external fixation with a locking plate provides sufficient stability to maintain fracture reduction, thereby achieving bone union. Biomechanical assessment analysis of this case series were performed to demonstrate whether the use of the external metaphyseal locking plate for open tibial fractures is a rational and optimal surgical approach.

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http://dx.doi.org/10.1016/j.injury.2016.11.031
0020-1383/

Patients and methods

Patients

A total of 52 patients with 54 open tibial fractures, were included in this study (Fig. 1) [6]. 9 had Gustilo-Anderson grade II and 45 had grad III (grade IIIA, 20; grade IIIB, 23; grade IIIC, 2) [13]. In addition, the fractures were classified according to the AO Foundation and Orthopaedic Trauma Association (AO/OTA) classification (Table 1). If the fracture site was at the proximal or distal tibia extending to the shaft, the fracture classification was determined according to its center [14]. The study was approved by the institutional review board, and informed consent was obtained from each patient.

All 54 fractures were evaluated clinically and radiographically, as reported in previous studies [5,7,8]. Time to union, time between admission and external locked plate fixation, nonunion, malunion, leg shortening, and deep infection were evaluated. All patients' knee and ankle ranges of motion were measured, and they completed two validated and reliable clinical outcome measurement scores, i.e., the Hospital for Special Surgery (HHS) knee score [15] and American Orthopaedic Foot and Ankle Society (AOFAS) ankle score at 4 weeks postoperatively and at the final follow-up [16].

Biomechanical test

The authors used 15 reinforced solid, fourth-generation composite large tibia samples as the extra-articular proximal tibial metaphyseal gap model. The samples were divided into internal locked plate fixation (ILPF, n = 5), external locked plate fixation (ELPF, n = 5), and conventional external fixation (EF, n = 5) groups. In the ILPF group, an internal locked plate fixation with titanium 13-hole proximal tibia LISS (less invasive stabilization system) plates (LISS-PLT; Synthes Inc., PA, USA) was applied laterally to the tibia, according to the manufacture's instruction. Four 5.0 × 55-mm screws were fixed in the proximal metaphyseal region and another three screws in the diaphysis region. The ELPF utilized 13-hole distal femur LISS plates (LISS-DF; Synthes Inc., PA, USA) with four 5.0 × 85-mm screws fixed in the proximal metaphyseal region and three 5.0 × 55-mm screws in the diaphysis

Table 1
Characteristics of the cohort.

Age	Mean 41 years (range, 21–77)
Sex (Male:Female)	32:20
Open fracture (Gustilo)	Grade II: 9
	Grade IIIA: 20
	Grade IIIB: 23
	Grade IIIC:2
AO/OTA classification	41-A: 2 (0 A1, 0 A2, 2 A3)
	41-B: 4 (0 B1, 2 B2, 2 B3)
	41-C: 6 (0 C1, 4 C2, 2 C3)
	42-A: 2 (0 A1, 1 A2, 1 A3)
	42-B: 5 (1 B1, 3 B2, 1 B3)
	42-C: 19 (6 C1, 4 C2, 9 C3)
	43-A: 8 (0 A1, 2 A2, 6 A3)
	43-B: 0 (0 B1, 0 B2, 0 B3)
	43-C: 8 (2 C1, 5 C2, 1 C3)

AO/OTA, AO Foundation and Orthopaedic Trauma Association.

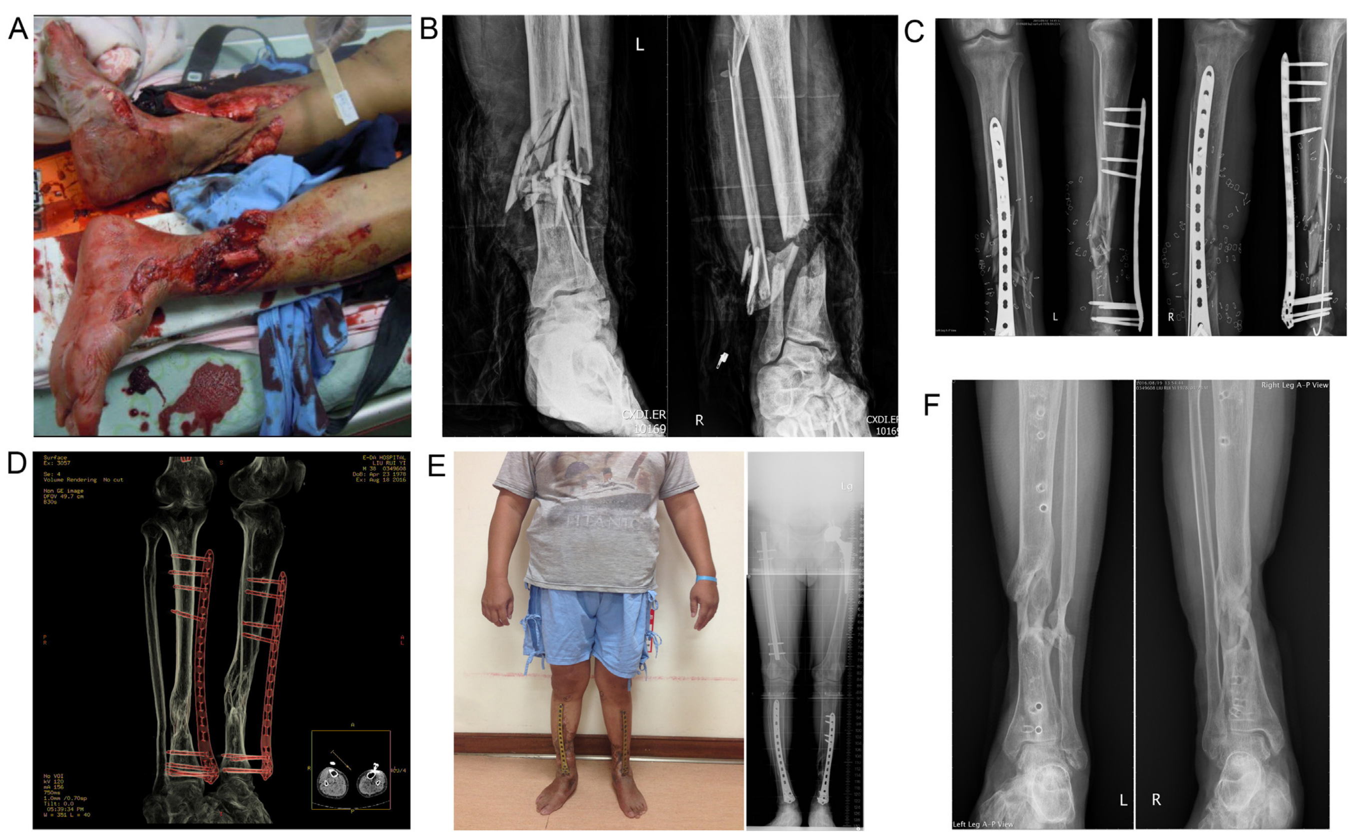

Fig. 1. A 34-year-old man sustained bilateral Gustilo type IIIb, open tibial fractures (AO/OTA 42-C3) (A, B). Bilateral Lisfranc fractures, right femoral shaft fracture, and left hip fracture-dislocation. Both tibial fractures were stabilized using a metaphyseal locking plate for external fixation after appropriate fracture reduction was achieved; subsequently, the soft tissue defect of both legs was repaired and new skin grafted (C). Fracture union without limb discrepancy observed at 1-year follow-up (D, E). Radiograph showing bilateral tibial fracture union 1 year after plate removal. (F).