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Treatment of distal intraarticular tibial fractures: A biomechanical evaluation of intramedullary nailing vs. angle-stable plate osteosynthesis

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KEYWORDS

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intraarticular fractures
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ABSTRACT

In factures of the distal tibia with simple articular extension, the optimal surgical treatment remains debatable. In clinical practice, minimally invasive plate osteosynthesis and intramedullary nailing are both routinely performed. Comparative biomechanical studies of different types of osteosynthesis of intraarticular distal tibial fractures are missing due to the lack of an established model. The goal of this study was first to establish a biomechanical model and second to investigate, which are the biomechanical advantages of angle-stable plate osteosynthesis and intramedullary nailing of distal intraarticular tibial fractures. Seven 4th generation biomechanical composite tibiae featuring an AO 43-C2 type fracture were implanted with either osteosynthesis technique. After primary lag screw fixation, 4-hole Medial Distal Tibial Plate (MDTP) with triple proximal and quadruple distal screws or intramedullary nailing with double proximal and triple 4.0mm distal interlocking were implanted. The stiffness of the implant-bone constructs and interfragmentary movement were measured under non-destructive axial compression (350 and 600 N) and torsion (1.5 and 3Nm). Destructive axial compression testing was conducted with a maximal load of up to 1,200 N. No overall superior biomechanical results can be proclaimed for either implant type. Intramedullary nailing displays statistically superior results for axial loading in comparison to the MDTP. Torsional loading resulted in non-statistically significant differences for the two-implant types with higher stability in the MDTP group.

From a biomechanical view, the load sharing intramedullary nail might be more forgiving and allow for earlier weight bearing in patients with limited compliance.

Introduction

Fractures to the distal tibia with or without articular extension are frequently the result of a high-energy trauma with significant soft-tissue damage [1,2]. Surgical treatment needs to ensure a stable fixation while minimising the secondary trauma to the soft tissues induced by the surgical approach and implants. In fractures with simple articular extension (AO 43 C1/C2) the optimal surgical treatment remains debatable. Traditional open reduction and internal fixation has the disadvantage of devascularizing fragments and causing additional damage to the soft tissues. Minimal invasive plate osteosynthesis (MIPO) reduces these disadvantages and has largely replaced the classical ORIF technique in simple intraarticular fractures. MIPO can be regarded as the current standard of treatment for these fractures [3]. However, anatomically pre-contoured, angular stable plates are usually prominent under the skin and can still cause soft tissue irritation [4,5]. This is mainly problematic in elderly patients or patients with comorbidities such as peripheral vascular disease, diabetes and cortisone intake.

The latest generation tibial nails with multiple multidirectional locking options near the nails end have extended the indications of intramedullary nailing [6-8]. They allow for placement of up to four distal interlocking screws in three different planes within 50 mm of the tibial plafond [9]. Intramedullary nailing preserves the vascularity of the fracture site and the integrity of the soft-tissue. In case of simple extension of the distal tibial fractures into the joint (AO 43 C1/C2), intramedullary nailing after primary lag screw fixation is an alternative to plating [10,11]. However, intramedullary nailing is technically challenging with the specific risk of fixing the fragments in a non-anatomic position. Techniques such as Poller screws or intramedullary blocking screws are often used to avoid this problem [12,13]. The further the fracture extends distally, the less stability is provided by the nail itself. The cross

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section of the tibia changes from the distal shaft to the metaphysis from a narrow triangular to a wide round shape. Clinical studies of distal tibial fractures showed a higher incidence of malalignment for intramedullary nailing in comparison to plating [14-16].

So far, no biomechanical model exists, which allows for an evaluation of the stability of distal tibial fractures with articular involvement. The goal of this study was to establish such a biomechanical model and to investigate, which are the biomechanical characteristics of the two techniques, angle-stable plate osteosynthesis and intramedullary nailing, in fixation of distal intraarticular tibial fractures.

Methods

Hypothesis

Biomechanical testing was performed to investigate the properties of the two-implant types. Our null hypothesis was that there is no difference in the biomechanical properties after intramedullary nailing (Expert Tibial Nail, DePuySynthes®, West Chester, PA, USA) compared to Angle Stable Plate Osteosynthesis (Medial Distal Tibial Plate, DePuySynthes®, West Chester, PA, USA) in an articular simple, metaphyseal multi-fragmentary distal tibial fracture model (AO/OTA 43 C2).

Implants

Implantations of the 4-hole Medial Distal Tibial Plate (MDTP) were performed according to the surgical guide of the manufacturer with three proximal and four distal screws. First a lag screw was introduced to address the intraarticular fracture, followed by two non-angular stable screws (one proximally and one distally) to fix the plate to the tibia. Afterwards the three angle-stable screws were drilled and introduced distally while proximally two angle-stable screws were used.

Implantations of the Expert Tibial Nail (ETN) were also performed after lag screw fixation and according to the surgical guide of the manufacturer. Nails with 34mm length and 8mm diameter were used. Proximal locking was performed with two standard 4.0mm locking screws. Distally, triple 4.0mm locking screws through the antero-posterior, medio-lateral and oblique locking option were employed.

Osteotomy

To ensure identical osteotomies in all samples, we used a specifically built osteotomy appliance. The osteotomy parameters to simulate an AO/OTA 43 C2 type fracture were established on the composite bone (Fourth-generation biomechanical composite bone tibiae, medium size, item number 3401, Sawbones Europe, Malmö, Sweden). A transverse defect osteotomy of 10mm between 40 and 50mm for the tibial plafond and a sagittal split into the joint at the lateral third were first carried out incomplete. The distal split was completed before the lag screw was introduced. The osteotomized bone segment between 40 and 50mm from the tibial plafond was fully resected by a parallel saw at the end of the implantation. Before testing, all constructs underwent radiological control in two planes to exclude damages or incorrect implantation.

Table 1

Test sequence of the biomechanical evaluation. The constructs underwent the test sequence 1.a., 1.b., 2.a., 2.b. and 3.

Test sequence	7 ETN vs. 7 MDTP each with additional lag screw fixation	
1. Non-destructive tests (low)	a. Axial compression 350 N	b. Torsion 1.5Nm
2. Non-destructive tests (high)	a. Axial compression 600 N	b. Torsion 3Nm
3. Destructive tests	Axial compression up to 1200 N	

Biomechanical testing

The proximal tibial end was potted in poly-methyl methacrylate (PMMA). Distally, two different forms of load transmission had to be replicated for axial and torsional loads. For axial loading, a frictional connection was established through a pseudo-talus. A PMMA-imprint was produced and ensured a save load transmission distally. For torsion, the force was transmitted through the lateral intraarticular fragment. Similarly to the axial load transmission, a PMMA-imprint was produced of the medial and distal aspect and secured by two screws to ensure the torsional force transmission.

A universal pneumatic testing machine (SincoTec; Clausthal-Zellerfeld, Germany) controlled by PneuSys software (SincoTec, Clausthal-Zellerfeld, Germany) was used for biomechanical testing. The setup was based on the method described by Kuhn et al [17,18]. The point of load transmission for all axial compression testing was in accordance to Horwitz et al. [19] The force was introduced into the tibial plateau at a 10mm posterior offset from the tibial eminence. This was coupled by a force-transmitting bar, which applied the pressure. Distally the samples were placed on a Cardan joint to simulate the human ankle joint.

All test specimens underwent the same testing sequence. First, a non-destructive test for axial force with 350 N followed by a bi-directional rotational test with 1.5Nm was carried out. Afterwards a higher load, non-destructive test for axial force with 600 N followed by a bi-directional rotational test with 3Nm performed. As a final test increased loading for destructive tests took place for axial compression up to 1200 N. Table 1 shows an overview of the testing sequence.

In all axial loading tests, a constant preload of 18 N was applied first and was then increased to 350/600/900 N before decreasing back to 18 N. Each cycle was performed after a constant speed and duration of 20 seconds. Three measurement cycles were recorded after an initial pre-cycle. The actuator,

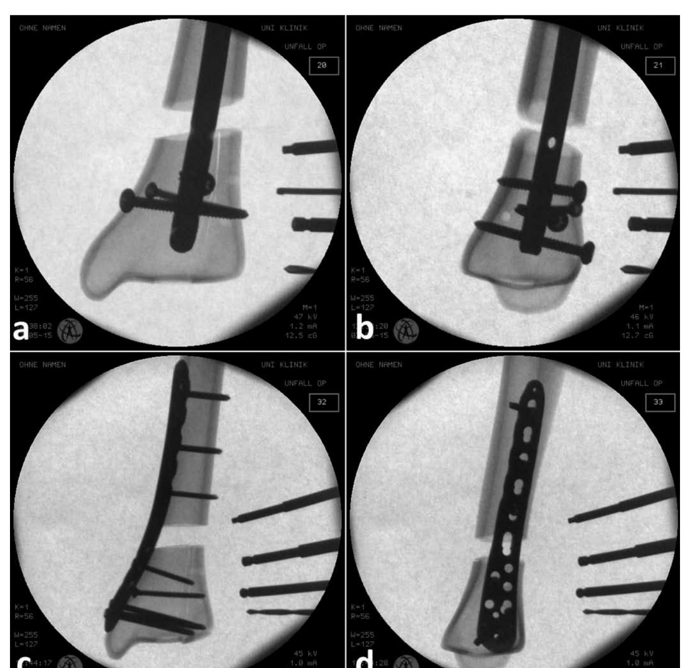

Fig. 1 a-d. Osteosynthesis of the AO 43 C2 fracture. Fluoroscopy images of ETN with lag screw fixation (Fig. 1 a,b) and MDTP with lag screw fixation (Fig. 1 c, d) implanted in an AO 43 C2 fracture type.