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Primary stability of an intramedullary calcaneal nail and an angular stable calcaneal plate in a biomechanical testing model of intraarticular calcaneal fracture

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ABSTRACT

Background: Nowadays, open anatomic reduction and internal fixation can be considered as a valuable treatment for displaced intra-articular fractures of the calcaneus. However, the application of a calcaneal plate via an extensile lateral approach is at risk for a substantial rate of complications including delayed healing, skin necrosis, or infection. There is some evidence that a limited exposure might contribute to a decreased soft tissue complication rate bearing in mind that most minimally invasive techniques have to accept a reduced primary stability compared with the open application of an angular stable plate. Recently, an intrafocal minimal invasive reduction technique has been established employing an intramedullary nail for fracture stabilisation and support of the subtalar joint. The aim of this study was to compare the primary biomechanical performance of the new device versus lateral angular stable plating.
Material and methods: Biomechanical testings were performed on 14 human cadaveric feet (7 pairs). Dry calcaneal bones were fractured resulting in a Sanders type IIB fracture pattern and fixed by either a calcaneal locking plate or an intramedullary calcaneal nail. Compressive testing via the corresponding talus was employed at a constant loading velocity until failure with an universal testing machine and a specific mounting device to avoid any shear forces. Apart from the data of the load deformation diagram the relative motion of the fracture elements during loading was recorded by 8 extensometric transducers. After failure the specimens were carefully examined to check the failure patterns.
Results: The displacement of the subtalar joint fragment was substantially lower in specimens fixed with the nail. Stiffness and load to failure were significantly higher after fixation with the intramedullary nail than after application of the angular stable plate. Failure with both fixation modes generally occurred at the anterior calcaneal process fragment.
Conclusions: The primary stability of an intramedullary nail appeared to be superior to an angular stable plate representing the present standard technique in open reconstruction of the fractured calcaneus. The results from the experimental model speak in favour of the clinical use of the intramedullary calcaneal nail.

Introduction

Intra-articular calcaneal fractures comprise around 75% of all calcaneal fractures and are frequently associated with severe functional impairment [1,2]. At present, there is not a single effective treatment option for intra-articular calcaneal fractures [2–9]. There is even not sufficient evidence that surgical treatment would be generally superior to non-operative treatment [1]. But, operative treatment seems to be beneficial for several subgroups of patients, e.g. women and younger males, patients with lighter workload, for those who are not receiving Workers' Compensation and those with simple displaced fracture types [1,10–12]. Finally, the subtalar arthrodesis rate is significantly less with surgical treatment and, in addition, on a socio-economic basis, operative management appears to be less costly and more effective than nonsurgical treatment [1]. On the other hand, open reduction and

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internal fixation via the lateral extended approach representing the most frequently recommended and applied approach nowadays exposes the patient to inherent risks as wound healing problems, skin necrosis and infection [2,13,14]. Despite that fact that this particular approach respects the vascular anatomy of the corresponding skin flap soft tissue complication rates are reported within the range from 1 to more than 25% [2,14,15]. These high complication rates again may limit a generous indication for surgery, in particular with patients at risk for delayed wound healing due to concomitant diseases [13,14]. Therefore, other operative procedures have been suggested including two-staged procedures, external fixators, medial approaches, percutaneous reduction and fixation via the limited lateral or sinus tarsi approach [13,16–21,9]. Due to the limited exposure most modifications of the latter procedure are technically demanding, make alternative tools for the verification of adequate reduction necessary (e.g. arthroscopy, 3-D fluoroscopy) and are currently reserved for experienced surgeons or simple fracture types, only [13,19,9]. Meanwhile, there exists sufficient evidence on the basis of studies comparing the outcome and risks of the sinus tarsi and the extended lateral approach that the minimised approach may allow for a comparable functional result at a reduced risk for soft tissue complications [6,22,23]. Due to the limited surgical exposure less stable implants as K-wires, multiple screws or special plates are used with less stability of fixation and the potential for a secondary loss of reduction within a range from 1 to 67% [9,13,20,21,24].

For these reasons a posterior approach had been developed to perform both an intrafocal reduction of the subtalar joint and the tuber calcanei fragment and an internal fixation with a novel intramedullary interlocking implant having in mind the high degree of stability and the favourable outcomes of epi-metaphyseal locking nails in various locations [17,25]. It was the aim of the study to compare the primary stability of the intramedullary calcaneal nail with an angular stable calcaneal plate during compressive loading in an experimental model of a standardised calcaneal fracture.

Materials and methods

Cadaver specimens and test set-up

7 pairs of enzymatically corroded human calcaneal and talar bones ("dry bones") were recruited for biomechanical testing. A 3-fragment intra-articular calcaneal fracture (Sanders type 2B, Utheza horizontal, vertical and mixed) was generated using a motorised oscillating saw according to the protocol of Bardet el al. [26,27]. The fractures of the corresponding calcaneal bone pairs were fixed either by an uniaxially angular stable AO locking plate (Synthes Inc., Paoli, PA 19301-1222, USA) according to the recommendation of Sanders and Gregory or with a calcaneal interlocking nail with 2 locking screws (Calcanail™, FH ORTHOPEDICS, 68990 Heimsbrunn, France) according the original implantation technique [25,28] (Fig. 1). A hydraulic testing machine (monoaxial MTS® machine with 25 kN of maximum load, MTS® headquarters, Eden Prairie, MN, USA) was employed for compressive loading, force and motion analysis. The talus, the anterior calcaneal process and the calcaneal tuberosity were fixed each with epoxy power glue (Pattex®, Henkel AG & Co. KGaA Headquarters, D-440589 Düsseldorf, Germany) to the fixation devices providing a 15° calcaneal inclination angle and a hindfoot angle of 0° to simulate the anatomic position of the heel. The calcaneal tuberosity was positioned onto a sliding platform to avoid any additional shear forces during vertical loading (Fig. 2a and b). Progressive loads were applied through the corresponding talus. As pretests had shown that corroded bones were far not able to carry load levels of 1000 N and more as applied by Bardet et al. in fresh-frozen cadaveric bones the original testing protocol was modified [26]. A preload of 18 N was applied at a constant loading velocity (0.5 mm/min) via the traverse of the testing machine carrying the embedded talus. The calcaneus was instrumented with a total of 8 extensometric sensors to record the displacement of each fracture element during loading. Sensors 2 and 3 registered

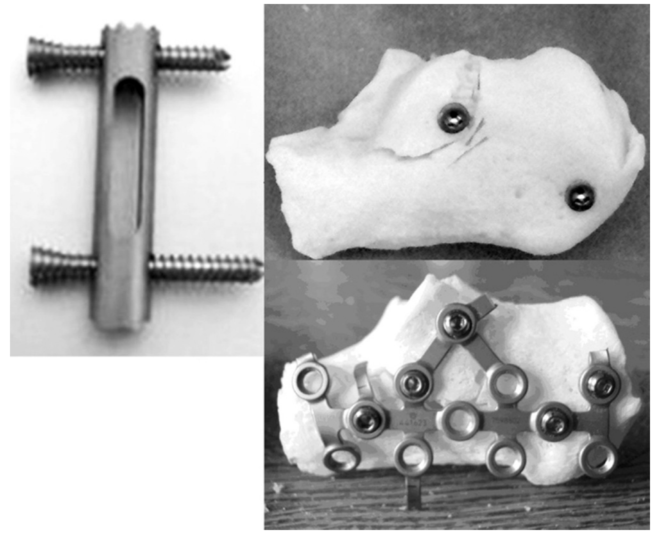

Fig. 1. Calcaneal nail (Calcanail®) (left above) and lateral views of the locked Calcanail® (above right) in situ and the fixed-angle AO calcaneal locking plate (below).

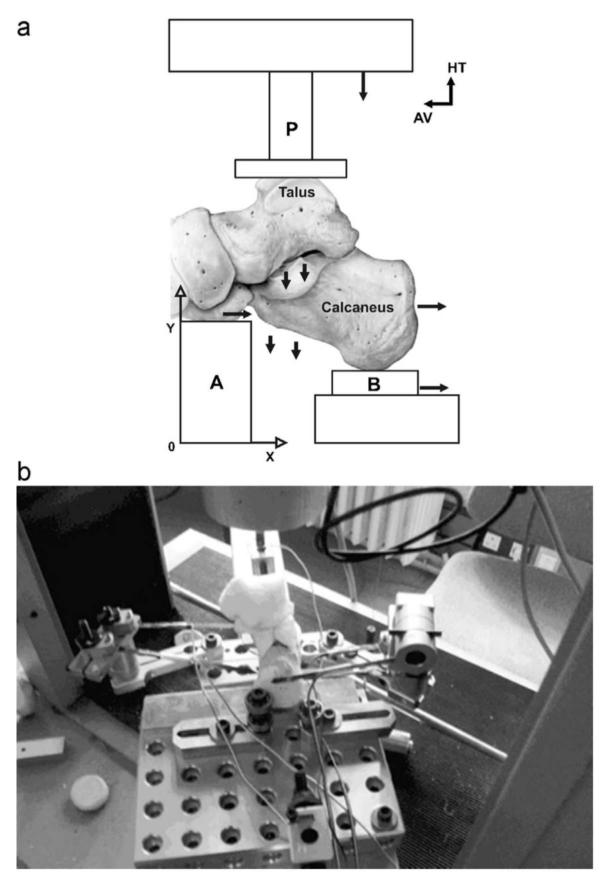

Fig. 2. (a) Schematic experimental set-up acc. to Bardet et al. [21]. (b) Experimental set-up (posterior view of the calcaneus).