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Effect of additional fixation in tibial plateau impression fractures treated with balloon reduction and cement augmentation

Raul Mayr [a], Rene Attal [a], Marit Zwierzina [b], Michael Blauth [a], Werner Schmoelz [a,*]

[a] Department of Trauma Surgery, Medical University Innsbruck, Anichstrasse 35, 6020 Innsbruck, Austria
[b] Division of Clinical and Functional Anatomy, Department of Anatomy, Histology and Embryology, Medical University Innsbruck, Müllerstrasse 59, 6020 Innsbruck, Austria

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ABSTRACT

Background: Isolated tibial plateau impression fractures can be reduced through minimally invasive techniques using balloon inflation and cement augmentation. No evidence exists yet if an additional fixation at all and which method of fixation is necessary in the treatment of these fractures. The purpose of this study was to compare a locking plate and a screw raft for additional fixation after balloon reduction and cement augmentation in isolated tibial plateau impression fractures. Loss of reduction was subsequently analysed without additional fixation.
Methods: Lateral tibial plateau impression fractures were created in eight matched pairs of human cadaveric tibiae. Reduction was performed using a balloon inflation system, followed by cement augmentation. Additional fixation was performed with a lateral locking plate or a screw raft (four 3.5-mm screws). Specimens were cyclically loaded at 20–240 N, 20–360 N and 20–480 N. Subsequently, additional fixation was removed and the last cyclic interval (20–480 N) repeated. Loss of reduction was assessed by measuring subsidence of the subchondral bone.
Findings: Fractures treated with plate fixation exhibited less subsidence at higher loads compared with those treated with screw raft fixation ($P < 0.05$). Loss of reduction significantly increased after removal of the additional fixation.
Interpretation: This experimental study suggests that loss of reduction can be minimised by using locking plate fixation after balloon reduction and cement augmentation in the treatment of isolated tibial plateau impression fractures.

1. Introduction

The number of geriatric fractures is continuously increasing. Lateral tibial impression fractures are usually seen in older patients who have reduced metaphyseal bone substance. With decreased bone quality, the tibial head fracture tends to be a pure impression of the articular surface, rather than a split-impression fracture. Without a split in the outer cortex, this impression fracture results in a Schatzker III type of fracture (Schatzker, 2005). The primary aim of surgical treatment in this patient population is anatomical restoration of the articular surface and stable fixation in order to allow weight-bearing as soon as possible. However, after surgical treatment of tibial plateau fractures, subsidence of the articular surface when the patient becomes mobile again, with consequent valgus malalignment of the limb, has frequently been reported in the literature (Russell et al., 2008).

Recently, several authors have described minimally invasive techniques using inflatable balloon systems for reduction of a depressed articular surface (Ahrens et al., 2012; Broome et al., 2012; Craiovan et al., 2014; Hahnhaussen et al., 2012; Mauffrey et al., 2014; Pizanis et al., 2012). Metaphyseal defects after reduction of the joint surface are augmented with bone substitutes to avoid secondary loss of reduction. Reduction can be additionally secured by screws passing across the cement cloud in the metaphyseal bone. Combination of balloon reduction followed by percutaneous screw insertion represents a full minimally invasive treatment of tibial impression fractures (Craiovan et al., 2014; Mauffrey et al., 2014). Previous biomechanical studies have reported a high degree of stability for tibial plateau impression fractures treated with cement augmentation and screw fixation without using a lateral plate (Doht et al., 2012; Yetkinler et al., 2001). Nevertheless, a locking plate is often used for additional fixation, in order to reduce the risk of screw-head cut-out at the lateral cortex and subsequent loss of reduction (Hahnhaussen et al., 2012; Pizanis et al., 2012). There is as yet no evidence on which method of fixation provides the greatest

* Corresponding author at: Department of Trauma Surgery, Medical University of Innsbruck, Innsbruck, Austria.
E-mail addresses: raul.mayr@uki.at (R. Mayr), rene.attal@uki.at (R. Attal), marit.zwierzina@i-med.ac.at (M. Zwierzina), michael.blauth@i-med.ac.at (M. Blauth), werner.schmoelz@i-med.ac.at (W. Schmoelz).

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stability in the treatment of tibial plateau impression fractures after balloon reduction and cement augmentation, or even whether fixation is necessary at all.

The purpose of this study was to compare a locking plate and a screw raft for additional fixation after balloon reduction and cement augmentation in isolated tibial plateau impression fractures. Loss of reduction was also analysed after the additional fixation was removed. It was hypothesised that a screw raft is biomechanically equivalent to a lateral locking plate in tibial plateau impression fractures reduced by balloon inflation and cement augmentation. The second hypothesis was that removing additional fixation results in increased loss of reduction and cement cloud subsidence.

2. Methods

In the first part of the study, plate and screw raft fixation for tibial plateau impression fractures were tested using a cyclic protocol with stepwise-increasing load magnitudes. In the second part, the plate or screw raft fixation was removed and the specimens were tested with cement augmentation alone.

2.1. Specimen preparation

Eight matched pairs of human fresh-frozen tibiae were used for testing (mean age: 78 years, SD 10 years, six females). The bodies were donated by people who had given their informed consent for their use for scientific and educational purposes prior to death (McHanwell et al., 2008; Riederer et al., 2012). Local bone mineral density (BMD) was measured 10 mm below the lateral articular surface of the tibia using quantitative computed tomography (LightSpeed VCT, GE Healthcare, Milwaukee, Wisconsin, USA), showing a mean BMD of 90.0 mg HA/cm^3 (SD 30.0). The specimens were stored at −20 °C and thawed overnight at 6 °C prior to preparation and biomechanical testing. At room temperature, skin and musculature were removed. The tibia was cut at the mid-diaphysis, 20 cm distal to the tibial plateau, and potted in a metal cup using polymethylmethacrylate (Technovit 3040, Heraeus Kulzer, Wehrheim, Germany), resulting in a free specimen length of 15 cm. The tibia was oriented with the long axis of the tibial shaft at a 5° angle to vertical in order to simulate a slight valgus orientation (Doht et al., 2012; Yetkinler et al., 2001).

2.2. Fracture creation

The fracture was created by impressing a cylindrical indenter (diameter 14 mm) into the lateral tibial plateau surface. Prior to impression, twelve holes (diameter 2 mm), arranged in a circle with a diameter of 14 mm, were drilled as predetermined breaking points (Doht et al., 2012; Yetkinler et al., 2001). The indenter was positioned in the centre of the arranged predetermined breaking points and impressed to a depth of 8 mm at 1 mm/s using a servohydraulic materials testing machine (Mini-Bionix II 858, MTS, Eden Prairie, Minnesota, USA).

2.3. Balloon reduction and cement augmentation

All of the procedures were performed by an orthopaedic trauma surgeon (R.M.). The impression fracture was reduced using a balloon inflation system (Kyphon; Medtronic, Sunnyvale, California, USA) inserted from the anteromedial aspect of the tibia. Under fluoroscopy, the balloon was positioned centrally under the impressed subchondral bone. Anatomical reduction was achieved by balloon expansion. The volume of contrast solution determined the minimum quantity of cement that was subsequently injected into the void (VertecemV+; Synthes Inc., West Chester, Pennsylvania, USA).

2.4. Fixation

The tibiae in each pair were randomly assigned to the two fixation techniques (Fig. 1), ensuring an equal number of left and right tibiae for each method. The lateral locking plate (3.5 mm; Synthes) was provisionally positioned to the lateral aspect of the tibia with the proximal screw holes parallel to the articular surface of the lateral condyle. In a craniocaudal direction, the plate position was chosen in such a way that at least one proximal screw passed centrally through the cement cloud. The plate was fixed with K-wires.

In the group with plate fixation, locking screws (3.5 mm; Synthes) were inserted with four proximal, one kickstand and one diaphyseal locking head screws. In the group with screw raft fixation, holes for the raft were drilled using the four proximal holes in the locking plate. The plate was removed and four 3.5-mm cortical screws (Synthes) were inserted through the lateral tibia. The length of the proximal screws was chosen in order to avoid perforation of the medial cortex.

2.5. Biomechanical test set-up

The femoral component of a hemi-total knee arthroplasty (TKA) (Oxford; Biomet, Bridgend, United Kingdom) was rigidly attached to the actuator of the servohydraulic materials testing machine (Fig. 2). The embedded specimen was mounted on an X–Y-bearing table in order to ensure uniform loading across the reduced impression fracture.

The cyclic loading protocol consisted of three loading intervals of overall 15,000 compression load cycles at 20–240 N, 20–360 N and 20–480 N (5000 load cycles per interval) applied at 2 Hz, representing a high range of physiological gait. These load magnitudes simulate a patient weighting 80 kg in the rehabilitation with 66%, 100% and 133% of weight-bearing during gait (McDonald et al., 2011). Load magnitudes were chosen on the basis of the following considerations: firstly, during gait, the net joint contact force for a single leg stance is reported as being three times body weight (Taylor et al., 2004). Secondly, load-sharing

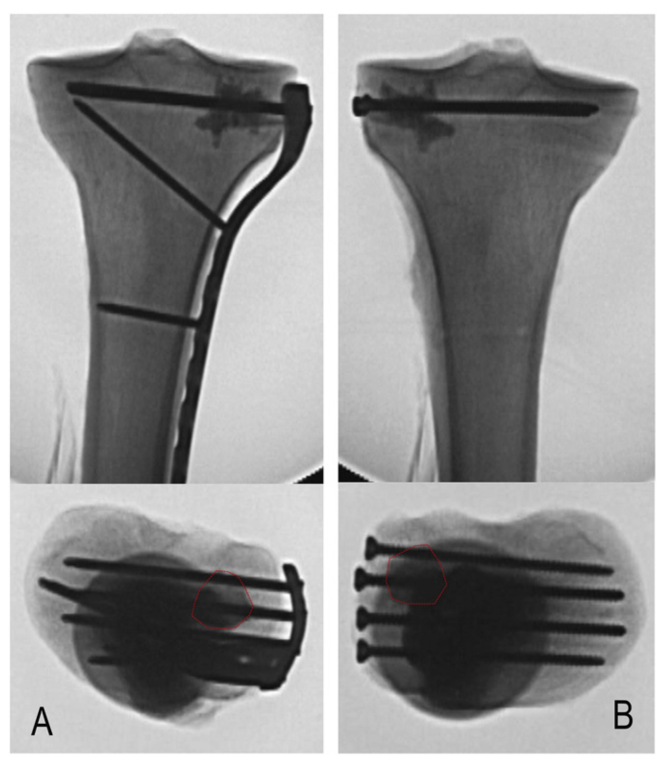

Fig. 1. Radiographs of the instrumented specimens, with plate fixation (A) and screw raft fixation (B). The red circle marks the cement cloud in the axial view.