Clinical Biomechanics 29 (2014) 595–598

Contents lists available at ScienceDirect

Clinical Biomechanics

journal homepage: www.elsevier.com/locate/clinbiomech

Brief report

Locking plates and their effects on healing conditions and stress distribution: A femoral neck fracture study in cadavers

Trude Basso [a,b,*], Jomar Klaksvik [a], Olav A. Foss [a,b]

[a] Orthopaedic Research Centre, Department of Orthopaedics, Trondheim University Hospital, Norway
[b] Department of Neuroscience, Norwegian University of Science and Technology, Norway

ARTICLE INFO

Article history:
Received 19 December 2013
Accepted 18 March 2014

Keywords:
Femoral-neck fracture
Internal fixation
Micromotion
Fracture healing
Locking plate
Biomechanics
Cadavers

ABSTRACT

Background: Implants are used to stabilize femoral neck fractures to achieve successful fracture healing, but there is still a high rate of fracture non-unions. We compared micromotions in femurs with fractured femoral necks stabilized with three screws with or without a locking plate. We also investigated whether osteoporosis was associated with micromotion magnitudes, and explored the influence of implants on load distribution in the upper femur.

Methods: Twelve pairs of human cadaver femurs with femoral neck fractures (AO/OTA 31-B1) were allocated to fracture fixation by three locked screws or three individual screws. All femurs underwent dual energy X-ray absorptiometry. Physiological subject-specific axial load and torque was applied for 10,000 cycles. Micromotion of the head fragment was measured every 100 cycles with high-resolution optical motion detection. Load distribution was measured with strain-gauge rosettes attached to the lateral and medial proximal diaphysis.

Findings: The locking plate group showed reduced micromotion about the femoral neck axis ($P = 0.035$, effect size $= 0.62$). No differences were found in valgus–varus or antegrade–retrograde rotations, or in the three translations. Micromotion magnitudes were not associated with osteoporosis. The overall micromotions of the upper femur and the load distribution in the proximal diaphysis were not influenced by fixation type.

Interpretation: The locking plate group showed increased resistance to shear forces compared with the screw group. This effect was not associated with a diagnosis of osteoporosis. The locking plate did not affect the load distribution in the proximal femur.

1. Introduction

Intracapsular femoral neck fractures must heal without a stabilizing external callus (Szechinski et al., 2002) and therefore these fractures require stable fixation for proper revascularization and successful endosteal healing. Currently the rate of fracture non-unions ranges from approximately 8% for non-displaced fractures to 30% for displaced fractures (Bjorgul and Reikeras, 2007; Parker et al., 2007).

Locking-plate fixation of femoral neck fractures is a new treatment, and thus the preclinical and clinical literature is sparse. Biomechanical experiments have shown increased mechanical strength (Aminian et al., 2007; Nowotarski et al., 2012), but clinical reports of catastrophic outcomes also exist (Berkes et al., 2012). The effect of adding a locking plate to three screws on the plastic deformation in femoral neck fractures has previously been presented in this journal (Basso et al., 2014).

The primary aim of this study was to investigate how adding a locking plate to fracture-fixating screws affects micromotion of the femoral head fragment. The secondary aims were to see whether osteoporosis affects the micromotion magnitudes and to explore if the load distribution in the upper femur changed when using a locking plate.

2. Methods

An extensive description of the included femurs and the experimental method can be found in a related article published in this journal (Basso et al., 2014). A brief summary of the method follows.

Twelve pairs of fresh-frozen cadaver femurs were included and subcapital femoral neck fractures (AO/OTA 31-B1) were created. The first femur of each pair was randomly allocated to osteosynthesis using either three screws with a locking plate (Dynaloc System; Swemac Innovations, Linköping, Sweden) (Fig. 1A), or three individual screws (Dynaloc Bone Screws; Swemac Innovations, Linköping, Sweden) (Fig. 1B).

The femurs were mounted into a hip jig (Fig. 2) fitted into a material-testing machine (MTS 858 MiniBionix II; MTS Systems Corporation, Eden Prairie, MN, USA). The hip simulator applied a combined axial load and torque based on donor bodyweight (BW) and the loading regime resulted in a joint resultant force of 2.5 BW (SD 0.2). The femurs were cyclically loaded at 0.5 Hz for 10,000 cycles. Testing was performed sequentially, first on intact femurs, and then repeated on the

---

* Corresponding author at: Orthopaedic Research Centre, Department of Orthopaedics, Trondheim University Hospital, Postboks 3250 Sluppen, 7006 Trondheim, Norway.
E-mail address: trude.basso@ntnu.no (T. Basso).

http://dx.doi.org/10.1016/j.clinbiomech.2014.03.006

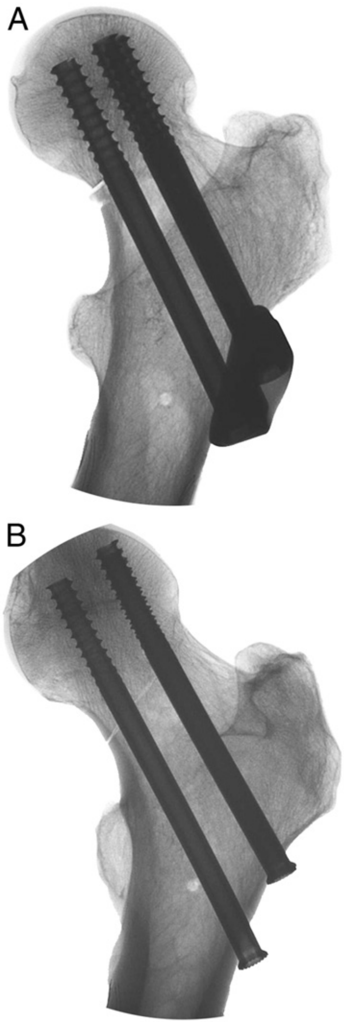

Fig. 1. Three cannulated bone-screws in an inverted triangle configuration with a locking plate (A) and without a locking plate (B).

operated femurs. By doing so, data recorded from the intact situation could serve as the subject-specific reference.

Multiple digitized surface points on the femoral head were used to calculate the center of the femoral head (Labview 8.6; National Instruments, Austin, TX, USA). An infra-red camera (Polaris Spectra; NDI, ON, Canada) captured three-dimensional (3D) positions of passive rigid marker tools (Fig. 2). To define the coordinate system, a two-marker tool was fixed into the head end of the distal screw. The spatial orientations and positions of the markers were recorded every 100 cycles at maximum and minimum loads, and micromotions were defined as the difference between these two measurements. Measurement error (ζ_w) of total rotations was 0.068° (Basso et al., 2014; Bland and Altman, 1996). Fig. 3 shows the average (95% CI) micromotions based on 100 measurements for each femur.

Load distribution was evaluated by exploring cortical bone deformations. Two pre-wired strain-gauge rosettes, composed of three strain gauges angled at 45° with respect to one another were used (Tokyo Sokki Kenkyujo Co. Ltd, Tokyo, Japan). The strain-gauge rosette fixation was performed according to an established procedure (Aamodt et al., 2001). One rosette was attached 10 mm distal to the inferior pin-hole on the lateral cortex, while the other was placed at exactly the same level on the medial cortex, and the rosettes were aligned with the long axis of the diaphysis. The accuracy of the strain measurements was 1%. Outputs from strain gauges and passive load cells were recorded by a measurement amplifier (UPM 100; HBM, Darmstadt, Germany).

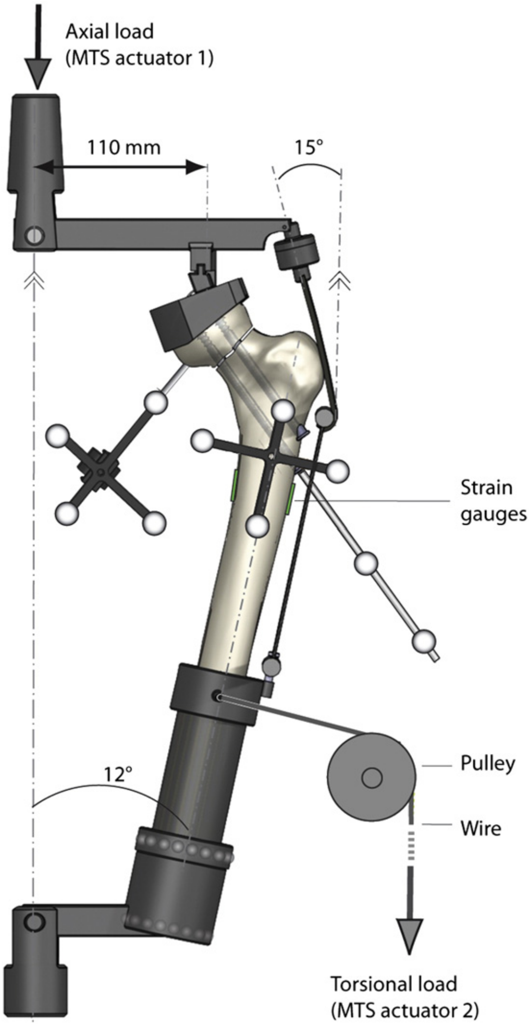

Fig. 2. The hip jig.

The principal strains on the lateral and medial aspects of the proximal diaphysis were calculated during data acquisition. Strain measurements were presented as the average value of three cycles recorded at maximum load.

The total micromotion of the head fragment was decomposed into rotations about the x-axis (valgus–varus), y-axis (antegrade–retrograde),

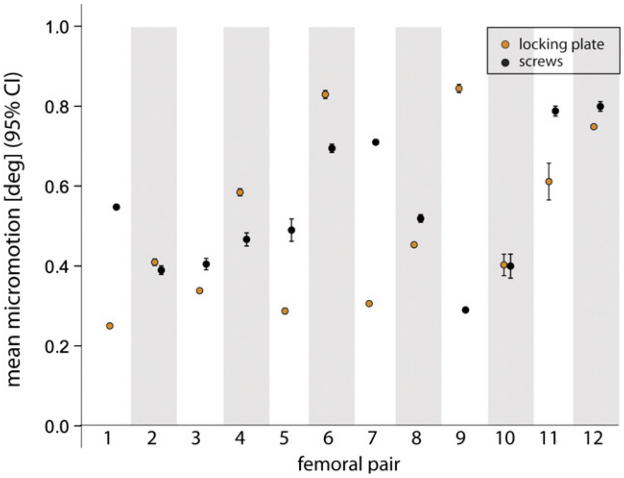

Fig. 3. Accuracy of 100 repeated measurements presented as average rotational micromotion (95% CI).