Clinical Biomechanics 26 (2011) 141–146

Contents lists available at ScienceDirect

Clinical Biomechanics

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

Side plate fixation vs. intramedullary nailing in an unstable medial femoral neck fracture model: A comparative biomechanical study

G. Röderer, S. Moll, F. Gebhard, L. Claes [1], G. Krischak *

Ulm University, Department of Orthopaedic Trauma, Steinhoevelstrasse 9, 89075 Ulm, Germany

ARTICLE INFO

Article history:
Received 5 May 2010
Accepted 27 September 2010

Keywords:
Femoral neck
Fracture
Blade

ABSTRACT

Background: The objective of this study was to investigate primary stability of the proximal femoral nailing antirotation for the indication of unstable medial femoral neck fractures. The device was compared to the dynamic hip screw blade, which is a "gold standard" in the treatment of proximal femoral fractures.
Methods: Six pairs of human cadaver femurs were tested in a cyclic loading model with loads up to 200 N, 400 N, 600 N, 800 N, and 1000 N, respectively. Iliotibial tract was simulated by a chain that applied forces on the greater trochanter during loading. *In vitro* combined axial and bending loads were applied. Angular displacements during loading were recorded in all directions, and loads to failure were recorded.
Findings: For the cyclic loading test no statistically significant differences between the two groups could be detected. Specimens fixed with the dynamic hip screw blade showed higher displacements in the varus direction at 400 N and 600 N, in the external rotation at 200 N, 400 N and 600 N, and in the anterior direction at 400 N. Load to failure revealed no statistical difference between the two implants.
Interpretation: The proximal femoral nailing antirotation achieves primary stability comparable to the dynamic hip screw blade. The proximal femoral nailing antirotation combines the biomechanical favorable concept of intramedullary fixation with a minimally invasive surgical technique, which theoretically may be advantageous in clinical use. Further biomechanical studies are required to clarify to what extent the results of the present study can be transferred to the clinical situation.

1. Introduction

Femoral neck fractures are typical injuries of elderly patients frequently associated with osteoporosis (Melton et al., 1982; Boyce and Vessey, 1985). Due to the aging population the incidence continuously increases, i.e. 14% of all fractures in the United States in 2005 were related to the hip and caused 72% of total costs for fracture treatment (Burge et al., 2007). The dynamic hip screw (DHS) is one of today's preferred methods for the internal fixation of femoral neck fractures yielding success rates of over 95% (Bonnaire et al., 1995; Sommers et al., 2004). However, the presence of severe osteoporosis can considerably increase complication rates due cut out of the hip screw in the femoral head with consecutive varus collapse (Weil et al., 2008). This typical complication of geriatric i.e. osteoporotic proximal femoral fractures is directly related to local bone mineral density (BMD) (von der Linden et al., 2006; Stoffel et al., 2008). Helical-shaped femoral neck blades have been developed to address this problem by improving implant anchorage and increasing cut-out resistance in a weak bone stock (Lenich et al., 2006; Strauss et al., 2006; Gardner et al., 2007).

The DHS-blade (Synthes Inc., Bettlach, Switzerland) combines the well-established side plate concept of the traditional DHS with a helical-shaped femoral neck blade design. Superior *in vitro* implant anchorage in an osteoporotic bone stock compared to the traditional DHS has been shown before (Windolf et al., 2009a). The concept of helical-shaped femoral neck blades is also applied in nailing systems, among which the proximal femur nailing antirotation (PFNA, Synthes Inc., Bettlach, Switzerland) is a wide spread standard in the treatment of unstable per- or intertrochanteric femoral fractures (Penzkofer et al., 2009). This implant combines the biomechanically favorable characteristics of an intramedullary nail with a minimally invasive surgical technique (Mahomed et al., 1994). However, it is not known whether the PFNA is a suitable implant for the treatment of unstable medial femoral neck fractures. In the present study, the DHS-blade and the PFNA were compared in an unstable medial femoral neck fracture model. The purpose was to investigate if there are differences in the primary stability of the two devices in this specific type of fracture which may be of relevance for the clinical situation.

---

* Corresponding author.
E-mail address: goetz.roederer@uniklinik-ulm.de (G. Krischak).
[1] Ulm University, Institute of Orthopaedic Research and Biomechanics, Helmholtzstrasse 14, 89081 Ulm, Germany

0268-0033/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.clinbiomech.2010.09.020

2. Methods

2.1. Specimens

After consent from the local ethics committee board had been obtained (103/08, Ethics Committee Board, Ulm University), 6 pairs ($n = 12$ femurs) of fresh-frozen cadaveric bones were harvested (Southeast Tissue Alliance Inc, Florida, USA). All specimens were of Caucasian ethnicity (4 females and 2 males). The age of the donors ranged between 69 and 87 years with a mean age of 78.8 (SD 6.9 years). For each specimen anthropometric measurements of the total length of the femoral neck (the linear distance between the base of the greater trochanter and the apex of the femoral head), the femoral neck and head diameters, and the neck angle to the shaft were performed (Kukla et al., 2001; Krischak et al., 2007). Radiographs of each bone were taken to ensure the absence of deformity, prior fracture and severe arthritis including cysts using high resolution X-ray (Faxitron 43805N, Hewlett-Packard, Palo Alto, USA) with 45 kV and an exposure time of 5 min.

2.2. Bone mineral density

Evaluation of bone mineral density (BMD) of each femoral head was performed using a peripheral quantitative computed tomography (pQCT) scanner (XCT 960, Stratec, Pforzheim, Germany). First, the whole specimen was scanned and then BMD was evaluated at the centre of the femoral head (sagittal plane in a 45° angle to the femoral shaft) along three parallel sections with a 1-mm distance to each other (Fig. 1). The square region of interest was positioned over the cross-sectional area of the bone slice in that way only the cancellous bone was measured. The mean of the three measurements was calculated. CT scans had a slice thickness of 1 mm, an in-plane pixel size of 0.590 mm, and a matrix size of 128×128 pixels. After every 50 scans, the calibration of the scanner was controlled with a hydroxyapatite phantom of known density (262.5 mg/cm^3). Specimens were then stored at −20 °C until preparation and osteotomy were performed.

2.3. Preparation and osteotomy

Before preparation, specimens were stored overnight at 4 °C. All soft tissues were stripped off the bones. To ensure proper fixation and initial orientation of the fracture fragments the implants were mounted to the unfractured specimens. After removal of the devices the osteotomy was performed as described earlier (Windolf et al., 2009a). The bones were clamped in a cutting template, and an oscillating hand saw was used. The femoral neck osteotomy was cut in a 20° angle to the femoral shaft axis. To simulate posteromedial comminution, wedge osteotomies were performed. First, a 15° posterior wedge was removed, and then a 30° medial wedge including 50% of the femoral neck diameter (Fig. 1).

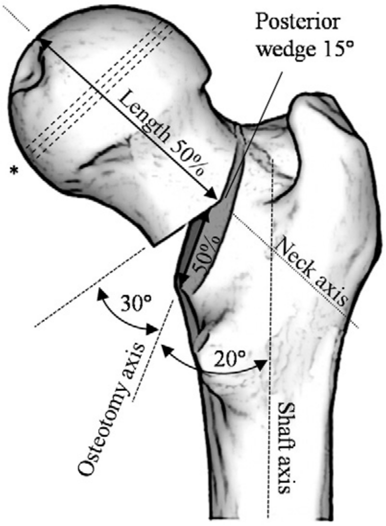

Fig. 1. Osteotomy model of unstable medial femoral neck fracture (posterior view) as proposed by Windolf et al. (2009a). Posterior and medial wedges have been removed to simulate comminution. *Position of the three parallel BMD sections.

2.4. Surgical technique

The surgical techniques were performed according to the manufacturers' manuals. Fixation with either the 135° DHS-blade (dynamic hip screw, Synthes, Switzerland) or the PFNA (proximal femoral nail antirotation, Synthes, Switzerland) of 130° angulation was randomized within one respective pair of bones (Fig. 2). For the purpose of minimally invasive placement and standardization, the DHS-blade was implanted using the plate mounting system, and the PFNA using the manufacturer's aiming device. During insertion of the DHS-blade the femoral head was fixed with a K-wire and by hand to prevent it from rotation. The DHS side plate was fixed to the bone with 4.5 mm cortical screws, and the blade was locked against rotation of the head with a 1.5 N m torque limiting screw driver. After completion of the procedures radiographs were taken to ensure the correct placement of the implants. The blade of both implants had to reach the subchondral layer to obtain a tip–apex distance of 10 mm (Baumgaertner et al., 1995). Finally, specimens were shortened at the shaft to a total length of 19 cm, potted in a custom made metal cylinder with polymethylmethacrylate (Technovit, Heraeus Kulzer GmbH, Wehrheim, Germany) and stored at −20 °C until mechanical testing.

2.5. Mechanical testing

Specimens were again stored at 4 °C overnight and then at room temperature for at least 3 h before testing. The bones were mounted to a material testing machine (TMTC-FR 010 TH, Zwick, Ulm, Germany) in a 6° valgus position (Fig. 3). Femurs were loaded as described before (Krischak et al., 2007). The axial load was applied via a ball-bearing socket to allow horizontal sliding during loading and deformation of the specimen. A metal chain was attached to the fixture lateral and superior to the femoral head in a position simulating the origin of the muscle group on the ilium. The chain passed over the greater trochanter and continued distally parallel to the shaft, corresponding to the location where the iliotibial tract is inserted at the distal femur (Krischak et al., 2007). An ultrasound based three-dimensional motion analysis system (CMS 70 P, Zebris, Isny, Germany) was mounted to the specimens. The measuring principle is based on transmission time measurement of ultrasonic pulses and allows the registration of movements in all degrees of freedom with an accuracy of 0.1°. The sensor array consisted of an ultrasound transmitter and a receiver. Both sensors were mounted on a line that started at the centre of the diameter of the femoral head and crossed the middle of the femoral neck. The proximal sensor was fastened to the centre of the femoral head, and the distal to the proximal shaft. Both sensors were oriented parallel to the osteotomy in all planes. Measurements were taken from angular displacements along the x-axis (varus–valgus displacement), y-axis (rotational displacement), and z-axis (anterior–posterior displacement). The data was recorded by the manufacturer's software (WinBioMechanics, version 0.1.2, Zebris, Isny, Germany) during testing.

Before starting the measurements the specimens were preloaded to 50 N to obtain full contact of the fragments when displacement was recorded. Then the specimens were cycled under displacement control for three loadings up to 200 N at 10 mm/min, with the angular displacements from the third loading cycle used for