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Is there a benefit of proximal locking screws in osteoporotic distal radius fractures? – A biomechanical study

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ABSTRACT

Introduction: The distal radial fracture is a common fracture and frequently seen in geriatric patients. During the last years, volar plating has become a popular treatment option. While the application of locking screws at the distal fragment is widely accepted, there is no evidence for their use at the radial shaft.
Materials and methods: In six osteoporotic pairs of matched human cadaver radii an extra-articular model creating an AO 23-A2.1 fracture was employed. Osteosynthesis were performed using the APTUS 2.5 Adaptive TriLock Distal Radius System (Medartis AG) with locking (LS) or non-locking screws (NLS) for proximal fixation. Biomechanical testing was performed in a staircase fashion: starting with 50 cycles at 200 N, the load was continuously increased by 50 N every 80 cycles up to a maximum force of 400 N. Finally, load to failure was analyzed with failure defined as sudden loss of force measured (20%) or major deformation of the radii (10 mm).
Results: At 200 N, 250 N, 300 N, 400 N and load to failure, the NLS group showed a higher degree of elastic modulus. In contrast, the LS group showed higher elastic modulus at 350 N. Maximum force was higher in the LS group without reaching statistical significance. Reasons for loss of fixation were longitudinal shaft fractures, horizontal peri-implant fractures and distal cutting out. No difference was seen between the two groups concerning the development of the above mentioned complications.
Conclusion: Our study did not show biomechanical superiority for distal radius fracture fixation by using locking screws in the proximal holes in an osteoporotic cadaver study. At load to failure, longitudinal shaft fractures and peri-implant fractures seemed to be a more relevant problem rather than failure of the proximal fixation.

Introduction

The distal radial fracture is a common fracture in adult patients [1,2]. The ratio of geriatric patients increases with age due to a decrease in bone density and mineralisation based on osteoporotic changes [3,4]. To restore optimal function of the wrist [5] and to avoid prolonged immobilization [6] operative treatment with volar locking plate systems is nowadays more frequently used in geriatric patients [7]. Initial biomechanical stability is substantially influenced by the number and the design of inserted screws [8]. While the use of locking screws in the epiphyseal fragment has been shown to prevent secondary loss of reduction their role in the proximal fragment remains unclear. In addition, the number of applied locking screws determines the cost effectiveness in the operative treatment of distal radius fractures with volar locking plates [9]. To date, there is no study available investigating the benefit of locking screws (LS) as compared to non-locking screws (NLS) at the proximal fragment in volar plating of distal radial fractures. The goal of the present study was to evaluate the effect of proximal locking screws on the initial stability of distal radius fractures.

Materials and methods

Ethical approval

All donors gave full written consent and confirmed a donation of their own free will for the use of their body for research purposes. Our study received ethical approval by the local ethics committee (file number 12/15).

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Specimen preparation

Seven pairs of matched adult human cadaver radii donated from the local Institute of Anatomy and Cell Biology were used for the present study. Human cadavers were fixated with 15 l of an ethanol solution (96% ethanol, 2% formaldehyde) and were stored for one year before use for anatomic teaching purposes.

Radii were prepared and adjacent soft tissue was removed. Bones were then wrapped in moist towels containing the above mentioned ethanol solution and stored at −30 °C to avoid drying out. One radius and the corresponding contralateral bone were excluded due to premortem plate osteosynthesis of a diaphyseal radius fracture.

Patients

The specimens originated from 2 male and 4 female adults with an average age of 81.2 years (range 66–93 years). The bone mineral density was evaluated by peripheral quantitative computed tomography (pQCT) using a Stratec XCT Research SA instrument (Stratec Medizintechnik GmbH, Pforzheim, Germany). Measurements were performed at the distal radial region two times at each specimen and averages were calculated.

Before biomechanical testing, random assignment of the stabilization method resulted in insertion of LS in right sided and NLS in left sided radii.

The bones were then tested for osseous integrity by performing a CT scan with a 128-slice scanner including 3D reconstructions (Somatom Volume Zoom, Siemens Medical Solutions, Erlangen, Germany). An experienced radiologic consultant examined all scans.

Implant and fracture model

The APTUS 2.5 Adaptive TriLock Distal Radius System (Medartis AG, Basel, Switzerland) was used for stabilization. An extra-articular fracture model as described by Windolf et al. was used, creating an AO 23-A2.1 fracture by removing a dorsal wedge 10 mm proximal to the articular surface with a volar cortical base remaining [10]. In all distal holes, locking screws were inserted using the designated twist drills, depth gauge and screwdriver. At the proximal side of the fracture, three LS were inserted in right sided radii and three NLS were inserted in left sided radii. The fracture model and the osteosynthesis were performed by an experienced orthopaedic trauma surgeon. After plating a second CT scan with 3D reconstructions was performed to document correct positioning of the implant.

Embedding and final preparation

The radii were shortened at the proximal end 14 cm proximal of the wrist joint line and embedded in Technovit 3040© (Heraeus, Wehrheim, Germany) blocks of 2 cm thickness at the proximal end in anatomical, straight axial position and dried at room temperature for 24 h. At the distal part, an individual jig made of Technovit 3040© was formed for each radius in order to apply continuous and equal pressure on each part of the articular side. These jigs were then placed in a custom plastic cylinder and connected to the testing machine.

Biomechanical testing protocol

For mechanical testing a hydraulic Instron 5566© testing machine (Instron Corp., Darmstadt, Germany) was used. All specimens were fixed in the testing machine with a compensator allowing horizontal shifting.

In accordance with the method published by Windolf et al., each radius was subject to a preload of 50 N to stabilize the specimens and ensure optimal positioning in the testing machine [10]. The test sequence started with 50 cycles at 1 Hz with 200 N, simulating a functional post-operative treatment with low axial compression forces. Mechanical load was continuously raised in steps of 50 N every 80 cycles until the maximum force of 400 N was reached. Afterwards, a load to failure analysis was performed with a speed of 80 N/min, applying increasing pressure on each radius until failure of the osteosynthesis occurred, defined as a sudden loss of force measured of 20% or major deformation of the radii of 10 mm. The data were collected at 100 ms intervals using the Instron Bluehill 2 software (Instron Corp., Darmstadt, Germany).

Following biomechanical testing, radii were CT-scanned, characteristics of peri-implant fractures identified and complications documented.

Statistics

Prior to biomechanical testing an a priori power analysis was performed. A sample size calculation on the primary outcome based on the results of Weninger et al. showed that 8 specimen, 4 in each group, are needed to detect a biomechanically relevant difference with 80% power and a significance level of 5% [8].

All results were electronically saved and analyzed using IBM SPSS statistics 22 (Statistical Package for the Social Science, IBM Cooperation, Armonk, NY, USA). Values were tested for standard distribution using the Kolmogorov–Smirnov test. For parameters showing a standard distribution further evaluation was performed with the analysis of variances (ANOVA). For parameters that differed significantly from standard distribution the Mann–Whitney-*U*-test was used. A p-value < 0.05 was considered statistically significant.

Results

Pre-test results

None of the radii tested showed osseous lesions prior to testing. All bones were highly osteoporotic presenting a *T*-Score of -7.3 ± 1.8 for the right radii and -6.5 ± 1.1 for the left radii without statistically significant differences between both groups ($p = 0.366$).

After performing the fracture model and osteosynthetic stabilization, no accidental fractures were observed in the CT scans.

Results of biomechanical testing

The elastic modulus of the fracture models is shown in Table 1. During the first three cycles of loading from 200 N till 300 N as well as at 400 N and load to failure, the NLS group showed a higher degree of elastic modulus. In contrast, the LS group showed higher elastic modulus at 350 N. Maximum force was increased in the LS group. However, these differences did not reach statistical significance.

Mechanism of biomechanical failure

No differences were detected between the two groups concerning implant failure ($p = 0.290$). The aetiology of the loss of fixation was verified by CT scans and is shown in Table 2. The specimens showed three mechanisms resulting in biomechanical failure: Longitudinal shaft fractures that included proximal screws, horizontal peri-implant fractures that did not include the proximal screws and cutting out of the distal locking screws (Fig. 1a–c).

Discussion

Distal radius fractures represent an increasingly relevant injury in the geriatric population with approximately 32% of all geriatric fractures [11]. Considering the expected demographic changes in

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