PRIMARY STABILITY TESTING OF PROXOMAL HUMERAL PLATE CONFIGURATIONS BY MECHANICAL SIMULATION OF THE ROTATOR CUFF

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SUMMARY

Missing medial support in proximal humeral fractures can result in varus malalignment and cut through of the proximal screws when using locking plates. The objective of the present study was to evaluate the influence of an additional intramedullar bone graft on the biomechanical characteristics of proximal humeral fractures stabilized by locking plate fixation.

In 20 Synbone® humeri, standardized proximal fractures were created and fixed conventionally (n=10) or using an additional fibula graft inserted intramedullarily (n=10). In an experimental setup with a simulated rotator cuff, active abduction from 45° to 60° was performed for 400 cycles. Fragment gap distance was measured by an electromagnetic sensor, where the fragment migration and residual plastic deformation were determined.

Locking plate fixation with additional intramedullar fibula graft resulted two times lower plastic deformation ($p=0.02$) and two times lower fragment migration. Screw pullout, cut through or implant failure were not observed.

Intramedullar bone graft for medial support in locking plate fixation of proximal humeral fractures *in vitro* increases overall stiffness of the bone-implant construct and reduces migration of the head fragment. This technique might provide a useful alternative in surgical treatment. Experimental rotator cuff simulation by applying tensional muscle forces was reproducibly performed.

INTRODUCTION

The clinical result after fracture treatment by proximal humeral osteosynthesis plates is not satisfactory. Almost one third of all surgical interventions show malintegration of the bone, fragment displacement, bone resorption or screw or plate breakage (Figure 1). Migration and resorption of bone fragments lead to a complete failure of the reconstruction. In particular, clinically detected (secondary) fragment displacement by forward tilting of the humeral head is shown by x-ray and CT scans [1]. It is strongly assumed that this forward tilting is applied by muscular tension, because the tendon insertions of the shoulder abductors are located on the fragments. As a consequence, reduced mobility and pain of the patient needs a revision surgery.

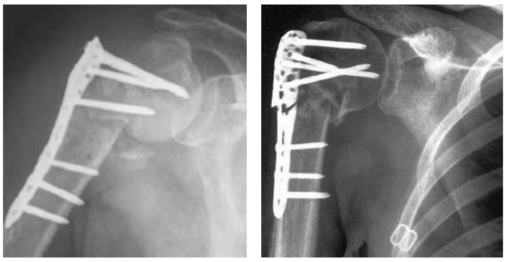

Figure 1: Tilting of the humeral head (left) and failure of the osteosynthesis plate (right).

The improvement of the stability by medial bone support, analysed by a physiological loading scenario, is therefore in the focus of present investigation.

METHODS

Implants and bone fracture model

Conventional surgery by using the Philos plate (Synthes Inc.) is compared to a reinforced system by using am additional fibular bone graft (Figure 2). This graft is fixed by the screws in the long bone of the humerus, and supports the humeral head proximally. Artificial humeral bone samples made of polyurethane foam were used for the tests (Synbone AG, Malans, Switzerland) [2]. Fracture type AO-11-A3 according to the AO fracture classification was performed.

Artificial tendons made of a 100 % polyester webbing (Tobby GmbH, Austria) were used to introduce the muscle forces to the proximal humerus at the corresponding insertions. Tendon-to-bone fixation was realised with instant adhesive (Loctite 406, Henkel & Cie. AG, Switzerland).

Figure 2: Conventional (left) vs. additional fibular bone graft for medial bone support.

Experimental test setup

The design of the shoulder testing device comprises a fixed scapula and a moving humerus which is activated by muscular tension according to [3]. Tensile forces of the supraspinatus and deltoideus tendons were applied to the humerus by universal testing machine (UPM 1475, Zwick GmbH, Germany, Figure 3).

- Cyclic muscular tension from 50 N to 125 N is applied by the supraspinatus and deltoideus muscles each.
- Infraspinatus/teres minor and the two segments of the subscapularis are statically loaded with 25 N each.
- An arm weight of 3.5 kg is introduced at the centre of gravity of the upper arm, located at ¾ of humeral length.
- Failure criterion: Collapse of the fragment gap or instability of the humerus (tilting out of scapular plane).

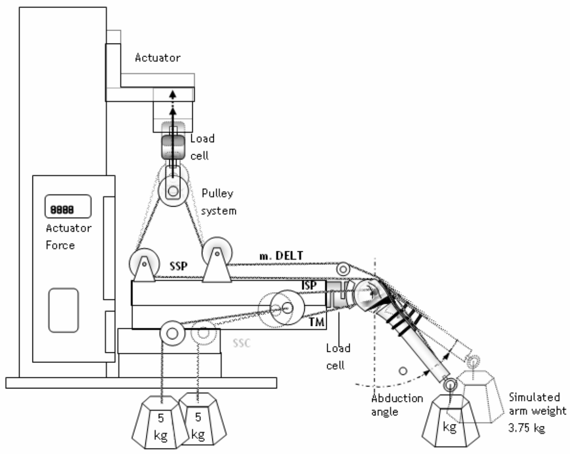

Figure 3: Mechanical shoulder test setup simulating the rotator cuff muscles which apply humeral abduction movement.

Measured parameters

Residual fragment gap deformation Δd [mm]:

The difference in the gap distance before and after loading in the unloaded condition (plastic deformation) was determined.

Fragment migration [mm]:

The change of the fragment gap distance during cyclic testing in the loaded condition represents the fragment migration.

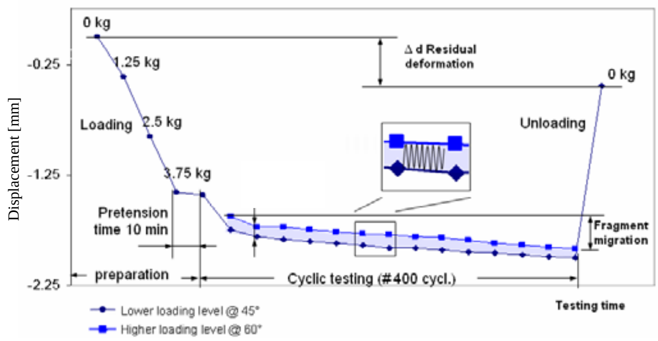

Figure 4: Testing procedure and evaluated parameters during cyclic testing.

RESULTS AND DISCUSSION

The residual (remaining) deformation for the conventional design is two times higher than the fibula design (p=0.02). The conventional design shows approx. two times higher fragment migration over the 400 loading cycles' period.

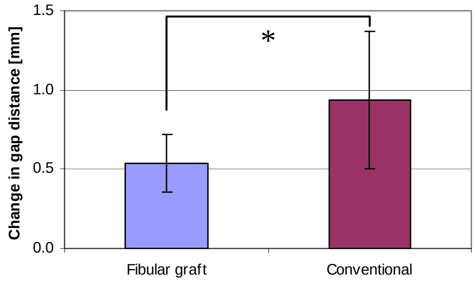

Figure 5: Residual deformation [mm] after testing the fibular design in comparison to the conventional design (p=0.02).

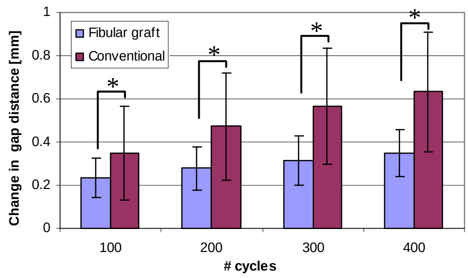

Figure 6: Fragment migration in [mm] at 100, 200, 300 and 400 loading cycles (p<0.03).

By applying force controlled muscular tension, the abduction angle resulted in of 45° for the lower force level and 60° for the upper force which is in correspondence with literature [4].

CONCLUSIONS

The intramedullary, medial bone support of a fibular graft in the proximal humerus increases the overall stiffness of the fracture reconstruction and reduces the migration of the humeral head fragment.

The test setup applies reproducible, muscular tension forces over the whole loading sequence.

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