Introduction: Angle stable plate systems have become a well-established surgical treatment of displaced proximal humeral fractures. An anatomical reduction and stable retention can often not be achieved in the elderly patient with osteoporotic bone structure. Studies about the complication-rate after angle stable plate fixations have revealed secondary displacement and angularly head deformities in 10 and 17% [1]. Therefore, an additional and already clinically widely-used fiber-cerclage which attaches the three main parts of the rotator cuff additively to the plate has been postulated to reduce displacement forces of the inserting rotator cuff.

The hypothesis of the present biomechanical study was that additive fiber-cerclage in 3-part proximal humeral fractures stabilized by angle stable plate systems reduces secondary displacement. This is the first study on this topic.

Materials and Methods: An unstable 3-part fracture model of the humeral head was developed, by which the insertions of rotator cuff were preserved in paired human shoulder specimens (n=24) harvested from median 77(66-85) years old female donors.

All left-side specimens obtained an additive fiber-cerclage of the M. supraspinatus (SSP), M. infraspinatus+M. teres minor (ISP+TM) and M. subscapularis (SSC) after an angle stable plate fixation using two implants which differed in head screw orientation: Humeral Suture Plate (HSP®), Arthrex, Karlsfeld, Germany, v-shaped-, and Proximal Humerus Internal Locking System (PHILOS®), Synthes, Bettlach, Switzerland, cross-shaped screw orientation. Four different clinically relevant load cases were simulated: 1) axial load at 0° and 2) 60° glenohumeral abduction; 3) internal and 4) external rotation at 0° abduction. During loading, physiological rotator cuff muscle forces were simulated by means of force-controlled hydraulic cylinders, while a robot assisted shoulder simulator simulated axial loading (120 N) in modes 1 and 2, and resisted rotation in modes 3 and 4 (Fig. 1). Interfragmentary motion was observed in real-time between the greater tuberosity and the head fragment (gap I), as well as between the head fragment and the shaft (gap II). Changes in rotator cuff tension due to fiber-cerclage were analyzed by an optical system.

Results: In all loading situations matched pair-analysis showed no significant differences between the groups with and without additive fiber-cerclage in 3D-total interfragmentary motions in gap I or II (Fig. 2).

Viewed seperately, in mode 1 and 2 mostly affected vertical direction motions, interfragmentary motions did not differ, too. No significant differences were found between the two different implants (Tab. 1). Capacity of SSC, SSP and ISP+TM to bear strain, was not significantly impaired by an additive fiber-cerclage in physiological pretension of the rotator cuff.

Discussion: For the first time, 3-part fracture model created in this study involves the complex anatomy of the humeral head by preserving and physiologically loading of the intact rotator cuff. It imitates the most frequent fracture type in the elderly [1]. Previously, biomechanical studies mainly used 2-part models [2], rarely described 3-part models were synthetic or not unstable in the fracture line between greater tuberosity and humeral head [3].

The Hypothesis that an additive fiber-cerclage reduces secondary displacement in osteoporotic 3-part proximal humeral fractures stabilized by angle stable plates cannot be confirmed. A v- or cross-shaped head screw orientation did not result in significantly different interfragmentary motions in all load cases when head screws were aimed to the regions of maximal bone density[4].

Fiber-cerclages may be useful in multiple fractured tuberosities to appropriate and retain small fragments; in 4-part fractures it could stabilize lesser tuberosity fragment which received no stability by the plate.


Meant±SD[mm]. Four load cases: axial load at 0° (al 0°), and at 60° (al 60°) glenohumeral abduction; internal- (IRO), external (ARO) rotation at 0° abduction. I-gap I, II-gap II.

3D motions in gap I and II; v- (HSP®) and cross-shaped (PHILOS®) head screw orientation.

Changes in gap I and II-widths with and without fiber-cerclages in 1) axial load at 0° (al 0°), and 2) at 60° (al 60°) glenohumeral abduction (al 60°); 3) internal (IRO 0°) and 4) external rotation in 0° abduction (ARO 0°).