

Fixation Strength in the Treatment of Proximal Humeral Fractures A Biomechanical Study

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Abstract

A recently designed test method was applied to evaluate the fixation strength of different plate types for treating proximal humerus fractures. The test method simulated clinically observed loading and failure modes well. Among the implants tested, the angularly constrained AxSOS locking plating system showed the highest fixation capabilities.

1 Introduction and Purpose

Fractures of the proximal humerus are a frequent injury especially among elderly people [PALVANEN 06]. The treatment of these fractures is becoming more and more difficult with the increasing age and number of patients and the increasing number of bone fragments resulting from such an injury. In cases with comorbidities, such as osteoporosis, arthritis or bone degeneration, treatment can be very challenging. Current operative treatments for proximal humerus fractures include the use of plating systems. However, the fixation capabilities of these devices are limited and failure of the osteosynthesis is a common problem. Typical failure modes are the loss of fixation between implant and head fragments which usually leads to re-operation [KETTLER 05, LIEV 2000, SCHOEPP 2008 & VOIGT 2006]. The aim of this study [OBST 08] was to compare the fixation capabilities of different plate types utilising a recently designed and established test method [Trapp 05/1]. In addition, the failure modes should be analysed and compared amongst the plate types tested.

2 Materials and Methods

2.1 Test set-up

Test set up and test method was in accordance with a previously designed study [Trapp 05/1]. A three-part fracture in osteoporotic bone was simulated as seen in Figure 1.

To increase the reproducibility of the biomechanical tests, artificial bone substitutes were used (see Figure 1) as their inter-sample variation is small. PUR-Foams [PUREN 05] with different densities for tubercle and humeral head were used to match the mechanical properties of the bone in each region as closely as possible.

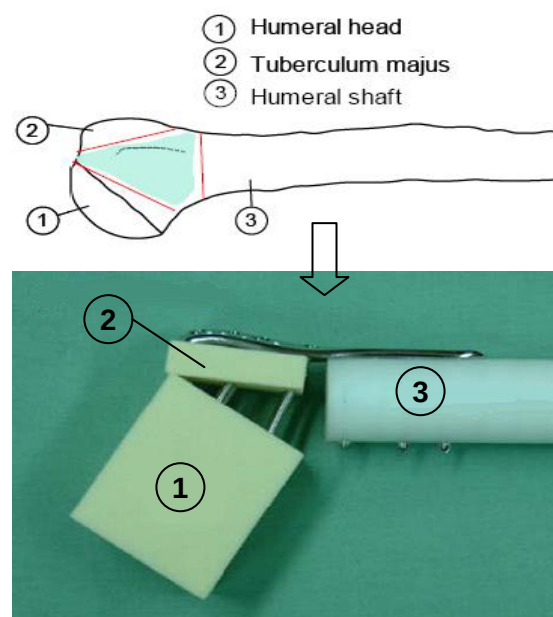


Figure 1: Simulated 3-part fracture of a human humerus with artificial model for testing purposes. The centre gap simulates a large osteoporotic defect zone.

Although many muscles are involved in arm movement, in the present study these were simplified and reduced to a two-dimensional model. The main forces are generated by the deltoid muscle and the

supraspinatus muscles. An external sinusoidally varying load was applied at the distal end of the humerus simulating a 60° abduction as it is typical in physiotherapy after fracture fixation. Loads according to the findings of Bergmann [BERGMANN 05] and van der Helm [VANDERHELM 94] were applied. The centre of rotation is located in the centre of the humeral head (see Figure 2).

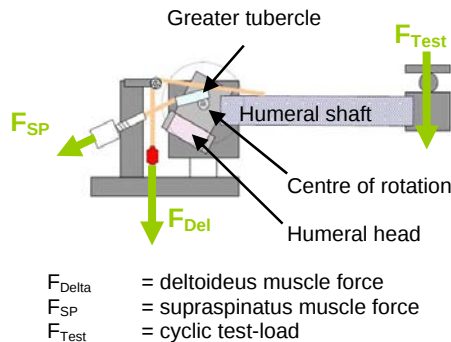


Figure 2: Schematic illustration of the test set up

The load upon the proximal humerus (F_{Test}) was applied according to a so-called “staircase method” whereby the load magnitude was increased every 500 cycles by 5 N (see Figure 3) until the end of the test.

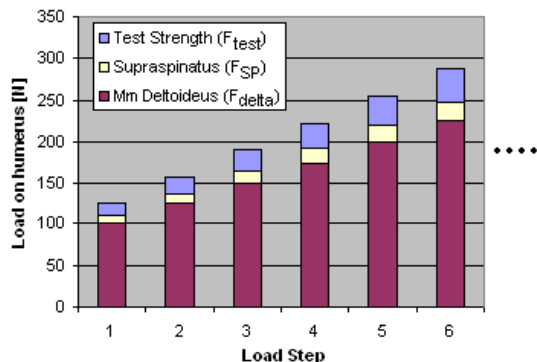


Figure 3: Load-increasing staircase method

The test ended when gross failure occurred (e.g. proximal break-out of the screws into the joint-gap).

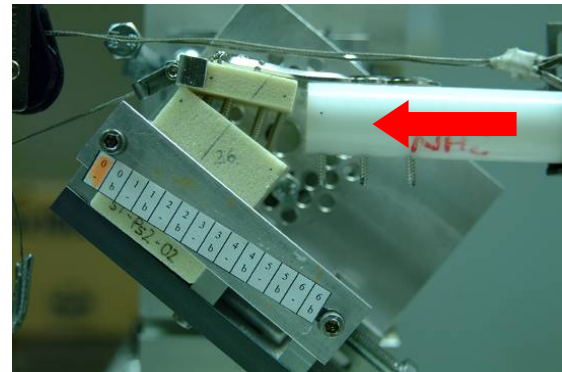


Figure 4: Proximal movement of implant and humeral shaft towards head (red arrow)

In order to enable subsequent intra-implant comparison of fixation strength the following consistent failure criteria was set: a proximal translational movement of implant and humeral shaft towards the head of 4mm. In contrast to previous work [TRAPP 06] this threshold value was reduced from 6mm to 4mm in order to enable comparison of those implants not at all reaching 6mm displacement until end of test. For AxSOS the load stage for reaching this threshold value was partially extrapolated.

2.2 Implants

Table 1 lists the implants compared within the study and these are illustrated in Figure 5 and Figure 6. To obtain statistically relevant results, 6 implants of each type were tested.

Type	Designation	Manufacturer	Item No.
Locking plates	AxSOS	Stryker	437103
	LCP PHILOS	Synthes	241.903
Conv. Plates	T-Plate	Synthes	240.150

Table 1: List of implants

AxSOS and LCP Philos both represent the angle constraint locking plate technique whilst the T-Plate represents the conventional plating technique.

The implantation of each implant followed the operative technique recommended by the manufacturers.

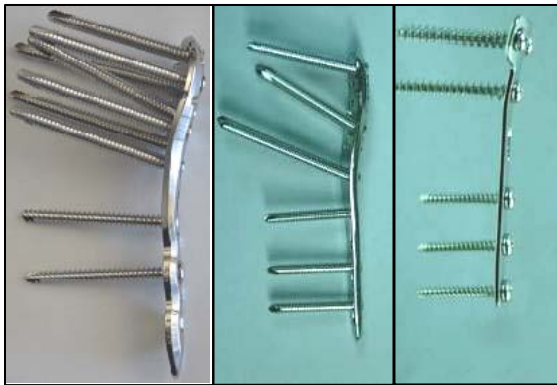


Figure 5: Plate types from left to right: AxSOS (Stryker), LCP PHILOS (Synthes), T-Plate (Synthes).



Figure 6: Proximal locking configuration from left to right: AxSOS (Stryker) with 7 x 4.0mm locking screws, LCP PHILOS (Synthes) with 6 x 3.5mm locking screws, LCP PHILOS locking configuration chosen following [HESSMANN 03] and Synthes operative technique.

3 Results

Except for the AxSOS plates, the consistent failure mode of plate implants was break out of the screws at the proximal side into the joint gap. The failure mode of AxSOS plates was a rupture of the tubercle at the most proximal screw.

Failure loads for all plating systems are shown in Figure 7. The AxSOS plates demonstrated the best fixation characteristics followed by the Synthes PHILOS plate. The conventional T-plate failed at the first load step. Thus the failure loads of the angle constraint plates were significantly higher compared to the T-Plate constructs. A Two-Tailed Student t-test showed a significant difference ($p=0.05$).

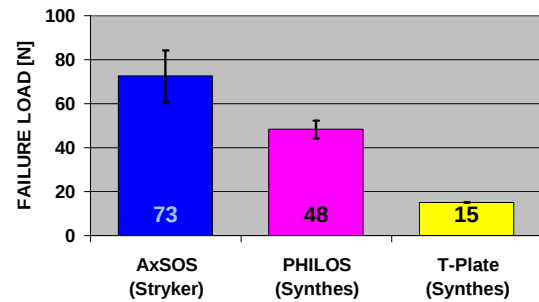


Figure 7: Failure loads for plating systems, including standard deviations

Figure 8 shows the proximal movement of the fixed fractures.

The plating systems tend to allow a movement of the shaft towards the head, since the head fragment inclines towards the humeral shaft ("closing"), cf. Figure 9 and Figure 10.

Clinically the closing of the plate systems may facilitate the perforation of the screws into the humeral joint by spearing through the humeral head.

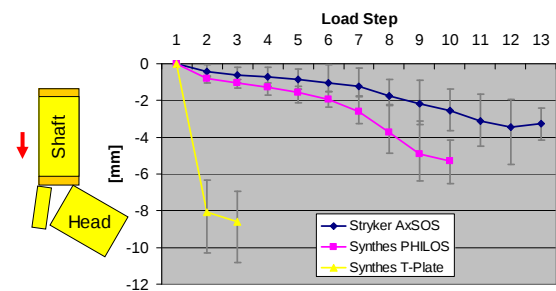


Figure 8: Proximal translation of the shaft towards humeral head in plate fixed fractures

In addition, the elastic deformation (head vs. shaft) observed was smallest for the AxSOS System and largest for the Synthes T-plate. Clinically, such an elastic deformation may lead to delayed unions or even pseudarthrosis [LILL 97].

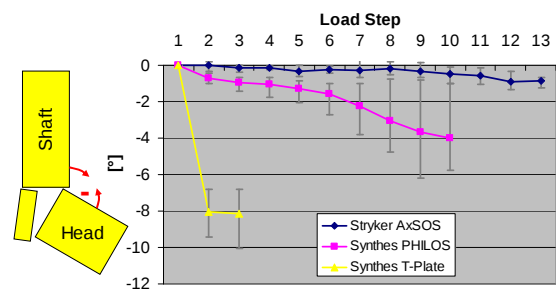


Figure 9: Angle deviation of humeral head and shaft for plate systems

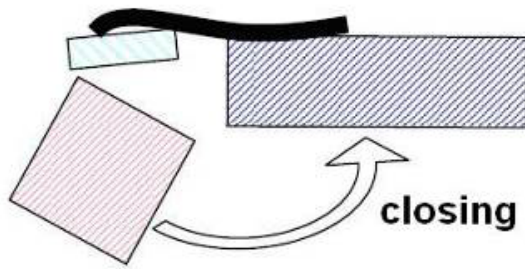


Figure 10: Deformation tendencies of plates

4 Discussion and Conclusion

As previously demonstrated [Trapp 05/1] the test method applied is capable and valid to simulate in-vivo failure modes such as proximal implant translation as well as the spearing of screws into the joint gap, which are clinically well documented [SPECK 96; TRAPP 05/2; KETTLER 05], and to detect differences in fixation strength between different plating systems for proximal humerus fractures.

In this investigation the state-of-the-art angle constraint plating systems showed their biomechanical advantage over the conventional plating system tested. The AxSOS (Stryker) showed the highest fixation strength within the field of tested systems.

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6 Additional Reading

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