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Locking plate fixation of humeral head fractures with a telescoping screw. A comparative biomechanical study versus a standard plate

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ABSTRACT

Objectives: Locking plate fixation of humeral head fractures bares the risk of glenohumeral screw penetration. In order to circumvent this problem it is recommended to insert shorter locking screws having at least a 6 mm distance to the humeral head cortex. This in turn may reduce fixation stability and may lead to early varus displacement. One second frequent failure mechanism is cranial displacement of the greater tubercle. The study evaluates the biomechanical properties of a locking plate employing an additional telescoping screw that may enhance resistance to varus displacement. Screw in screw fixation of the greater tubercle may reduce the rate of cranial displacement.
Methods: In four paired fresh-frozen human cadaver humeri (age > 70 years) a Neer IV/3 fracture was created with a 5 mm osteotomy gap simulating metaphyseal comminution. Limbs were randomly assigned to receive plate fixation with an additional telescoping screw (Humerus Tele Screw: HTS) and on the contralateral limb Philos plate fixation before biomechanical evaluation (MTS-Bionix 858.2). Standard locking screws were placed in both groups 6 mm below the radiological head circumference; the telescoping screw was placed in the subchondral layer. The greater tubercle was fixed with an additional screw in both techniques, in the HTS group the screw was anchored in the sleeve of the telescrew (screw in screw fixation).
Findings: Fixation stability with a mean stiffness of 300.9 ± 28.8 N/mm in the HTS plate group proved to be significantly higher than in the Philos plate group (184.2 ± 23.4 N/mm; $p = 0.006$). The HTS plate also resisted higher loads in terms of fixation failure with loss of reduction at 290 ± 58.6 N in comparison to 205 ± 8.6 N for the Philos plate ($p = 0.2$). Displacement of the greater tubercle occurred in no case of the HTS plate group and in two out of four cases in the Philos plate group.
Interpretation: The HTS plate provides high fixation stability in an in vitro humeral head fracture model and securely prevents displacement of the greater tubercle.

Introduction

Fractures of the proximal humerus are a common injury particularly in the elderly and account for 5% of all fractures and 45% of all humeral fractures.[1,2] Surgical options for treatment are numerous including extra- or intramedullary fixation techniques and hemiarthroplasty.[3–6]

Common mechanisms of failure after open reduction and internal fixation of the proximal humerus in which screw and plate constructs have been used are varus displacement, glenohumeral screw penetration and avascular necrosis.[7,8] By far more frequent than a complete avascular necrosis of the humeral head is the partial necrosis, which comes along with a progredient loss of humeral head volume.[8] Screw tips forwarded in the subchondral area may in cases of shrinking humeral head as well as during the process of subsidence slowly penetrate into the glenohumeral joint. The glenohumeral perforation is one major and specific drawback of angular stable implants, since regular screws may protrude laterally.[9–11]

Screw related complications account for more than 40% of the over all complication rate and up to 50% of the reoperation rate and

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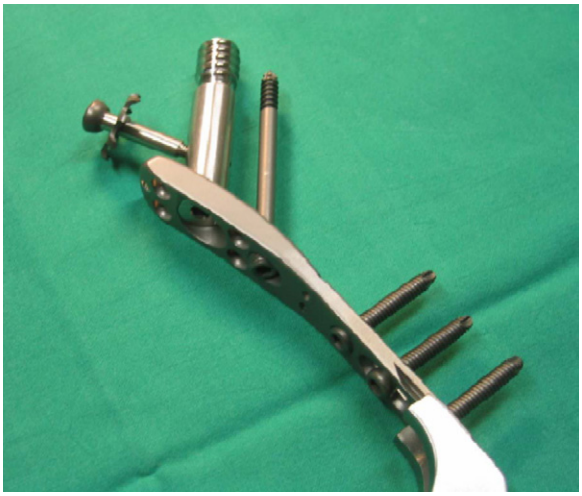

Fig. 1. Example of a HTS plate, mounted on an insertion tool.

it is known that minimal screw overlength can cause severe damage to the glenoid and may enhance retractive capsulitis.[12–14]

It is therefore recommended not to drill through the humerus head cortex and to choose a shorter length of screws. As a consequence, screws may not be securely anchored in the firm subchondral bone and thus primary stability of the whole construct may be reduced.

This unsolved dilemma between prevention of screw perforation and loss of primary stability with the risk of early varus displacement prepared the ground for the development of a DHS-like implant for proximal humerus fractures. In contrast to the DHS screw for the treatment of trochanteric fractures the implant was designed to allow for only minimal subsidence and thus was supplied with additional non-telescoping screws. Furthermore a specially designed screw seating for the fixation of the major tubercle was introduced (Fig. 1).

The objective of the study was to evaluate the biomechanical properties of this new implant in comparison to a locking plate (Philos), especially the fixation stability of a dynamic sliding mechanism (Tele Screw) in the treatment of humeral head fractures.

Materials and methods

Four paired fresh-frozen human cadaver humeri (age > 70 years) stripped of soft tissue were stored at minus 20 °C until tested. A Neer IV/3 fracture was created with a 5 mm osteotomy gap simulating metaphyseal comminution. Transverse osteotomies at the surgical neck were created removing a circular bone segment of 5 mm in width using a handheld thin oscillating saw. Afterwards the osteotomy of the greater tubercle was performed. Symmetry in fracture patterns was visually assured between right and left limb pairs. For each humeral pair, one limb was randomly assigned to receive HTS plate (Fig. 1, M.O.R.E. Medical Solutions, Rostock, Germany) (Fig. 2a and b) fixation and the contralateral limb received fixation with a standard locking plate (Philos plate, Clinical House, Düsseldorf, Germany) (Fig. 2c and d). Adequate reduction and implant position was assured under fluoroscopic control.

Special care was taken to not drill through the contralateral cortex and to use screw lengths that anchor not closer than 6 mm to the cortical circumference of the humeral head in order to prevent screw perforation, similar to a clinical setup. After placement of locking screws an additional telescoping screw was inserted solely in the HTS plate group. The HTS was forwarded in the firm subchondral layer but not closer than 3 mm distant to cortical circumference. The greater tubercle was either fixed with an additional isolated screw anchoring to the cancellous bone of the head fragment (Philos plate), or with an isolated screw firmly fixed in the sleeve of the telescrew (HTS plate).

The distal humeral condyles were removed and the humeral shafts potted with polymethylmethacrylate in steel tubes. During testing at room temperature, all specimens were wrapped in saline-soaked gauze to avoid exsiccation. Specimens were tested with use of a servohydraulic materials testing machine (MTS-Bionix 858.2) and were placed on a XY-table (range ±3 cm) to minimise shear loads. Axial loads were then applied to the superior

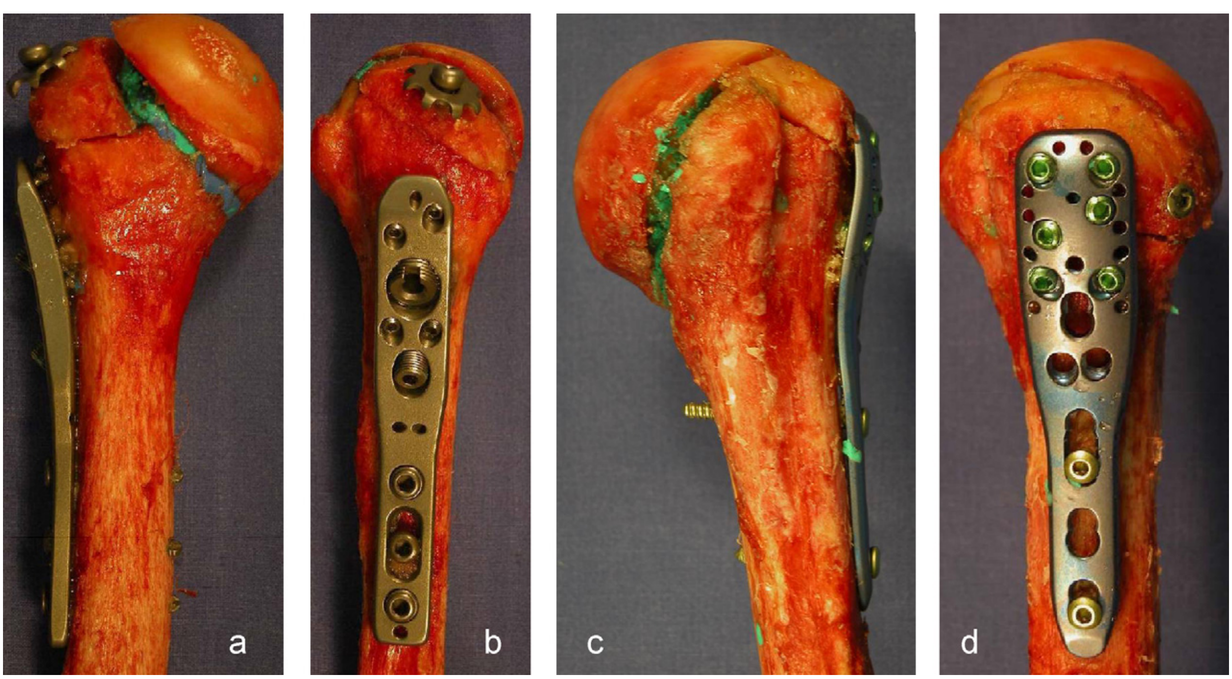

Fig. 2. Photographic image of the humeral head fracture model. Fragments are fixed with HTS plate (a, b) or Philos plate (c, d). The osteotomy gap was filled in both groups with Plasticine® in order to facilitate bony fixation in a standardised manner. Plasticine® was removed prior to biomechanical testing.