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Fixed-angle plate osteosynthesis of the patella – An alternative to tension wiring?

M. Wild [a,*], C. Eichler [b], S. Thelen [a], P. Jungbluth [a], J. Windolf [a], M. Hakimi [a]

[a] Heinrich Heine University Hospital Düsseldorf, Department of Trauma and Hand Surgery, Moorenstrasse 5, D-40225 Düsseldorf, Germany
[b] University of Cologne, Department of Anatomy II, Joseph-Stelzmann Str.9, D-50931 Cologne, Germany

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ABSTRACT

Background: The goal of this study is carry out a biomechanical evaluation of the stability of a bilateral, polyaxial, fixed-angle 2.7 mm plate system specifically designed for use on the patella. The results of this approach are then compared to the two currently most commonly used surgical techniques for patella fractures: modified anterior tension wiring with K-wires and cannulated lag screws with anterior tension wiring.
Methods: A transient biomechanical analysis determining material failure points of all osteosyntheses were conducted on 21 identical left polyurethane foam patellae, which were osteotomized horizontally. Evaluated were load (N), displacement (mm) and run-time (s) as well as elastic modulus (MPa), tensile strength (MPa) and strain at failure (%).
Findings: With a maximum load capacity of 2396 (SD 492) N, the fixed-angle plate proved to be significantly stronger than the cannulated lag screws with anterior tension wiring (1015 (SD 246) N) and the modified anterior tension wiring (625 (SD 84.9) N). The fixed-angle plate displayed significantly greater stiffness and lower fracture gap dehiscence than the other osteosyntheses. Additionally, osteosynthesis deformation was found to be lower for the fixed-angle plate.
Interpretation: A bilateral fixed-angle plate was the most rigid and stable osteosynthesis for horizontal patella fractures with the least amount of fracture gap dehiscence. Further biomechanical trials performed under cycling loading with fresh cadaver specimen should be done to figure out if a fixed-angle plate may be an alternative in the surgical treatment of patella fractures.

1. Introduction

Only 1% of all injuries to the human skeleton are patella fractures. Of this percentage, only approximately one-third require surgical attention (Bostrom, 1972; Lotke and Ecker, 1981). Most fractures occur between the age of 30 and 60 years, and 34% of patella fractures are horizontal fractures (Bostrom, 1972; Brill and Hopf, 1987). Surgical intervention becomes necessary either when the fracture gap exceeds 2–3 mm or in case of joint incongruence (Gosal et al., 2001; Bostrom, 1972). As the patella is an essential component of a fully functional knee joint, every effort needs to be made to preserve it (Sutton et al., 1976; Kaufer, 1971; Watkins et al., 1983). Along with preservation of the majority of the patella, the overall goal underlying surgical treatment is to anatomically reposition the articulating surface while subsequently stabilising it. Reconstruction of extensor function and early mobilization also constitute key objectives in surgical intervention (Catalano et al., 1995; Hung et al., 1985; Benjamin et al., 1987; Levack et al., 1985; Mueller et al., 1992; Torchia and Lewallen, 1996; Weber et al., 1980).

The most widely used treatment for a horizontal patella fracture at present is modified anterior tension wire with or without circumferential wiring (Benjamin et al., 1987; Berg, 1997; Burvant et al., 1994; Carpenter et al., 1997; Curtis, 1990; Lotke and Ecker, 1981; Weber et al., 1980). Despite several technical modifications of the anterior tension wiring, early fracture dislocation occurs in 22–30% of all cases (Smith et al., 1997; Wild et al., 2008). Failure of fixation, K-wire migration, post-operative pain and revision surgery are not uncommon, and long-term study results are suboptimal (Bostman et al., 1981, 1983; Catalano et al., 1995; Gosal et al., 2001; Hung et al., 1985; Levack et al., 1985; Torchia and Lewallen, 1996). Secondary post-operative pain due to skin irritation caused by the K-wires is also a common problem when using modified anterior tension wire (Bostman et al., 1981; Carpenter et al., 1997; Catalano et al., 1995; Hung et al., 1985; Torchia and Lewallen, 1996; Wu et al., 2001). Thus, revision surgery with K-wire removal becomes necessary in up to 65% of cases (Bostrom, 1972; Catalano et al., 1995; Hung et al., 1985; Torchia and Lewallen, 1996).

The development of fixed-angle plates, which are based on the internal fixator concept, has led to an improvement in the biomechanical stability of the plate-bone interface (Egol et al., 2004; Schutz and Sudkamp, 2003). Thanks to this improved stability, it

* Corresponding author.
E-mail address: post@michaelwild.de (M. Wild).

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has been possible to develop even smaller and thinner fixed-angle plates with further enhanced biomechanical properties.

The goal of this study is to biomechanically evaluate the stability of a bilateral, polyaxial, fixed-angle 2.7 mm plate osteosynthesis system specifically designed for use on the patella. The results will then compared to the two currently most commonly used surgical techniques in the case of patella fractures: modified anterior tension wiring with K-wires and cannulated lag screws with anterior tension wiring. We hypothesized, that biomechanical experiments conducted to absolute failure would show the bilateral fixed-angle 2.7 mm plate osteosynthesis to be superior to the modified anterior tension wiring and cannulated lag screw osteosynthesis with anterior tension wiring in both stability and rigidity.

2. Methods

Biomechanical analysis was conducted on 21 identical left patellae made from polyurethane foam (manufacturer: Sawbones, Pacific Research Laboratories Inc., Vashon, Washington, USA). A corresponding femoral condyle (manufacturer: Sawbones, Pacific Research Laboratories Inc., Vashon, Washington, USA) was used in order to built a pivot point for simulated knee flexion during testing.

Using plaster molds, two 1.8 mm axial drill holes were made in 14 patellae to guarantee identical and parallel positioning of K-wires and cannulated screws, respectively.

After creating the drill holes, all patellae were identically osteotomized horizontally in the center using a second set of plaster molds. In order to simulate the patellar and quadriceps tendon, the superior and inferior section of the osteotomized patellae was glued to a polyester tension belt loop with a maximum load capacity of approximately 4000 N at less than 5% strain.

The classic modified anterior tension wire approach featured two stainless steel K-wires (manufacturer: Synthes® Oberdorf, Switzerland) 2 mm in diameter, which were drilled into the aforementioned drill holes. The wires ran parallel to each other and orthogonally to the osteotomy plane. The superior and inferior ends of the K-wires protruded approximately 5 mm, serving as fixation points for a 1.25 mm stainless steel wire loop (manufacturer: Synthes® Oberdorf, Switzerland), which was laid around the protruding K-wire ends, forming a figure-eight on the anterior surface of the patella. The wire was manually twisted by an experienced trauma surgeon (senior physician) until it straightened and a stiff and stable osteosynthesis was achieved.

The cannulated lag screws with anterior tension wiring consisted of two parallel stainless steel cannulated screws (diameter = 4.0 mm, length = 36 mm length, thread = 12 mm, manufacturer: Synthes® Oberdorf, Switzerland) which were also screwed in the drill holes. A 1.25 mm stainless steel wire was passed through the cannulated screw and formed into a figure-eight on the anterior surface of the patella. This was followed by cerclage tightening by twisting the 1.25 mm wire ends until a stiff and stable osteosynthesis was obtained.

The fixed-angle plate made it necessary to develop special 5-hole, 2.7 mm titanium plates (manufacturer: Königsee® Allendorf, Germany), which allowed polyaxial, fixed-angle screw placement. Both plates were bent in a semicircular shape prior to implementation. They were then placed on the medial and lateral surface of the patellae in an 80° angle to its anterior surface. The plates designed for patellar osteosynthesis also have an additional loop on both ends, which allowed the plates to be tensed with each other to attain additional stability in the traction direction of the quadriceps muscle. During the implementation of the plates, tapered surgical clamps were set in these additional proximal and distal loops used to tense the plates with each other and to stabilize the plates on the lateral and medial surface of the patella. After securing the plates on the osteotomized patella and drilling holes using a guide, a fixed-angle screw 3.5 mm in diameter (manufacturer: Königsee® Allendorf, Germany) was introduced into the proximal hole of the plate on each side. These screws spanned the fracture gap. The next step was to insert two similar screws into the distal holes on each side. Except for the center slot on the 5-hole plate, which lay right on top of the fracture gap, all the slots were filled with 3.0 mm diameter screws so that each plate was attached to the patella with four screws (Fig. 1).

All patellae were tested in a simulated 60° angle knee flexion using an artificial femur condyle as a pivot point following the biomechanical model of Brill and Hopf (1987) and Sharkey et al. (1997). Tension was applied via the previously attached polyester belt loop. Analysis was performed on an Instron 5565® using the Bluehill 2 Software®. (Fig. 2) All the experiments were conducted with a preload of 100 N and an extension rate of 15 mm/min. A preload was necessary due to the fact that the tension belt loop, which simulated the anatomical patellar suspension ligaments, needed to be extended to a point at which a linear increase in the stress–strain diagrams could be observed. For each construct one patella was used for a calibration run and was thus not included in the analysis. This resulted in six test runs being available for analysis for each type of osteosynthesis. The parameters which were recorded were load (N), displacement (mm) and run-time (s). This allowed the elastic modulus (MPa), tensile strength (MPa) and strain at failure (%) to be calculated. In order to eliminate the influence of the artificial tension belt on the analysis, and in order to procure results which are comparable to those in the literature, a separate video analysis of the fracture gap was conducted as well. The video analysis was performed in order to correlate values gained from the stress strain measurements to the actual behavior of the tested constructs and to determine the failure mode. In order to quantify fracture gap increase throughout the experiments, the gap was measured on the medial and lateral limit of the patella before and after the testing. These values were averaged, which allowed a numerical value to be derived for the fracture gap before the biomechanical testing and after osteosynthesis failure. Additionally, a before- and after- ratio (B/A-ratio) was calculated which describes the osteosynthesis behavior under extensional stress while disregarding the impact the simulated patellae suspension had on the test set-up.

Osteosynthesis failure was determined by stress–strain analysis. A sudden and permanent decrease in a stress–strain diagram was defined as failure. Additionally, the cutting of the 1.25 mm

Fig. 1. Fixed-angle plate osteosynthesis of the left patella.