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A short plate compression screw with diagonal bolts—A biomechanical evaluation performed experimentally and by numerical computation

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Abstract

Introduction. Decreasing the length of the side plate of the dynamic hip screw would theoretically allow a smaller surgical incision, a shorter surgical time, decreased operative blood loss and minimal periosteal stripping. A new design of a very short plate dynamic hip screw based on two diagonal screws has been developed. Our study compares the new design and the four-hole side plate in respect to mechanical properties and bio-mechanical outcomes utilizing the Finite Element Analysis method.

Methods. Four pairs of fresh frozen cadaveric femora were extracted from male corpses aged 25–43 years (mean 34.8). One femur of each pair was fixated by means of the new system and the other by means of the conventional design. Mechanical loading was applied to all four pairs. The decline which occurred during the periodical loadings and the breakage loads of fixated bones were measured. Mechanical performance and probability of failure was assessed by conducting a mathematical analysis using the finite element method.

Findings. The average deflection under excessive cyclic loading was 33% higher in the bones fixated with the very short plate-dynamic hip screw device than in those fixated with the conventional dynamic hip screw. The average load failure during the collapse-loading test was 3120 N for the very short plate-dynamic hip screw as compared to 4160 N for the regular device. Mechanical testing did not provide decisive results regarding failure. The mathematical analysis performed indicated that the maximal stress in the very short plate-dynamic hip screw reached values 3–4-fold higher than in the regular dynamic hip screw.

Interpretation. Although the new design offers a minimally invasive approach to subtrochanteric femur fracture fixation, it was found to have insufficient biomechanical performance resulting in high probability of mechanical failure. The authors believe that the finite element method may have the potential to serve as an additional clinical tool for performing surgical preplanning and assist in decision making.
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Keywords: Intertrochanteric fracture; Dynamic hip screw; Short plate; Biomechanical evaluation; Finite elements analysis

1. Introduction

Intertrochanteric hip fracture in the elderly is considered a serious medical problem and a difficult social and rehabilitation task, with an incidence rate of 44–98 per 100,000 people in the western world (Gallagher et al., 1980). There is an exponential rise in fracture incidence with age, especially in the 7th decade (Cummings et al., 1989). Worldwide reports present data showing a steady increase in hip fractures. Approximately 50% of hip fractures in the old age are intertrochanteric fractures, a large percentage of which are unstable (Bartucci et al., 1985; Cummings et al., 1989; Desjardins et al., 1993; Gallagher et al., 1980).

The gold standard surgical treatment for intertrochanteric fractures is by means of Dynamic Hip Screw (DHS). The disadvantages of this method were previously

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reported and mainly derive from the relatively expansive open surgical approach (Gotfried, 2000; Laros and Moor, 1974; Stappaerts et al., 1995). Minimal invasive surgical techniques (MIS) in fracture fixation can reduce operative complications and post operative morbidity, and the application of the MIS approach in fixating hip fractures in the elderly is promising. So far, two major percutaneous surgical approaches have been described in the treatment of intertrochanteric hip fractures in the elderly, using either percutaneous plating (Gotfried, 2000; Krettek et al., 1997; Lunsjo et al., 1996; Wenda et al., 1997) or intramedullary nailing (Barquet et al., 2000; Bridle et al., 1991; Stapert et al., 1993). The use of intramedullary fixation involves high percentage of post-operative femoral fractures and a significant secondary fracture re-displacement, which leads to varus malunion, lag screw cut-out or excessive sliding with distal fragment medialization (Stapert et al., 1993). Clinical reports of recently developed minimal invasive plate osteosynthesis have shown significant demands in the surgical technique and an increased incidence of mechanical complications (Gotfried, 2000).

Another "biological" approach, which has received only little attention, is a dynamic hip screw with a very short side plate (McLoughlin et al., 2000; Reich et al., 1995). Decreasing the length of the side plate has several theoretical advantages such as allowing a smaller incision and approach, shorter surgical time, decreased operative blood loss and minimal periosteal stripping. All of these factors can potentially lead to shorter hospital stay, enhanced healing and rehabilitation potential of the elderly patient with an unstable intertrochanteric hip fracture, and may ultimately result in fewer complications. On the other hand, a potential drawback of this technique may be a decreased biomechanical performance.

In order to evaluate the latter concept, a new design of a very short plate dynamic hip screw (VSP-DHS) has been developed. The plate design consists of two diagonal screws that originate 1 cm below the dynamic screw, at a fixed 45° angle, in order to replace the 4-hole side plate DHS. We wanted to investigate whether the diagonal axis of the two long screws in the VSP-DHS device would compromise for the lack of 4-screws and long side plate of the classical design.

In this study the biomechanical compatibility of the VSP-DHS was evaluated and compared with the conventional DHS. The evaluation was performed experimentally and theoretically applying computerized numerical analysis (Finite Element Analysis—FEA).

2. Methods

2.1. Bones

Four pairs of fresh frozen cadaveric femora were extracted from male corpses aged 25–43 years (mean 34.8). The bones, which were selected at random, underwent a peeling process of muscles and soft tissues, and were kept deep frozen at −20 °C.

2.2. Plates

Four-hole side plates of dynamic hip screws (DHS) (Richards Medical Corps, Compression hip screws and plates, stainless [ASTMF 138], Memphis, TN, USA) served as control to the investigated device. The new fixation device (VSP-DHS) was designed by shortening of the plate up to 2 cm below the sliding screw oval hole. In a distance of 1 cm below the oval hole two diagonal screw slots were drilled at an angle of 45° in relation to the longitudinal axis of the plate. Both new design and control plates had the same compression screw—plate angle of 140° (Fig. 1).

2.3. Preparations

1. Every bone was thawed for a period of 24 h at 40 °C during which time AP and lateral X-rays were performed in order to assess the bone quality, and to measure the neck-shaft angle. In order to avoid bias due to pathological bony defects the Singh Index was determined for each bone as a measure for bone density (Singh et al., 1970). All bones were graded 6 points, i.e. no signs of osteoporosis detected. No other pathological findings were detected in all bones. For the mechanical tests, a plastic base was prepared in order to enable stable placement of the bone in a physiological position. The distal femoral condylar region was cast into the Epicur base plastic material [epoxy resin] used for casting. The bones were then refrozen to −20 °C.
2. The bones were thawed out again for a period of 24 h, as previously described, after which time an identical intertrochanteric medially based wedge resection, mimicking an unstable intertrochanteric fracture, was performed in all specimens.
3. In each pair of femora, the intertrochanteric fractures were fixed using the VSP-DHS device on the one side, and DHS device on the other, for comparative purposes. In two pairs of bones the VSP-DHS was applied to the left neck of femur, and in the two other pairs the new

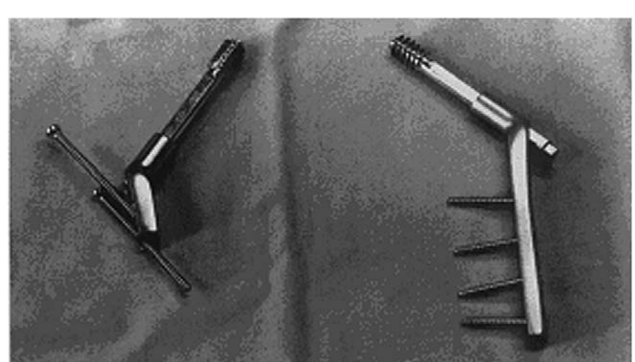

Fig. 1. Right—control device (DHS); Left—VSP-DHS device. The VSP has two screws angled at 45°.

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