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# Biomechanical analysis of the percutaneous compression plate and sliding hip screw in intracapsular hip fractures: Experimental assessment using synthetic and cadaver bones

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#### **KEYWORDS**

Hip; Fracture; Biomechanics; Internal fixation; Intracapsular **Summary** We compared the mechanical behaviour of osteosynthesis with the percutaneous compression plate (PCCP) compared with the standard osteosynthesis sliding hip screw (SHS) in intracapsular hip fractures. We created 10 stable and 10 unstable intracapsular hip fractures in 20 synthetic femurs. Each fracture was fixed with either the SHS or PCCP. In six pairs of cadaver femurs, we created unstable intracapsular hip fractures and fixed them with the SHS or PCCP, at random on the left or right side. All femoral heads were exposed to a cyclic, combined axial and torque load until failure. In each group, the PCCP resisted a significantly higher load than the SHS. Clinical prospective studies are needed to confirm these in vitro findings that the PCCP is more stable than the SHS.

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# Introduction

The main goal of treatment of intracapsular fractures of the proximal femur is restoration of pre-injury

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function without associated morbidity. Therefore prerequisites are anatomical or near anatomical reduction and stable fracture fixation,<sup>1,3,8,9,11,20</sup> withstanding axial and rotational forces. Stability of the reconstruction depends on the stability of the implanted device, particularly in the comminuted type of fracture where a stable anatomical reposition is not possible. The sliding hip screw (SHS) is one

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of the most commonly used types of osteosynthesis in the treatment of intracapsular hip fractures, and seems to perform well in clinical studies, but with a failure rate of 12-32%.<sup>5,14,15,17,19,21</sup> This is partly due to a lack of rotational stability. An improved design should optimise stability and thereby reduce the clinical failure rate, possibly with a minimally invasive approach reducing blood loss, infection and other wound problems.

The percutaneous compression plate (PCCP) was developed by Gotfried, as a double-axis, minimally invasive implant providing rotational stability, preventing fracture dislocation and allowing immediate full weight bearing.<sup>12</sup> However, the device was used and biomechanically tested only in pertrochanteric hip fractures.<sup>4,12,13,16</sup> The PCCP could also be suitable to treat intracapsular hip fractures, but this application has evidently not yet been assessed. The present study was undertaken to compare the mechanical behaviour of the PCCP with that of the SHS in intracapsular hip fracture. The following questions were addressed.

- Does the PCCP withstand higher rotational loads because of its double-axis neck screw configuration, and thus prevent early failure following fracture collapse and varus retroversion of the head?
- Is the PCCP, with posteromedial comminution, a more rotational stable implant in intracapsular hip fracture than the SHS?
- Is the PCCP, from a biomechanical perspective, capable of reducing the number of failures?

## Materials and methods

This study was carried out in two phases. First, we used 20 composite femora (type 3306, Sawbones<sup>TM</sup>, Pacific Research Laboratories, Vamont, WA, USA) to assess the inherent characteristics of the two implant devices, and subdivided the femora into four groups of 5. These synthetic models have been shown to behave adequately in a mechanical sense, according to Cristofolini et al.<sup>7</sup> In each synthetic femur an intracapsular hip fracture was created using a drill-mould to produce numerous subcapital drill holes and subsequent mechanical fracture. A Garden 1/2 or AO 31B1 type of fracture was formed in this way. In addition, a 5-mm thick slice of cortical bone was removed from the posteromedial wall of 10 of the composite femora, to simulate comminution according to Deneka et al.,<sup>8</sup> producing a Garden 3/4 or AO 31 B3 fracture.

In the second phase, identical experiments, with simulated comminuted fractures, were performed using six pairs of fresh cadaver femora. The right and left cadaver femurs were randomised for fixation either with the PCCP or the SHS in a paired way. The procedure for fracturing, fixation and creating comminution was identical to that followed for the synthetic femora.

The fractures were fixed with either the SHS (DHS, Synthes<sup>®</sup>, Bettlach, Switzerland) or the PCCP (Orthofix<sup>®</sup>, Guildford, UK) according to standard surgical technique by a consultant orthopaedic surgeon. In all groups, neck screws were placed in the subchondral bone, with the screw tips within a distance of 5-10 mm from the subchondral bone. With the internal fixation in situ, the femora were radiographed in anteriorposterior and lateral planes to assess the correct reduction of the fracture and placement of the implant devices.

We classified the types of fracture-osteosynthesis into six groups as follows:

- (1) Intracapsular hip fracture, reconstructed with the SHS (stable fracture type), synthetic femur.
- (2) Intracapsular hip fracture, reconstructed with the PCCP (stable fracture type), synthetic femur.
- (3) Intracapsular hip fracture with posterior comminution; reconstructed with the SHS (unstable fracture type), synthetic femur.
- (4) Intracapsular hip fracture with posterior comminution, reconstructed with the PCCP (unstable fracture type), synthetic femur.



Figure 1 Percutaneous compression plate in synthetic bone in test situation.

- (5) Intracapsular hip fracture with posterior comminution, reconstructed with the SHS (unstable fracture type), cadaver femur.
- (6) Intracapsular hip fracture with posterior comminution, reconstructed with the PCCP (unstable fracture type), cadaver femur.

The distal end of each synthetic and cadaver bone was resected 30 and 20 cm, respectively, below the tip of the greater trochanter. Each bone was oriented in neutral position (without any adduction, abduction, flexion or extension) and potted just below the end of the plate. The femoral heads were exposed to a cyclic combined axial and torgue load, simulating clinically relevant failure. This load was created by a cyclic axial force (servo-hydraulic MTS machine) that was applied 5 cm posteriorly relative to the centre of the femoral head (Fig. 1) in a dynamic way, with a 0.5 Hz frequency and stepwise increments of 25 N. Each loading increment lasted 2.5 min; loading was sequentially increased until the reconstruction failed. Failure mode was recorded in detail and the load magnitude was used as an indicator of the strength of the reconstruction. Statistical analysis of the strength values of the SHS or PCCP reconstructions was performed with a paired t-test, using SPSS 9.0.0.

### Results

The typical mode of failure for the SHS reconstructions was posterior rotation with retroverted varus deviation of the head, as would be observed clinically. For the PCCP reconstructions, failure usually involved posterior rotation with twisting of the two neck screws, for the comminuted and non-comminuted fracture groups. The specimens in groups 1 and 3 (SHS) maintained maximal loads to failure of 36.0 N (S.D. 23.3) and 75.8 N (S.D. 24.3), respectively, compared with the groups 2 and 4 (PCCP) which maintained maximal loads to failure of 157.4 N (S.D. 57.7) and 137.2 N (S.D. 13.5), respectively. Hence, surprisingly, the unstable fractures produced a higher failure load than the stable fractures. In each synthetic bone group tested, the PCCP resisted significantly higher maximal load to failure than the SHS in both the stable (p = 0.004) and unstable (p = 0.002) types of fracture reconstruction. In the cadaver bones, the mean maximal load to failure for the SHS group 5 was 51.0 N (S.D. 38.4), and in the PCCP group 6 was 103.8 N (S.D. 72.0). In each cadaver femur pair tested, the PCCP resisted a higher load to failure than the SHS. This difference was significantly in favour of the PCCP (p = 0.037). These results are listed in Table 1 and Figs. 2 and 3.

Table 1 Results of synthetic bone study-phase I		
Group number	Mean of maximum load to failure	95% CI of difference
(1) SHS—stable fracture	36.0	7.0–64.9
(2) PCCP-stable fracture	157.4	85.7–229.1
(3) SHS—unstable fracture	75.8	45.6-106.0
(4) PCCP—unstable fracture	137.2	120.5—153.9
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PCCP-stable vs. SHS-stable fracture 0.00		
PCCP-unstable vs. SHS-unstable fracture 0.002		



Figure 2 Mean maximal load to failure per group of synthetic bone.



Figure 3 Mean maximal load to failure per group of cadaver bone.

#### Discussion

Intracapsular hip fractures require superior fixation<sup>1</sup> that withstands axial and rotational forces, particularly in the comminuted type of fracture, where a stable anatomical reposition is not always reached and the quality of the reconstruction depends more on the stability of the implanted device. To our knowledge, this is the first biomechanical study using an eccentric applied cyclic load, which enables simulation of clinical failure. By combining axial and rotational loading, we tried to reproduce naturally occurring stresses on the hip as in sitting, standing, walking, stair climbing and descending, and turning. The unidirectional load often used, 10,11,15,18,22 cannot test the rotational stability of the reconstruction. The eccentric loading configuration in this study applied a rotational torque in combination with an axial load and therefore simulated clinical trigger failure mechanisms, but to a limited extent, which should be taken into account when interpreting the results.

We used a drill-mould to create a standardised fracture instead of the smooth osteomised fracture used by others,<sup>11</sup> in order to mimic clinical fracture,<sup>2,6</sup> as closely as possible. This has probably resulted in somewhat more variation in the fracture geometries and therefore of the failure loads of the reconstructions, but has in our opinion greater relevance to the clinical situation which could be described as the chaotic fracture behaviour of bones. The fact that we found significant differences

between the groups illustrates that the number of specimens and the reproducibility of our experimental method were adequate for our purposes.

In treating these types of fractures, the SHS is most often used,<sup>6,8,10</sup> particularly because of its load-bearing capability. Shortcomings of the SHS include its low rotational resistance and lack of stable angular neck screws. The rotational stability could be improved by an additional 6.5 mm cancellous screw as reported by Swionkowski et al.<sup>23</sup> However, this lacks the function of a stable angular screw and has proved useful only during introduction of the neck screw, preventing turning of the head.

The higher failure loads for the unstable fractures can be explained by the way in which failure was initiated and progressed. In the unstable fracturetype reconstructions treated in by the SHS (group 3), directly after starting the testing secondary stabilisation occurred because of slight posterior rotation impaction and indentation of fracture parts. The reconstructions then resisted a higher load than the stable fracture treated with the SHS. This secondary stabilisation is shown in Fig. 4(a and b).

The PCCP is a minimally invasive implant originally developed for the treatment of pertrochanteric hip fractures. It has two stable angular parallel neck screws which should resist higher rotational forces, as required particularly in comminuted intracapsular hip fractures, to prevent posterior rotation and retroverted varus deviation of the head and failure of fixation, seen often in fractures treated with the



Figure 4 Sliding hip screw fracture reconstruction: (a) before start of testing and (b) directly after start of testing.

SHS. The failure mode of the PCCP reconstruction in our study was posterior rotation with twisting of the two neck screws.

This study shows that the PCCP indeed enhances the stability of the reconstruction in a combined axial and rotational loading configuration. It was not feasible to compare our failure loads with those reported by Goodman et al., Husby et al., Seto et al...Neustadt et al. and Engesaeter et al.,<sup>10,11,15,18,22</sup> as the methods and loading conditions differ. These authors, however, showed no differences between the SHS and cannulated screws or pins in their particular biomechanical settings. We therefore, confined ourselves to gualitative analysis, showing that the PCCP failed at significantly higher loads than the SHS reconstructions.

Our results suggest that the PCCP will perform clinically at least as well as the SHS, and should reduce the failure rate in displaced, comminuted or unstable intracapsular hip fractures treated with osteosynthesis. In addition, the PCCP can be inserted using a minimally invasive surgical technique, as has already been demonstrated in the treatment of the pertrochanteric hip fractures by Gotfried, Janzing and Brandt and coworkers.<sup>4,12,16</sup> This should also reduce the incidences of blood loss, infection and other wound problems.

Clinical prospective studies are needed to establish whether these experimental findings can be confirmed in vivo.

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