Comparison of Torque Resistance between Three Fractured Neck of Femur Fixation Devices

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Introduction: The global figure of people above the age of fifty who sustained hip fractures in 1990 was 1.7 million. Cooper et al [1] estimated that this figure could be as high as 6.3 million per year by 2050. A more recent study carried out by Gulberg et al [2] gives a more conservative prediction of the total number of hip fractures as 2.6 million by 2025 and 4.5 million by 2050; but these still represent significant numbers.

Hip screws are predominantly used for the treatment of fractures of the proximal femur (AO 31). This includes the fractures of the trochanteric area (AO 31-A) and the femoral neck (AO 31-B). Data from the United States suggests that 49% of all hip fractures are intertrochanteric making it the most common type. [3] Using standard notation, AO 31-A3 is the most common hip fracture. This condition is often treated using the Dynamic Hip Screw (DHS). Failure rates of the DHS vary between 5% [4, 5] and 23% [6], with cut-out being the most common mode of failure.

Fixation with the DHS does not provide optimal rotational stability and a number of newer fixation devices have emerged to address this, with the DHS Blade (Synthes Ltd, Welwyn Garden City, UK) and X-Bolt (X-Bolt Direct Ltd, Bristol, UK) being two recent designs. The aim of the present study was to evaluate the rotational stability, using polyurethane foam bone analogue, of these newer designs compared to the DHS (Synthes Ltd).

Null Hypothesis:
The DHS Blade and X-Bolt have the same torsional stability as the DHS hip fracture fixation device.

Methods: A torque test protocol was established to determine the torque resistance of the three hip fracture fixation devices. This study used polyurethane (PU) foam (Sawbones, Malmo, Sweden) bone analogue blocks (47 mm x 47 mm x 40 mm) of three different densities (D1=0.08, D2=0.16, D3=0.24 g/cm3) representative of highly (D1), moderately (D2) and mildly (D3) osteoporotic bone[7]. A perpendicular hole was drilled a depth of 35 mm into each block and then the fixation devices were inserted, using the manufacturer recommended insertion protocols and instruments. The constructs were then mounted, using custom fittings, in a bi-axial material test machine (HBT 25-200, Zwick Testing Machines Ltd., Leominster, UK). The PU foam blocks were held fixed and the fixation devices were mounted in the rotating end effector of the test machine.

A ramp torque of 1°/minute was then applied whilst the torque and angular displacement achieved were recorded at a sampling frequency of 10 Hz. The data were then filtered using a third order Butterworth low-pass filter with 1 Hz cutoff frequency (Matlab R2012, The MathWorks, Natick, MA, USA). The primary outcome measures were the work done to achieve 6° of rotation, calculated from the area under the torque/displacement curve, and the peak torque achieved.

For each fixation device five trials at each foam density were performed.

Non-parametric statistical analysis (SPSS, IBM, New York, NY, USA) was then performed, first comparing the work done and peak torque between devices for each foam density level (Kruskal Wallis [KW] test), and then comparing the same variables between density levels for each device. When statistical significance (p≤0.05) was found, further Mann-Whitney U (MW) tests were performed to compare between various paired combinations of devices and densities.

Results: The overall trend for both the work done (Figure 1, Table 1) and the peak torque (Figure 2, Table 1) was for these values to increase as density of the PU foam increased. Generally highest values for both variables were seen for the X-Bolt, the next highest for the DHS Blade and the lowest for the DHS.

For work done the differences between devices were significant only for densities D1 (KW p=0.013) and D2 (KW p=0.002). For peak torque there were significant differences at all densities (D1: KW p=0.006, D2: KW p=0.002, D3: KW p=0.015). Comparing the X-Bolt and the DHS, the X-Bolt had significantly larger values for work done than the DHS for densities D1 (MW p=0.008) and D2 (MW p=0.008), whilst peak torque was significantly higher for the X-Bolt at all densities (D1: MW p=0.008, D2: MW p=0.008, D3: MW p=0.032). Comparing the DHS Blade and the DHS, the DHS Blade had significantly larger values for work done than the DHS for densities D1 (MW p=0.016) and D2 (MW p=0.008), this was also the case for the peak torque (D1: MW p=0.008, D2: MW p=0.008). Comparing the X-Bolt and the DHS Blade, the X-Bolt had significantly larger values for work done than the DHS Blade for density D2 (MW p=0.008), whilst peak torque was significantly higher for the X-Bolt at densities D2 (MW p=0.008) and D3 (MW p=0.008).

Examining the differences for each device for the three different foam densities showed that there were only significant differences for the X-Bolt (work done KW p=0.009, peak torque KW p=0.008) and the DHS (work done KW p=0.004, peak torque KW p=0.005).
**Discussion:** The findings indicate that the two newer designs of fracture fixation device, the X-Bolt and the DHS Blade, provide greater torsional stability than the DHS; thus the null hypothesis was rejected. It is interesting to compare the performance of the three devices over the range of PU foam densities used for the testing. The greatest variability for all devices were observed for the higher density foam, suggesting that insertion into higher density bone may be less repeatable than into lower density bone. It is not clear whether this is a function of the fixation device design or the instrumentation used for insertion. The greatest differences between the devices was seen for density D2; for this density the overall variability in peak torque was the least for each device.

This study has several limitations, firstly bone analogues were used instead of actual bone tissue. Whilst this makes the results more difficult to translate to the clinical situation, it does mean that more meaningful comparisons between devices were made than could be possible with cadaveric bone given the variability between specimens. The number of specimens and trials for each type of device was relatively low, however statistically significant results were obtained.

**Significance:** The findings indicate that the newer designs of hip fracture fixation device can confer greater rotational stability, and thus should reduce the failure rate due to rotational cutout.

**Acknowledgments:**

**References:**
Figure 1
<table>
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<th>Implant</th>
<th>PU Foam Density</th>
<th>Work Done (J) Mean</th>
<th>Work Done (J) SD</th>
<th>Peak Torque (Nm) Mean</th>
<th>Peak Torque (Nm) SD</th>
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