Computer assisted validation of femoral neck resection level for a modular metaphyseal short stem

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Introduction
Primary total hip arthroplasty (THA) has continued to grow in number exponentially per year. These numbers are predicted to continue to increase as the baby boomers age over the next decade in the U.S. This will continue to be one of the important cost factors for health care. Along with the increasing number of THA performed there continues to be a trend of younger patients succumbing to THA. Bone preserving implants have been utilized in these patients to aid in revision surgery in this population. Along with hip resurfacing another type of implant available include short metaphyseal stems to preserve proximal femoral bone stock in younger patients. The Mhula, modular metaphyseal short hip stem (Aesculap AG, Germany), is one of these type of implants. Unlike many other stems, this design is not a “shortened” version of a straight stem. It is a true metaphyseal and femoral neck stem based on previous short stem designs. In this cadaveric study we used computer navigation (OrthoPilot, Aesculap AG, Germany) and CT-scans with fiducial markers to answer whether the level of the neck cut has a significant effect on positioning of the metaphyseal type stem.

Materials and Methods
For this study 10 hips in 6 fresh frozen human cadavers (3 male and 3 female) were utilized. In two cadavers (1 male and 1 female) only the left leg was available. The cadavers then had 3 plastic fiducial screws placed in every femoral bone to register computer navigation data to CT scan. The three positions utilized in each femur included the medial and lateral epicondyle and the base of the greater trochanter. After placement of the fiducial markers was complete the cadavers underwent a spiral CT scan providing 0.5 mm slice thickness (GE corp). The CT-data were segmented using the AMIRA software (version 5, Visage Imaging, Inc., USA). The following structures and their coordinates in the coordinate system of the CT-scans were fiducialized: fiducial points belonging to the bottom of the groves in the screw heads; proximal femoral axis; center of the femoral head; and the femoral neck axis.

Using standard posterior approach Metha rapti implantations were performed by a senior fellowship trained surgeon. This step was done at 3 different resection levels in each cadaver. The lowest point of the upper femoral neck surface was used to define the 0 resection level. This is often referred to as the shoulder of the femoral neck (Figure 1). Starting from this point the resection was performed at +10 mm, +5 mm (+5 mm is recommended by manufacturer) and 0 mm. The aimed angle of the resection was 50 degrees in relation to the anatomical femoral axis. The bone was rasped till the maximal rasps size as estimated by the senior surgeon and was registered and recorded. This procedure was repeated for each femoral neck resection (+10mm, +5mm and 0mm neck cut levels).

The acquired OrthoPilot data was entered and transformed into CATIA (version 5, Dassault Systemes, France). The segmentation data defined the outer contour of the femur as well as the femoral canal. (Figure 2) The following anatomical parameters were measured: femoral neck anteversion, femoral offset, and the CCD-angle. Using fiducial points the OrthoPilot-data and the CT-data sets were fused to one CATIA product. The measurements and the graphical analysis of the implanted data to determine the positioning of the implant broach compared to the native anatomy of each cadaveric hip.

Results
Anteverision: The +10 mm neck cut resulted in greater anteversion relative to the native anatomy (2.5 ± 1.1). The +5 mm neck cut had higher anteversion (1.4 ± 0.6). The 0 mm neck cut resection in higher anteversion (0.2 ± 0.3). All p values were greater than 0.22.

Femoral Offset: The +10 mm neck cut resulted in greater femoral offset compared to the native anatomy (4.7 ± 3.4 mm) and was significantly different with a p value of 0.001. The +5 mm neck cut also had higher femoral offset than the native anatomy (1.9 ± 3.3 mm) but again was not statistically significant (p = 0.07). On average the 0 mm neck cut had a lower offset compared to the native anatomy but again not statistically significant (1.7 ± 3.1 mm and p = 0.072).

CCD Angle: The CCD angle changes were the most variable from each neck cut investigated. The +10 mm neck cut resulted in a CCD angle that was higher than the normal anatomy that was measured (5.6 ± 2.7) and was significantly different (p = 0.027). The +5 mm neck cut resulted in a significantly higher CCD angle (10.1 ± 6.9) with p = 0.001. The 0 mm neck cut also resulted in a significantly higher CCD angle compared to the native anatomy CCD angle (15.5 ± 7.2 and p = 0.0001).

Leg Length: When the leg length was calculated for a neutral neck length femoral head the +10 mm neck cut resulted in an average increase in leg length (9 ± 2.1 mm with p = 0.0001). A short neck cut would reduce this to 6.2 mm average increase in leg length. For the recommended femoral neck cut level of +5 mm the average leg length increased to 5.4 ± 7.2 mm (p = 0.002) and would be decreased to an average of 1.6 mm with a short neck cut length on average. The 0 mm low neck cut resulted in an average increase in leg length of 2.9 ± 3.7 mm with a neutral neck (p = 0.022) and with a short neck this would be decreased on average to 0.1 mm.

Discussion
This study has shown that the level of the neck resection with a short metaphyseal stem can significantly affect the final position of the stem as well as CCD angle, femoral offset, and leg length. With the increasing number of orthopaedic surgeons across the world turning to bone preserving hip replacement procedures, the effective techniques to surgically implant these devices is paramount. This study has shown that if the femoral resection level is at the shoulder of the femoral neck that the implant sits more vertically and cannot reproduce the femoral offset or the CCD angle. The higher the neck cut (+10 mm from the shoulder point) the longer the leg length and in some cases the modularity options may not allow recreation of the starting leg length for the patient. These are significant technical issues which need to be relayed to any surgeons who are thinking about utilizing this type of implant.

Conclusion
The findings of our study suggest that the level of the femoral neck cut and the anatomic shape of the bone dictate implant positioning of a short metaphyseal stem. The lower the neck cut, the more vertical the implant positions itself, which decreases offset, increases the CCD angle, and drives the rasp closer to the anatomic anteversion.

Figure 1: The lowest point at the lateral base of the femoral neck was considered the lowest 0 mm resection level. From this point 10 mm above and 5 mm above were utilized as resection levels along with a final resection at this level for investigation of the orientation of the implant.