

A novel three-dimensional method for modelling the femoral neck axis

MANDALIA R, MASJEDI M, HARRIS SJ, COBB JP

MSK Lab, Charing Cross Hospital, Imperial College London, UK

j.cobb@imperial.ac.uk

Introduction: Three-dimensional (3-D) identification of the femoral neck axis is potentially a valuable tool in planning surgery of the proximal femur. There is presently no standard method to obtain the 3-D neck axis. This has previously been attempted as a composite of 2-D methods, which is limited by its basis in 2-D. We present a novel 3-D method that we hypothesise can robustly model the femoral neck axis.

Materials & Methods: This study used segmented CT data from 40 femurs, of which 20 are normal with no known hip pathology (from patients who has abdominal CT scans), and 20 have cam-type femoral neck deformity as judged by the senior author of this study (from patients with symptomatic hips).

The 3-D model of each femur was imported into the newly developed software written in C++. Markers were randomly placed onto the surface of the femoral head. Following the addition of sufficient markers, the software developed a best fit sphere for the femoral head and the centre was obtained. Three other markers were then placed on the greater trochanter, lesser trochanter, and mid-point of the intertrochanteric line. The average position of these points, and the head centre, was used to calculate a preliminary neck axis.

A reliable neck axis was then achieved using an iterative method. The neck was divided from base to apex in 1mm cross sectional slices perpendicular to the estimated axis. The centre of gravity of each slice through the femoral neck was calculated, and these points were termed centroids and displayed as points within the femur (Figure 1). Points lying outside the neck region were excluded. A least squares fit of all selected points was performed to form a corrected femoral neck axis. The original axis was then replaced with the new axis. This method was iterated until the angle change between successive axes was less than one degree. At this point they were considered to have converged. One further iteration was performed to confirm this.

We obtained a value for the head centre offset in each case – the relationship between the femoral head centre and the centroid points. Furthermore, repeatability testing was conducted by performing

the neck axis adjustment three times for 10 randomly selected femurs (5 normal, 5 with cam-type deformity). Statistical analysis was then performed.

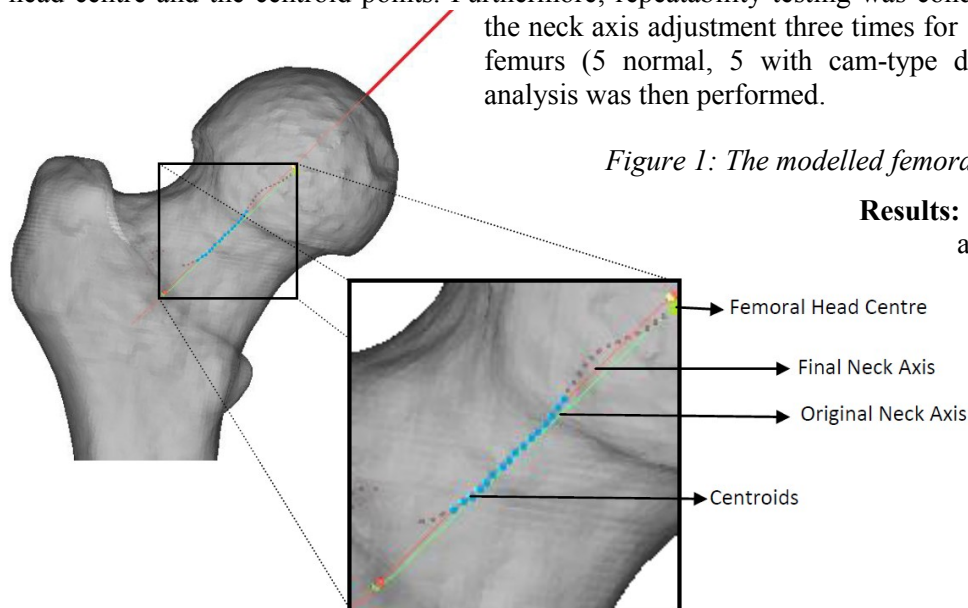


Figure 1: The modelled femoral neck axis

Results: The method was applied to the 3-D femoral neck in 40 femurs. The 20 normal femurs required a mean value of 8 iterations (range 6 to 11) to achieve convergence. The head centre was effectively on the

neck axis, at a mean of 0.8mm posterior and 0.03mm inferior to the mean neck centre (range 1.4mm anterior to 2.8mm posterior, and 4.1mm superior to 3.2mm inferior).

In the 20 cam femurs, it took a mean value of 7 iterations (range 4 to 12) to achieve convergence. The head centre was a mean of 1.7mm posterior and 1.8mm inferior to the mean neck centre (range 0.22-3.5mm posterior and 0.28-5.9mm inferior).

Discussion & Conclusion: In all cam femurs, the head centre was found to be postero-inferior to the mean neck centre, reflecting the antero-superior cam deformity. This is compared to normal hips where the head centre was on average directly co-incident with the robustly defined neck axis.

Obtaining an accurate femoral neck axis provides for the first time a reliable proximal femoral frame of reference. Previous methods for obtaining this have required radiographic imaging of the knee. The method proposed in this study allows a detailed description of the relationship between head and neck, that is independent of more distant features such as the knee.

This method also permits investigators to describe the size of the the femoral neck and head in three dimensions. This method has applications in the understanding and description of hip pathomorphology. By quantifying the angular and size relationships between the head and neck in a robust manner, this method allows investigators and surgeons to confirm diagnoses and plan procedures, both conservative and arthroplastic. Modelling the neck axis in this manner can be applied to all three-dimensional studies of the hip in a consistent manner, enabling comparison between methods. The method is currently being utilised in our group to quantify cam-type femoral head deformity and perform virtual surgical correction prior to robot assisted surgery.