Introduction

Correct alignment of the femoral component in the coronal and axial plane is of paramount importance to obtain good and reliable clinical results following total knee arthroplasty (TKA). However, very little is known about the alignment of the femoral component relative to the sagittal bowing of the femur. One of the explanations is that assessment of femoral bowing is difficult on plain radiographs and to date very few data determining and defining the femoral curvature have been reported. As a result, the positioning of the component relative to this bowing is not taken into account during the operative process.

In addition, in revision cases with severe distal femoral distortion or in cases with resection of the distal femur such as in tumour surgery, it can be very difficult for the surgeon to assess the correct rotational alignment of the component in the axial plane and an additional reference plane might be very helpful to solve this problem.

The relationships of the plane determined a plane that could be used as a new reference plane for axial alignment of TKA. However, very little is known about the alignment of the femoral component relative to the sagittal bowing of the femur. One of the explanations is that assessment of femoral bowing is difficult on plain radiographs and to date very few data determining and defining the femoral curvature have been reported. As a result, the positioning of the component relative to this bowing is not taken into account during the operative process.

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Materials and Methods

CT images of the pelvis and both femurs were acquired before and after 18 standard TKA procedures in 11 cadavers. Grey-value segmentation in Mimics (Materialise N.V., Leuven, Belgium) produced contours representing the bone geometry. The anatomical changes induced by the procedure were determined by linking the pre- and post-operative meshes by registration.

The determination of the femoral shaft curvature was performed on the pre-operative scans. To determine the femoral curvature, 4 different algorithms were developed. The first algorithm determined the femoral shaft axis based on rotational eigenmodes obtained from a system of springs attached to the surface of the femur. The second method was a torque-fitting algorithm and the third method used a least square best fit of a circle through the geometric centers of several femoral shaft sections. A fourth algorithm was developed based on the bisectors of two parts of the femur. The bisector method divided the femoral shaft in two equal parts along its longitudinal direction. The shaft axes of both parts were considered the chords of the curvature circle. All methods were subjected to a detailed sensitivity study. Both the stability of the curvature plane as the stability of the curvature radius were controlled.

The relationships of the plane determined by the femoral bowing circle relative to the femoral anteversion were evaluated. "Conventional" femoral anteversion was determined by the angle between the neck shaft and posterior condyles along the coronal plane whereas the same landmarks were also used to calculate the anteversion along the "curvature" plane. Assessment of correct alignment of the TKA component was done relative to the conventional landmarks such as the anatomical and mechanical axis, the trans-epicondylar, the antero-posterior axis and the posterior condylar axis.

All calculations were implemented using code written in Matlab (The MathWorksTM inc., Natick, MA, USA). For statistical analysis, the paired Student’s T-test with a confidence interval of 95% and a significant p-value of p<0.05 was used.

Results

Only the geometric center method and the bisector method produced good and reproducible results. The bisector method consistently calculated smaller curvature radii and the correlation between both methods was 0.91. The results of the varying input stability tests indicated that the stability of the curvature plane was comparable for both methods. However, the results for the stability of the curvature radius favored the bisector method. This was confirmed by a comparison of the results of the algorithms of the pre- and postoperative images. The mean curvature as measured with the bisector method was 896 mm +/- 185 mm.

The mean anteversion angle calculated along the projected mechanical or anatomical axis in the coronal plane were 8.2+/-5.2° and 7.6+/-4.8°. These angles calculated along the projected mechanical or anatomical axis in the curvature plane were 8.2+/-5.2° and 5.2+/-4.8° respectively (p>0.05).

Assessment of the component placement relative to the mechanical axis showed that in the coronal plane, an average deviation of 1.8° was measured. In the sagittal plane, the average deviation from the mechanical axis was 2.01°. The components were placed in 1 to 2° of extension relative to the femoral bowing.

Discussion

A new and stable algorithm was successfully developed to determine the curvature of the femoral shaft. This curvature was comparable to 2 previously reported curvatures. This curvature determined a plane that could be used as a new reference plane along which the anteversion angle was similar to the angle measured along the conventional coronal plane. As anteversion is determined by the angles of the neck shaft and the posterior condyles relative to a plane and the curvature plane can be reliably determined with the presented algorithm, anteversion can be back-calculated when the plane and the neck-shaft angle relative to this plane is known. The rotation of the posterior condylar axis relative to the curvature plane can then be calculated. This will allow the surgeon to accurately rotate the femoral component with navigation guidance in order to reconstruct the native anteversion angle in case the distal anatomical landmarks for correct rotational alignment are not available. Furthermore, abnormal rotational alignment of an axially maldigned component can be assessed accurately with this new reference plane. However, further research on implementing this algorithm and this plane into clinical practice is mandatory.

In addition, it was shown that the current alignment processes for a TKA work well with acceptable alignment in the coronal and sagittal planes. However most components are in slight extension relative to the femoral bowing.

There are some limitations. First, the results of this pilot study are gathered from a small population. Secondly it should be recognized that the circular curvature is a simplification of the real femoral curvature as results from the varying input suggest that the curvature of the femoral shaft decreases near its extrema.