The accuracy of image-free computer navigation in the placement of the femoral component of the Birmingham Hip Resurfacing

A CADAVER STUDY

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A cadaver study using six pairs of lower limbs was conducted to investigate the accuracy of computer navigation and standard instrumentation for the placement of the Birmingham Hip Resurfacing femoral component. The aim was to place all the femoral components with a stem-shaft angle of 135°.

The mean stem-shaft angle obtained in the standard instrumentation group was 127.7° (120° to 132°), compared with 133.3° (131° to 139°) in the computer navigation group (p = 0.03). The scatter obtained with computer-assisted navigation was approximately half that found using the conventional jig.

Computer navigation was more accurate and more consistent in its placement of the femoral component than standard instrumentation. We suggest that image-free computer-assisted navigation may have an application in aligning the femoral component during hip resurfacing.

Hip resurfacing is becoming accepted as a treatment in young patients with disabling arthritis giving excellent short-term results.1-3 Alignment of the femoral component in the coronal plane has been found to influence survival following hip resurfacing.4-6 The use of computer navigation in total joint arthroplasty is increasing. Image-free navigation systems have shown increased accuracy in alignment in both total hip and total knee replacement,7-13 and may improve the long-term outcome.

We studied the accuracy of an image-free computer navigation system in positioning the femoral component of the Birmingham Hip Resurfacing (Smith and Nephew Inc., Memphis, Tennessee).

Materials and Methods

Six paired cadaver lower limbs were obtained from patients who had not undergone previous surgery on the hip or femur. Five pairs were male and two were female. Anteroposterior radiographs were taken of all the hips to ensure that there was no deformity of the hip or femur. The control sides underwent templating using the manufacturer’s overlays with a magnification of 115% for the Birmingham Hip Resurfacing femoral component, in order to identify the position for the insertion of the alignment jig guide pin in the lateral cortex of the femur. This site is usually found to be approximately opposite the lesser trochanter. Therefore, on the templated radiographs the lesser trochanter was divided into quadrants which were used as a medial reference point on the femur opposite the point of insertion of the alignment jig guide pin in the lateral cortex. A pilot study was conducted on three synthetic femurs (Pacific Research Laboratories Inc., Boston, Massachusetts) in order to identify the most accurate reference point to place the lateral cortical alignment jig guide pin. Radiographs of the femurs were obtained and templated. A lateral cortical pin was then inserted and repeat radiographs obtained. The accuracy of using a measured distance from the tip of the greater trochanter, a measured distance from the centre of the lesser trochanter and division of the lesser trochanter into quadrants was assessed. Four quadrants were constructed by drawing horizontal lines through the most proximal and distal aspects of the lesser trochanter, then further dividing this distance by...
drawing two further equally spaced horizontal lines. This demonstrated that dividing the lesser trochanter into quadrants and using this as an intra-operative reference was the most accurate.

The control hips were operated on first to avoid introducing bias in the placement of the jig in the navigated procedure. All the operations were performed by a single surgeon (ETD) experienced in the technique. Each limb was placed in the standard lateral position, as would be done during a conventional resurfacing. A lateral incision curved posteriorly over the buttock was used to develop a posterior approach to the hip, with a complete capsulotomy in order to dislocate the femoral head. In the embalmed specimens, a more extensive approach was needed, which included the release of iliopectos but only to allow a similar exposure to that which would be expected during a conventional resurfacing. In the control group, the alignment pin was accurately placed in the lateral cortex of the femur as measured from the templates. The standard Birmingham Hip Resurfacing alignment jig was then used to place a 2.4 mm guide wire into the proximal femur (Fig. 1). The proximal femur was then prepared as for a standard Birmingham Hip Resurfacing with impaction of the femoral component. The experimental side was prepared using the VectorVision hip SR 1.0 system (BrainLab, Helmstetten Germany) to control the placement of the 2.4 mm guide wire. In order to establish a co-ordinate on the femur for real-time tracking during the procedure, a 5 mm threaded pin (BrainLab) was placed in the lesser trochanter and the optical array attached. The registration process was then performed. Four specific landmarks were registered: the medial and lateral epicondyles, the piriformis fossa, and the head-neck junction. Multiple points on the femoral head were then taken. Five clusters of points were then taken around the femoral neck (Fig. 2). The automatically generated surgical plan was then modified to place the femoral component at a stem-shaft angle of 135˚. The 2.4 mm guide wire was then inserted into the proximal femur using the navigated drill guide (Fig. 3). The femoral head was then prepared using the standard operating technique and the femoral component impacted into place.

All the femurs were then removed from the limbs and anteroposterior radiographs were taken with the femoral neck lying parallel to the radiological cassette. This was to ensure that the radiograph provided a true anteroposterior view of the femoral neck and to avoid errors in measurement due to projectional differences. The stem-shaft angle was then accurately measured from the radiographs using

Fig. 1
Photograph showing the standard jig used in control group.

Fig. 2
Photograph showing the registration process for navigation group.

Fig. 3
Photograph showing the guide wire placement using navigated drill guide.
the Magicview 300 software (Siemens Canada Ltd, Mississauga, Canada) by an experienced arthroplasty surgeon (PG). The observer was blinded to the insertion technique, and areas on the radiograph where the alignment guide pin or navigation array could have been identified were obscured. Statistical analysis was performed using the SPSS statistical package. Student’s t-test was performed to determine the significance between the two groups. A p-value of ≤ 0.05 was considered to be significant.

Results
All 12 hips were used. The navigation system was used in two left and four right hips.

The mean stem-shaft angle in the control group using the standard alignment jig was 127.7° (120° to 132°). That in the navigated group was 133.3° (131° to 139°). The mean angulations of the components were statistically different (p = 0.03).

The standard instrumentation group had a range of error of 15° (sd 4.2°). The computer navigation group had a range of error of only 8° (sd 2.9°).

The more accurate positioning obtained with computer-assisted navigation is demonstrated in Figure 4 and shows that all the control group were placed in a varus position compared with the planned stem-shaft angle.

Discussion
The importance of alignment of the femoral component in hip resurfacing was first reported by Freeman,14 who described the benefit of placing the component in a valgus position to align the component with the medial trabecular system of the proximal femur. More recently, varus malpositioning with a neck-shaft angle ≤ 130° has been associated with an increased risk of fracture of the femoral neck in the new generation of hip resurfacing arthroplasties.5,15 Biomechanical modelling has shown that this is due to an increased tensile stress in the superior neck, rendering it more susceptible to fracture.5

Our study demonstrates that the use of image-free computer navigation can improve the accuracy of placement of the Birmingham Hip Resurfacing femoral component. The standard jig consistently placed the component in a varus compared with the pre-operatively templated position. The jig also produced a greater scatter than the navigation system. This may be due to a number of factors. First, the positioning of the lateral cortical guide pin may be subject to error due to the uncertainty of the magnification of the radiograph used for templating. Secondly, there remains some play in the jig when it is attached to the guide pin placed in the lateral cortex of the femur. Lastly, the surgeon may induce a slight varus error in an attempt to avoid notchting the superior aspect of the femoral neck.

The small range of error within the navigated group may arise from the discrepancy between the long axis of the femur and the proximal third of the femur which was used for alignment measurements. The navigation system uses registration sites at the piriform fossa and the medial and lateral epicondyles to formulate a virtual model of the femur. Therefore, any angulation which may occur in the coronal plane distal to the proximal third of the femur will not be shown in our radiological measurements.

We accept that a weakness of our study is its reliance on a single observer in the recording of the component angulation from the radiographs. However, recent work has shown that the intra- and interobserver errors in the measurements of stem-angulation with respect to hip resurfacing are small compared with other radiological measurements, such as neck shaft angulation.16 The mean error in stem angulation was only 1.49° with an intraclass correlation coefficient of 0.86.16

There is evidence that computer-assisted navigation can improve the alignment of the components in total knee and hip replacement,7-13 and reduce the number of outliers. Our findings using navigation in a cadaver study for hip resurfacing improved the accuracy of placement of the femoral component and reduced the range of error by almost half. There has been limited investigation of this new application, with only one previous study being conducted on fluoroscopic-guided navigation.17 Computer-assisted hip resurfacing using CT-based navigation has been described, with excellent results.18 However, the requirement for a pre-operative CT scan may limit its general application. Our study appears to demonstrate that image-free computer navigation can provide an accurate tool without the disadvantages of needing fluoroscopic assistance or a pre-operative CT scan.

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References


