Computer navigation experience in hip resurfacing improves femoral component alignment using a conventional jig

Zachary Morison, Akshay Mehra, Michael Olsen, Michael Donnelly, Emil Schemitsch

ABSTRACT

Background: The use of computer navigation has been shown to improve the accuracy of femoral component placement compared to conventional instrumentation in hip resurfacing. Whether exposure to computer navigation improves accuracy when the procedure is subsequently performed with conventional instrumentation without navigation has not been explored. We examined whether femoral component alignment utilizing a conventional jig improves following experience with the use of imageless computer navigation for hip resurfacing.

Materials and Methods: Between December 2004 and December 2008, 213 consecutive hip resurfacings were performed by a single surgeon. The first 17 (Cohort 1) and the last 9 (Cohort 2) hip resurfacings were performed using a conventional guidewire alignment jig. In 187 cases, the femoral component was implanted using the imageless computer navigation. Cohorts 1 and 2 were compared for femoral component alignment accuracy.

Results: All components in Cohort 2 achieved the position determined by the preoperative plan. The mean deviation of the stem–shaft angle (SSA) from the preoperatively planned target position was 2.2° in Cohort 2 and 5.6° in Cohort 1 (P = 0.01). Four implants in Cohort 1 were positioned at least 10° varus compared to the target SSA position and another four were retroverted.

Conclusions: Femoral component placement utilizing conventional instrumentation may be more accurate following experience using imageless computer navigation.

Key words: Computer navigation, femoral component alignment, hip resurfacing

INTRODUCTION

Hip resurfacing arthroplasty (HRA) is a conservative alternative to total hip arthroplasty in a young and active patient, with the midterm survival reported between 95% and 96%.[1-3] Clinical outcomes in hip resurfacing have been shown to be dependent on both patient selection and surgical technique.[4-8] Femoral neck fracture remains a common failure mode in hip resurfacing and mechanical error, while preparing the femoral head has been well established as a risk factor for catastrophic neck fracture.[4,9-16]

The use of computer navigation has been shown to improve the accuracy of femoral component placement, thus reducing the likelihood of preparatory error.[17-22] Compared to conventional instrumentation, imageless computer navigation increases component alignment accuracy and reduces outliers.[23-27] There is a challenging learning curve associated with hip resurfacing, with many technical errors occurring early within a surgeon's experience.[28] The use of computer navigation has been demonstrated to reduce the length of the initial learning curve and improve the surgeon's ability to perform the procedure safely.[22]

Despite these demonstrated advantages, imageless computer navigation is sparsely used in many surgical centers. The lack of widespread use may be attributed to availability as well as cost of the navigation systems.[27] Considering the predisposition to technical error early on in hip resurfacing, it would be advantageous for the surgeon as a trainee to utilize computer-based methods to optimize the surgical technique and solidify component implantation methodology. Evidence suggests that the

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use of computer navigation in the operating room may improve the accuracy of freehand component placement in the absence of navigation.[29] Thus, there may be a role for computer navigation as a training device for novice surgeons, particularly in the context of learning challenging orthopedic procedures, to improve component implantation once navigation is discontinued.

The aim of this study was to examine whether femoral component alignment improved with conventional mechanical guidewire jig following experience with using imageless computer navigation in HSA.

MATERIALS AND METHODS

213 consecutive hip resurfacings were performed by a single surgeon (EHS) between December 2004 and December 2008. We retrospectively compared the first 17 (Cohort 1) and last 9 (Cohort 2) hip resurfacings performed using the conventional lateral pin guidewire alignment jig [Figure 1]. Cohort 1 was the surgeon's initial 17 cases of hip resurfacing, which were performed prior to our center's acquisition of an imageless computer navigation system (VectorVision SR, BrainLAB, Feldkirchen, Germany). After the center acquired the navigation system, the surgeon performed 187 hip resurfacings using the computer navigation. In December 2008, the navigation unit required replacing. In the period pending replacement of the unit, the surgeon performed nine Birmingham Hip Resurfacings (BHRs) using the conventional jig; these nine patients comprise Cohort 2. Thus, the hip resurfacings in Cohort 2 were performed after the surgeon had gained significant experience with using imageless computer navigation [Figure 2].

Of the 17 patients comprising Cohort 1, 16 patients had a preoperative diagnosis of osteoarthritis and one
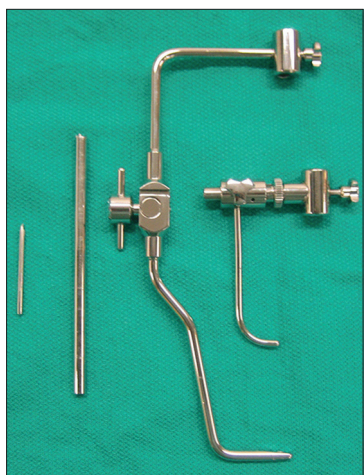

Figure 1: The Birmingham Hip Resurfacing conventional lateral pin femoral guidewire alignment jig (Smith and Nephew Inc.)

patient was diagnosed with avascular necrosis, who, as a result of this diagnosis was excluded from the analysis. The group included 14 males and 2 females. The mean age of the patients was 48.7 years (SD 6.6, range 39-63) with a mean body mass index (BMI) of 30.4 kg/m² (SD 3.9, range 23.3-40.4). Cohort 2 included nine patients all of whom were males with a preoperative diagnosis of osteoarthritis. The mean age of this group was 52.6 years (SD 10.8, range 29-71 years) with a mean BMI of 28.5 kg/m² (SD 3.0, range 25.1-34.3 kg/m$_2$). The differences in age and BMI between cohorts were not found to be significant ($P > 0.203$).

All patients received a BHR (Smith and Nephew Inc., Memphis, TN, USA) through a standard posterolateral approach. The 3-month postoperative digital anteroposterior and cross-table lateral X-rays were used for comparison. Images were obtained via a computed radiography system (DirectView CR850/950; Eastman Kodak, Rochester, NY, USA) using a standardized imaging technique and positioning protocol, and were stored on our institutional Picture Archive and Communication Systems server (Sienet MagicStore VE50; Siemens Medical, Erlangen, Germany). An observer (ZM) experienced in using digital radiograph templating software (MagicView 300, Siemens Medical) analyzed the radiographs, and was blinded to all patient data and operative dates. The component positions in both the coronal and sagittal planes were measured. The coronal stem–shaft angle (SSA) was defined as the angle subtended by the diaphyseal axis of the femur and a line drawn from the center of the prosthesis along the component stem toward the lateral cortex of the femur. The sagittal stem–neck angle (SNA) was defined as the angle subtended by the neck and component stem axis.

Measured values for component alignment were compared to the preoperatively planned position determined by the senior surgeon's (EHS) surgical protocol. The preoperative plan in each case positioned the component in 10° of valgus relative to the native neck–shaft angle (NSA) of the femur in the coronal plane and neutral to the neck axis in the sagittal plane. The component was considered neutral in the sagittal plane if the degree of component anteversion or retroversion was within 10° of the native neck version.[4]

Statistical analysis

A two-tail posthoc power analysis was conducted for each alignment variable. Descriptive statistics were calculated using Microsoft Excel (Microsoft Inc., Redmond, WA, USA) to determine differences between the final component placement and the target position. SPSS 16 (SPSS Inc., Chicago, IL, USA) was used to calculate two-sample *t*-tests for comparison of demographics as well as alignment values between the two cohorts. Statistical power was determined to be 85.2% ($\alpha = 0.05$, effect size $d = 1.02$) for the comparison of SSA.
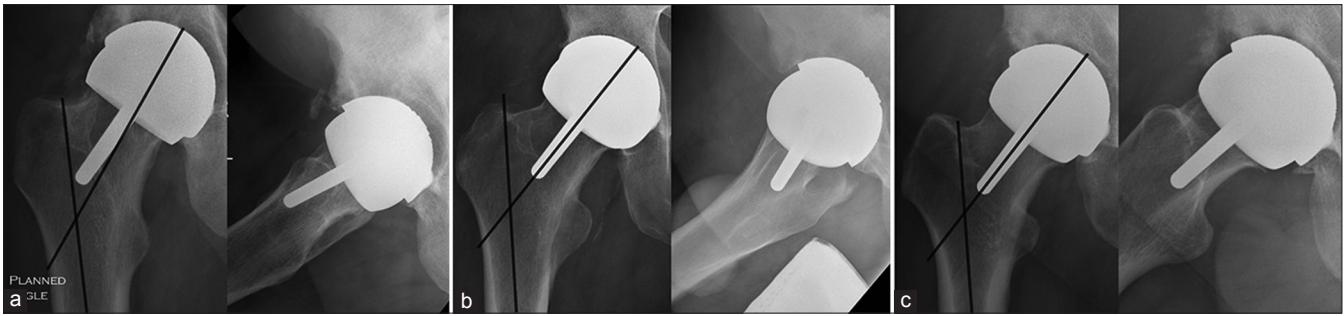
Figure 2: (a) Anteroposterior (AP) and lateral radiographs of a right BHR implanted using a conventional guidewire alignment jig prior to any experience with imageless computer navigation. (b) AP and lateral radiographs of a right BHR implanted using conventional guidewire alignment jig after experience with imageless computer navigation. (c) AP and lateral radiographs of a right BHR implanted using imageless computer navigation

RESULTS

Coronal alignment of the femoral component in Cohort 2 was more accurate than Cohort 1. The difference was statistically significant ($P = 0.01$). The mean deviation of the SSA from the target alignment was 2.2° (SD 2.2, 95% CI 0.8°-3.7°) in Cohort 2 and 5.6° (SD 4.3, 95% CI 3.6°-7.6°) in Cohort 1 [Figure 3]. The variance of Cohort 2 (4.9°, range 4° varus to 7° valgus) was threefold less than Cohort 1 (17.6°, range 14° varus to 1° valgus). The mean coronal alignment in Cohort 1 erred in varus relative to the planned SSA [Figure 3].

The component version in Cohort 2 was also more accurate than Cohort 1 [Figure 4]. This difference was also statistically significant ($P = 0.03$). The mean deviation from the target SNA of Cohort 2 had a mean difference of 4.0° (SD 2.2, 95% CI 2.6°-5.4°), while that of Cohort 1 was 7.3° (SD 5.3, 95% CI 4.8°-9.9°). The variance in Cohort 2 (27.7°, range 8.2° retroversion to 3.6° anteversion) was half that of Cohort 1 (4.7°, range 17.2° retroversion to 5.8° anteversion) [Figure 4]. Four implants in Cohort 1 were considered to be retroverted ($>10°$) [Figure 5].

DISCUSSION

Hip resurfacing provides a viable bone conserving option for a young, active patient with end-stage hip disease. In addition to patient selection, surgical technique contributes greatly to the clinical outcomes of the procedure.[5,6] In spite of many advances in surgical technique, femoral neck fracture remains a concern with hip resurfacing and continues to be the most common reason for revision.[10] The etiology of femoral neck fracture in hip resurfacing has been studied thoroughly, and although the causes are often multifactorial, the biomechanics of implant alignment play a large role in resurfacing construct strength and resilience. Previous biomechanical studies investigating implant alignment have shown that relative valgus alignment of the femoral
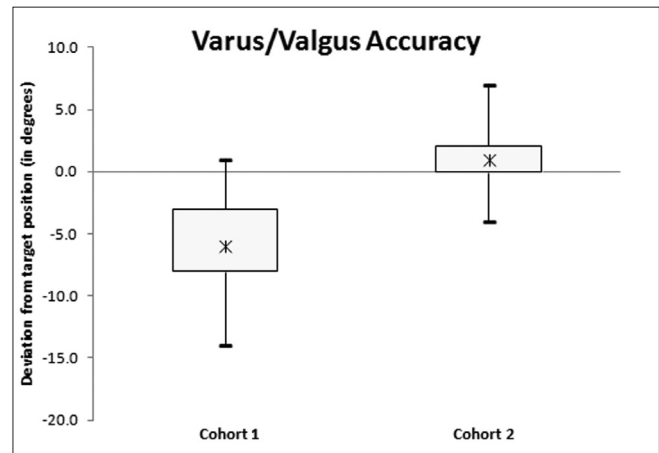

Figure 3: Box and whisker plot of stem–shaft angle accuracy for the two conventional jig cohorts (negative values denote relative varus and positive values denote relative valgus)
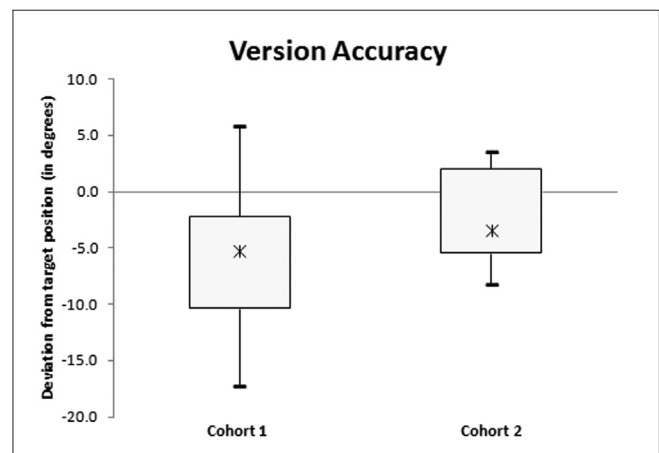

Figure 4: Box and whisker plot of stem-neck angle accuracy of the two conventional jig cohorts (negative values denote retroversion and positive values denote anteversion)

component strengthens the proximal femur and may be protective against neck fracture.[4,11,14,30] In addition, studies looking at femoral neck notching have demonstrated that as little as a 2-mm superior femoral neck notch may increase the risk of neck fracture.[9,11,30] Despite this knowledge,
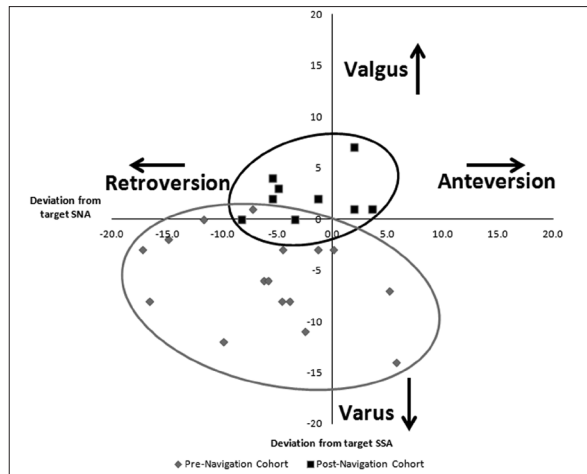
Figure 5: Comparison of the accuracy of implant positioning using a conventional jig between the pre and post navigation cohorts

notching of the femoral neck and femoral components implanted in relative varus are still encountered, particularly during the surgical learning period for this procedure.[7,28,31,32] These adverse events may be attributed to the difficulty of the procedure or the lack of experience of the surgeon.

In this study, we found that the cohort of hip resurfacing patients following experience using computer navigation (Cohort 2) was more accurate and showed less variance in component positioning. The mean SSA for Cohort 2 was 3.4° less than the mean SSA for Cohort 1. This decrease in mean SSA for component positioning results in a decrease of stress across the superior neck, potentially reducing the risk of femoral neck fracture.[12] Further, improved accuracy of positioning in the sagittal plane may theoretically reduce the risk of impingementn [Figure 5].

It has been well documented that computer-assisted surgery by way of imageless navigation functions to curtail femoral implant malalignment in hip resurfacing.[19,21,22,26] However, the cost and availability of current navigation systems make ubiquitous use unrealistic, particularly for those centers that perform only small volumes of hip resurfacings. In order for surgeons new to hip resurfacing to perform optimally using conventional instrumentation, it may be necessary to first train using computer-assisted methods in order to enhance both surgical technique and component insertion protocol. A concern of using computer navigation for training purposes is reliance on the technology with poor retention performance following discontinuation.[33] Thus, this study looked to establish whether femoral component implantation accuracy utilizing a conventional guidewire alignment jig improves following the use of imageless computer navigation in HSA. In this study, Cohort 1 was the senior surgeon's initial experience with hip resurfacing.

A limitation of this study is the inability to account for the learning process that would occur normally after performing a series of hip resurfacings. In a study by Seyler *et al.*, fellowship trained staff surgeons with experience in hip resurfacing (>75 cases) exhibited a greater scatter of insertion angles when using conventional instrumentation than less experienced residents using imageless navigation as a surgical aid.[22] This not only demonstrates the accuracy of computer navigation but also that experience alone may not prevent a greater degree of inaccuracy when using conventional manual instrumentation. A second limitation is that the number of resurfacings performed using a conventional jig is small relative to the number performed using computer navigation. The optimal number of procedures to achieve competency and a higher level of accuracy using conventional guidewire alignment jigs may be smaller than in the current study. Further investigation is required to determine the ideal number of training cases required in order to obtain proficiency using conventional instrumentation in hip resurfacing. Lastly, the lateral pin jig utilized in this study may not be representative of other guidewire alignment devices. The results of this study may not be extrapolated to other conventional guidewire alignment jigs in hip resurfacing.

In this study, all femoral components implanted with a manual jig after acquiring experience using imageless navigation achieved the desired minimum of 10° of valgus relative to the native NSA and all were considered to have neutral SNA angles. This is compared to three implants which were positioned more than 10° varus relative to the target SSA and another four which were considered retroverted in the group performed prior to experience using navigation. The improved use of the manual jig may be attributable to an increased familiarity with the location of the optimal guidewire insertion point. Often the native anatomy of the end-stage hip disease patient is distorted with osteophytes and remodeled bone which can prove problematic when using a manual jig, as alignment and positioning depend largely on a visual assessment of the local anatomy for guidewire placement.

The results from this study show improved accuracy and precision using a conventional guidewire alignment jig after training with computer navigation. This improvement conflicts with the literature on cognitive motor learning which suggests that the form of feedback that computer-assisted surgery provides may actually be detrimental to learning.[34] According to motor learning theory, individuals learn new motor skills by evaluating available feedback to alter future performance. Feedback can either be intrinsic (as a natural consequence of the action) or extrinsic (from an external source such as an instructor or a computer). Computer navigation provides a form of extrinsic feedback, or

continuous concurrent feedback, in which continuous visual feedback guides the trainee to the correct position, thus minimizing errors and reinforcing proper technique. It has been hypothesized, however, that concurrent feedback does not contribute to retention of task performance as a result of the learner developing dependence on extrinsic feedback or being distracted from using intrinsic feedback.[34,35] In contrast, a prospective randomized study by Gofton *et al.* analyzing the effect of computer navigation on the learning of surgical skills by trainees demonstrated that concurrent feedback during the insertion of the acetabular cup in hip replacement did not compromise the learning process of trainees.[36] This finding is supported by a systematic review by Saithna and Dekker looking at the influence of computer navigation in hip resurfacing training in which they concluded that there exists minimal evidence to support concerns regarding the detrimental impact of computer navigation on trainee learning and subsequent performance in hip resurfacing.[33]

The study demonstrates that femoral component placement utilizing conventional instrumentation may be more accurate following experience using imageless computer navigation. Training or experience using computer navigation may provide the surgeon with appropriate feedback to facilitate adequate motor skill acquisition and spatial awareness that can be transferred in turn to conventional instrumentation. The success of hip resurfacing is particularly sensitive to surgical technique and component alignment; training with computer navigation early in the learning curve may help optimize the subsequent use of conventional hip resurfacing instrumentation. Larger studies are required to provide more robust evidence.

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