Avoiding Short-term Femoral Neck Fracture With Imageless Computer Navigation for Hip Resurfacing

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Abstract

Background Femoral neck fracture in hip resurfacing has been attributed to technical error during femoral head preparation. In the absence of fracture, several radiographic findings have been speculated to increase the risk of femoral component failure.

Questions/purposes We examined whether (1) the use of navigation to reduce technical errors during femoral head preparation reduces the incidence of femoral neck fractures in the short-term followup period; and (2) alignment of the femoral component with the use of computer navigation reduces the incidence of femoral neck thinning, femoral stem radiolucencies, and stem migration.

Methods We retrospectively reviewed the first 100 Birmingham Hip Resurfacings performed in 94 prospectively followed patients between October 2005 and November 2007. We examined all radiographs on last followup. Eighty-six patients of the 94 patients had a minimum followup of 2 years (mean, 2.5 years; range, 2–4.1 years).

Results There were no cases of femoral neck notching, varus femoral component alignment, or femoral neck fractures in the series. Neck thinning of greater than 10% was observed in three patients and perimetaphyseal stem lucencies were noted in 10 patients. In three patients, the metaphyseal stem showed varus migration relative to the postoperative stem-shaft angle at latest followup. There was one revision to a total hip arthroplasty for deep sepsis. The overall survivorship at 4 years was 99%.

Conclusions The use of imageless computer navigation to reduce technical errors in hip resurfacing may reduce the incidence of femoral neck fracture in the short-term. However, neck thinning, stem radiolucencies, and stem migration remain radiographic sequelae of hip resurfacing despite the use of navigation for placement of the femoral component.

Level of Evidence Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Introduction

Hip resurfacing is an alternative to THA for the young, active patient with reported midterm survivorship of 95% to 96% [17, 29, 37]. Advantages of hip resurfacing include preservation of metaphyseal and diaphyseal bone, improved joint stability, and favorable wear characteristics of a metal-on-metal articulation. There are concerns, however, regarding complications associated with the procedure, including pseudotumors [12, 27], aseptic implant loosening [1, 3], and femoral neck fracture [20, 36] as well as the unknown long-term implications of increased blood metal ion levels [13, 18].

Computer-assisted surgery is gaining popularity in hip resurfacing arthroplasty and specifically, imageless

navigation provides the surgeon an accurate and reliable method for femoral component placement [7, 31]. When compared with conventional instrumentation, imageless navigation reduces the incidence of femoral neck notching and the occurrence of component alignment outliers [11, 14, 30, 32]. Navigation may help to minimize the occurrence of technical errors and diminish the learning curve associated with hip resurfacing enabling surgeons earlier proficiency in the procedure [33].

Femoral neck fracture remains the dominant failure mode in hip resurfacing accounting for more than one-third of failures [5]. Although the etiology of neck fracture has not been entirely elucidated, it is often associated with femoral head preparation error, including femoral neck notching and varus implant alignment [2, 8, 34]. Femoral neck fracture is typically a short-term phenomenon occurring within the first year postoperatively [2, 34, 36]. Second to fracture, aseptic implant loosening accounts for nearly one-third of failures [5] and typically follows a longer time course to onset. Adverse radiographic findings that have been associated with increased risk of femoral component failure include femoral neck thinning [22], femoral stem radiolucencies [4], and femoral stem migration [19]. Whether component alignment is associated with progression of aseptic loosening remains unclear.

We therefore examined whether (1) the use of navigation to reduce technical errors during femoral head preparation reduces the incidence of femoral neck fractures in the short-term follow-up period; and (2) alignment of the femoral component with the use of computer navigation reduces the incidence of radiographic sequelae of hip resurfacing, including femoral neck thinning, femoral stem radiolucencies, and stem migration.

Patients and Methods

We retrospectively reviewed the first 100 Birmingham Hip Resurfacings performed in 94 prospectively followed patients between October 2005 and November 2007. During that time, we performed 214 conventional THAs. General inclusion criteria for patients receiving hip resurfacing were males younger than 65 years and females younger than 55 years with adequate hip anatomy to accept the prostheses. Women of childbearing age or considering pregnancy were contraindicated. Ninety-three patients (96 hips) had osteoarthritis and three patients (four hips) had osteonecrosis. Three patients had anatomical deformities which we judged unsuitable for a stemmed total hip prosthesis and hip resurfacing was opted for as previously described [26]. Of these three patients, two had blade plates in situ from previous femoral fracture fixation or osteotomy and one patient had a severe varus proximal femoral

deformity. There were 77 males and 17 females. The mean age at the time of surgery was 51 years (SD 8.7; range, 25–82 years) and mean body mass index was 29.5 kg/m² (SD 5.2; range, 20.4–51.9 kg/m²). Two of the 94 patients were lost to followup. The minimum followup was 2 years (mean $\pm$ SD, 2.5 $\pm$ 0.5; range, 2–4.1 years). Eight patients had minimum 1-year followup data but failed to attend the 2-year followup and have been excluded from the analysis. Six patients were unable to attend a followup clinic at 2 years and were contacted by telephone to discuss their progress. Thus, 86 patients (90 hips) were followed clinically for a minimum of 2 years with radiographs available for 80 patients (84 hips). Each patient was prospectively monitored clinically and radiographically at followup periods of 6 weeks, 3 months, and 6 months postoperatively and annually thereafter. The study was approved by our Institutional Ethics Board.

All operations were performed by the senior author (EHS). A detailed description of the operative technique, including the use of imageless navigation for insertion of the initial femoral guidewire, has been previously described [25]. Digital templating was carried out before each operation. The native neck-shaft angle (NSA) and planned stem-shaft angle (SSA) and femoral component size were determined for use during intraoperative navigation. A standard posterolateral approach was used in all cases with the static navigation array fixed to the lesser trochanter. After impaction of the acetabular component, the patient's femur was registered using a dynamic navigation array. A patient-specific morphed model was created by the navigation system (Vector Vision SR 1.0; BrainLAB, Heimstetten, Germany) and used to plan the position and orientation of the femoral component. A navigated drill guide was used to insert the initial guidewire into the femoral head according to the planned component position. The remainder of the standard surgical protocol was used for preparation of the femoral head and implantation of the femoral component. A Birmingham Hip Resurfacing was implanted in all cases (Smith and Nephew Inc, Memphis, TN).

A single observer (MO) evaluated coronal stem alignment using digital AP unilateral hip radiographs. SSA was defined as the angle subtended by the diaphyseal and component stem axes [24]. Measured SSAs at latest followup were compared with the SSAs measured at 3 months postoperatively [25] to assess stem migration. Stem angulation was considered unchanged if measurement of SSA at latest followup was within 3°. This is the error in measurement anticipated as the result of minor rotational errors during radiography and intraobserver error during measurement [24]. Component version was evaluated at latest followup using digital crosstable lateral hip radiographs. The stem-neck angle (SNA) was defined as the angle

Fig. 1A–B Postoperative radiographic analysis was conducted to assess (A) stem-shaft angle (SSA), neck width, and metaphyseal stem radiolucent zones; and (B) stem-neck angle (SNA) in assessment of femoral component version.

subtended by the neck and component stem axes [23] and was considered neutral if the anteversion or retroversion value was less than 10° [1]. Femoral fixation was evaluated using the grading scale devised by Amstutz et al. [1]. A scoring system of 0 to 9 was used to evaluate radiolucencies in three zones around the metaphyseal alignment stem (Fig. 1). Femoral neck narrowing was evaluated at latest followup by AP radiographs using the method of Spencer et al. [35] and compared with that of the 3-month postoperative radiographs.

Descriptive statistics for the series were determined using Microsoft Excel (Microsoft Corporation, Redmond, WA). Kaplan–Meier survival analysis was performed using the statistical software package STATA 10 (StataCorp LP, College Station, TX).

Results

There were no cases of femoral neck fracture in the series. Assessment of femoral component version showed the SNA as neutral in all cases. As previously reported, there were no cases of femoral neck notching or absolute varus implant alignment assessed intraoperatively or at 3 months postoperatively [25]. The mean SSA at 3 months postoperatively was 11.7° of relative valgus to the native NSA of the femur (SD 3.9, range, 1° – 22°). The SSA assessed at latest followup showed no deviation (mean -0.6° , SD 1.9, range, -3° to 3°) in 96% of patients (81 of 84 hips) (Fig. 2). In three patients, the metaphyseal stem showed relative varus migration of between 7° and 16° relative to the postoperative SSA (Fig. 3). Detection of varus

Fig. 2 A radiograph of a patient with previous blade plate at 27 months after resurfacing is shown. No signs of neck thinning, stem radiolucency, or stem migration were noted.

migration was first noted between 16 and 24 months postoperatively. At latest followup (30–38 months), the patients were pain-free and asymptomatic.

Neck thinning of greater than 10% was observed in three patients (3.6%). Two patients had neck thinning of -13% at 24 and 43 months. In addition to relative varus stem migration, the third patient demonstrated -17% neck thinning at 16 months that recovered to -14% at 30 months (Fig. 3).

Fig. 3A–B Patient radiographs demonstrating signs of neck thinning, lucent lines, and relative varus stem migration are shown at (A) 3 months postoperatively; and (B) 16 months postoperatively demonstrating -17% neck thinning, lucencies in Zones 1 to 3, and relative varus stem migration of 16° . At 30 months postoperatively, the patient is pain-free and asymptomatic with no further radiographic evidence of stem migration. The degree of neck thinning has recovered from -17% at 16 months to -14% at latest followup.

Fig. 4 A patient radiograph demonstrates radiolucencies in all three zones around the metaphyseal stem corresponding to a radiolucency score of 8.

Perimetaphyseal stem lucencies were noted in 10 patients (11.9%) (Fig. 4). Five patients had a radiolucency score greater than 7 with three of the patients scoring 9 corresponding to lucencies in all three zones and stem migration. Evidence of reactive sclerosis in Zone 2 was noted in an additional three patients. At latest followup (24–35 months), the three patients were doing well and were asymptomatic.

Seven complications occurred in the series. There were two superficial wound infections, one postoperative bowel obstruction, one patient with a squeaking hip, one patient had elevated metal ion levels, one patient had erosion on the inferior aspect of the femoral neck resulting from local

impingement on the acetabular component, and one patient had deep joint sepsis. The latter patient underwent a two-stage revision to a THA 15 months after the index procedure. There were no other revisions. Kaplan–Meier survivorship analysis for the femoral component showed an overall survival rate of 99% (95% CI, 92.4%–99.8%) at 4 years.

Discussion

Midterm survivorship in hip resurfacing has been reported between 95% and 96% [17, 29, 37]. If the femoral component fails, it is often the result of femoral neck fracture or aseptic loosening. The former is a catastrophic event that occurs early in the course of recovery, whereas the latter occurs over time, often with radiographic evidence of its progression. Computer navigation reduces technical errors and outliers during preparation of the femoral head but there exists little evidence that the use of navigation prevents failure of the femoral component in the short-term. The aim of this study was to examine whether (1) the use of navigation to reduce technical errors during femoral head preparation reduces the incidence of femoral neck fractures in the short-term followup period; and (2) alignment of the femoral component with the use of computer navigation reduces the incidence of femoral neck thinning, femoral stem radiolucencies, and stem migration.

We acknowledge limitations of this study. First, we had only one observer for the radiographic measurements. The measurements of SSA and neck narrowing are reportedly repeatable [24, 35]; however, there are no studies to

support the same assertion for the assessment of perimetaphyseal stem radiolucencies or the measurement of femoral component version. Second, eight patients did not attend the 2-year followup but had minimum 1-year followup data. At 1 year, these patients were asymptomatic and none had radiographic signs of neck thinning, stem radiolucencies, or stem migration. Third, this study only investigated navigation for placement of the femoral component. The authors recognize the importance of acetabular orientation to the function and longevity of the joint couple. Further investigation of navigation for the acetabular component in hip resurfacing is warranted.

Hip resurfacing is described as a technically demanding form of hip arthroplasty and is associated with a steep learning curve [10, 21]. The majority of failures occur relatively early in a surgeon's experience and are often attributable to catastrophic femoral neck fracture. Della Valle et al. examined the initial American experience with hip resurfacing among a group of 89 surgeons who performed a total of 537 hip resurfacings [10]. Thirty-two major complications occurred within the first year post-operatively. There were 10 femoral neck fractures. Eight fractures occurred within the first six cases performed by the surgeon with two of those being the surgeon's first case. No cases of femoral neck fracture occurred in our series of navigated hip resurfacings at a maximum followup of 4.1 years. This series includes our initial learning curve with imageless computer navigation. Although we have previously shown that there was a learning curve with respect to a reduction in the length of time taken to navigate the femoral guidewire [25], no such learning curve existed for femoral component implantation accuracy [25]. This is in contrast to the findings of Nunley et al. who showed that although the rate of complications fell after the first 25 cases, it was not until beyond 100 cases before the desired femoral component position (avoidance of varus implant alignment) was achieved radiographically [21]. The findings of the current study support the use of imageless navigation as a tool to minimize the learning curve associated with hip resurfacing. In addition to prudent patient selection, the authors attribute the lack of femoral component failures to the avoidance of technical error as facilitated by navigation.

Three patients in the series (3.6%) exhibited neck thinning of greater than 10%. This figure agrees with the findings of Amstutz and LeDuff [3] in which neck thinning was noted in 2.8% of patients (21 of 753 hips); however, other studies have observed neck thinning exceeding 10% in as much as 28% of cases [16]. Neck thinning may be the initial result of stress shielding of the femoral component but appears to demonstrate a plateau effect beyond 2 years [35]. Two of the three patients in our series have followup beyond 2 years and both demonstrate stabilization in the

degree of neck thinning observed. Although the etiology of neck thinning remains unclear, this phenomenon has not alone been associated with an increasing risk of fracture of the femoral neck, functional impairment, or failure in the short-term [6, 9, 16, 34].

Three patients in the series (3.6%) showed relative varus stem migration of between 7° and 16°. This is less than that demonstrated by Pollard et al. who noted 9.6% of patients (five of 52 hips, four varus and one valgus) with stem migration [28]. Of these, only one was revised and they speculated that osteonecrosis was the underlying cause for the radiographic changes noted. Analyzing their first 230 hips, Hing et al. showed there was an overall absolute varus alignment of the femoral component (0.8°) at a mean followup of 5 years compared with an overall absolute valgus alignment (2.9°) at 3 years followup [15]. They noted that 8% (18 of 220 hips) of femoral components had migrated into greater than 5° of absolute varus alignment but showed no association of varus stem alignment with adverse clinical outcome. The authors are unclear at this time as to the prognostic value of varus stem migration on subsequent component failure and continue to closely monitor the three patients in our series with this finding.

Avoidance of femoral head malpreparation is vital in minimizing the risk of femoral neck fracture after hip resurfacing. Imageless computer navigation facilitates accurate and repeatable valgus orientation of the femoral component while avoiding femoral neck notching and varus malalignment. The use of imageless navigation to reduce technical errors may also reduce the incidence of femoral neck fracture in the short-term. However, neck thinning, stem radiolucencies, and stem migration remain radiographic sequelae of hip resurfacing despite the use of navigation for placement of the femoral component.

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