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Navigating the Reaming of the Acetabular Cavity in Total Hip Arthroplasty: Does it Improve Implantation Accuracy?

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ABSTRACT

Computer navigation in total hip arthroplasty is used to improve accuracy of component implantation. Reaming of the acetabular cavity during total hip arthroplasty (THA) can be navigated although this is not done routinely. We hypothesised that navigating the reaming of the acetabular cavity will improve implantation accuracy. A single surgeon series of 100 navigated THAs were analysed retrospectively. In 49 the reaming of the acetabular cavity was done using navigation and in 51 this was done freehand. The verified cup position and the error from the planned position were recorded. The mean error from planned to verified inclination was 2.20 degrees (SD 1.59°) in the navigated group versus 2.33 degrees (SD 1.96°) in the freehand group. The mean anteversion error was 1.92 degrees (SD 1.51°) for the navigated group and 1.45 degrees (SD 1.38°) for the freehand group. This was not statistically significant. This rejects our hypothesis. Navigating the reaming of the acetabular cavity did not improve the accuracy of the implantation against the set inclination and anteversion target during computer navigated THA.

The number of total hip arthroplasties performed per year is increasing. 80314 hip arthroplasty procedures were recorded in the National Joint Registry in England and Wales in 2011, representing a 5% increase over the year before [1]. Preventing complications and improving function and longevity of hip arthroplasty has been the main focus of arthroplasty research for decades. The importance of component positioning was identified early and was associated with postoperative range of movement [2], wear and osteolysis [3,4] as well as dislocation [5].

The optimal component positioning has been previously described in both retrospective clinical trials with a focus on dislocation [5] as well as modern mathematical models looking into impingement and range of movement [6]. However, there is significant variation in component positioning and the factors associated with suboptimal implantations have been identified [7]. Furthermore, recent developments in hip arthroplasty have highlighted the complexity of the ideal component positioning, its effect on impingement and new concepts such as the combined femoral and acetabular anteversion [8].

Computer assisted surgery was introduced in hip arthroplasty to improve the accuracy of component implantation. It provides real-time feedback to the surgeon regarding component orientation, position in space as well as several other parameters of interest such as range of movement. Navigation can be image based or imageless [9]. Recent meta-analyses have confirmed that navigation improves the precision of component alignment by reducing the number of implantations outside the recommended safe zones (outliers) [10,11].

Implantation of an uncemented acetabular component involves preparation of the acetabular cavity with reamers followed by impaction of the component. Using computer navigation both of those steps can be navigated although commonly this is only done for the impaction step. Each of those steps can potentially affect the final position of the cup and lead to deviation from the planned position.

The ability to ream the acetabular cavity in the exact orientation of the planned acetabular component placement may improve the accuracy of implantation towards the planned position. The purpose of this study was to compare the effect of navigated versus freehand acetabulum reaming on achieving the planned orientation of acetabular component. The hypothesis was that navigating the reaming process would improve the accuracy of the verified cup position after implantation towards the planned position.

Materials and Methods

Patients who underwent computer navigated total hip arthroplasty by a single surgeon (ETD) were analysed retrospectively.

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Imageless computer navigation was used for all cases (Hip Navigation System 5.1, Brainlab AG, Munich). Placement of the acetabular component was navigated with reference to the anterior pelvic plane. The software utilises a range of movement algorithm to calculate the optimal cup position which is set as the target. This is referred to as the planned inclination and anteversion target. The implantation of the cup is then navigated towards the planned position. The reference system used by the navigation unit is the radiographic coordinate system as defined by Murray [12]. The patients were divided into two groups depending on the technique used during reaming of the acetabular cavity. The decision to proceed with navigating the reaming or not was based on the availability of the required instruments. These were available in some of the navigated THA instrument sets but not all. The planning of the operating list did not take this into account.

All procedures were performed through a standard posterior approach. The acetabular cavity was reamed “line to line” or under-reamed by 1 or 2 mm according to the intraoperative judgment of bone quality by the surgeon. Two types of acetabular components were used in this study, the R3 (Smith & Nephew, Leamington Spa, UK) and the Pinnacle cup (DePuy, Warsaw, IN). Both are porous coated, hemispherical outer shell cups manufactured from Titanium alloy (Ti-6AI-4V). The cup was impacted using a navigated impactor that securely attaches to the thread in the centre of the cup. The planned acetabular component abduction and anteversion angles as well as post impaction intra-operative verification figures were recorded using the navigation system. The absolute value of the error from the planned position was used for the analysis.

All patients were reviewed in a routine follow up clinic at 6 weeks and an AP pelvis radiograph was acquired as per standard protocol. These AP radiographs were assessed for acetabular component inclination defined by an angle between horizontal tangent drawn along both ischia (or the inter-teardrop line) and along the axis of an ellipse formed by acetabular component projection on radiograph. The person taking the radiograph measurements was blinded to the reaming method used. These results were compared with the intra-operative verification values recorded by the navigation unit, which are also in the radiographic coordinate system.

Institutional Review Board approval was granted for this retrospective study.

Statistical Analysis

Data were assessed for normality using the Shapiro–Wilk test. The Student’s t-test and the Mann–Whitney U test were used to compare parametric and non-parametric data accordingly. Statistical analysis was performed using SPSS statistics 17.0.1 (SPSS Inc., Chicago, IL). A *post hoc* power analysis was performed based on an effect size of independent interest [13]. The effect size for our population was calculated based on the descriptive statistics of our sample. A sample size calculation based on a two-tailed t-test for a calculated effect size of interest (Cohen’s d) was performed using an online calculator (http://www.danielsoper.com/statcalc3/default.aspx).

Results

A series of one hundred patients underwent primary THA using navigation, mean age of patients was 66 years (range 35–80 years). In 49 the acetabular cavity was reamed using computer navigation and in 51 this was done freehand. There was no statistically significant difference between the groups in terms of age, cup size, and reaming “line to line”, Table 1.

Table 1
Parameters of Interest between Groups.

	Navigated Reaming	Freehand Reaming	*P* Value
Mean Age (SD)	66 (11.3)	66 (8.6)	0.455[a]
Mean Cup Size (SD)	52.9 (3.5)	53.3 (3.4)	0.272[a]
Ream to Line (%)	10 (20%)	18 (35%)	0.097[b]

[a] Mann–Whitney U test.
[b] Chi squared test.

In the navigated reamer group, the mean error from the planned to verified inclination angle was 2.20 degrees (SD 1.59°) versus 2.33 degrees (SD 1.96°) in the freehand group. The mean error from the planned to verified anteversion angle was 1.92 degrees (SD 1.51°) for the navigated group and 1.45 degrees (SD 1.38°) for the freehand one. This is graphically presented for inclination and anteversion in Fig. 1. Table 2 includes all the alignment parameters of interest.

There was no statistically significant difference in the mean error (planned minus verified position) between the navigated and non-navigated reaming groups for the inclination ($P = 0.885$) or anteversion ($P = 0.079$) (Mann–Whitney U test).

Radiographic analysis showed mean abduction of 39.7 degrees with a difference of 1.81 degrees from intra-op verification in navigated reamer group. In the freehand group mean abduction on radiographs was 40.3 degrees with a difference of 1.67 degrees from intra-op verification. The difference between the x-ray recorded inclination and intraoperative verification did not reach significance between the navigated and freehand groups ($P = 0.373$).

Our *post hoc* analysis involved a calculation of an independent effect size for a clinically relevant difference between the groups. For this calculated effect size (Cohen’s d), a sample size calculation was performed based on a two-tailed t-test. The sample size of our study would suffice to identify a difference of 0.8 degrees of anteversion and 1 degree of inclination between the planned and verified positions at a power of 80% with an alpha level of 0.05.

Discussion

The aim of this study was to investigate the effect of navigating the reaming of the acetabular cavity on the accuracy of component implantation in imageless navigated total hip arthroplasty. Our hypothesis was that improved alignment of the cavity may reduce deflection of the cup during impaction hence improving accuracy.

The main limitation of our study is its retrospective nature and lack of true randomisation. The decision to proceed with navigating the reaming or not was related to the availability of the instrumentation in the instrument tray to be used. This was a random occurrence and was known to the surgeon at the time of planning the operating list.

Our study showed no difference in the accuracy of the acetabular component implantation, against the planned position, when using navigated reaming. This rejects our hypothesis. Our *post hoc* power analysis showed that our study was adequately powered to reveal an error of 0.8 degrees of anteversion and 1 degree of inclination from the planned position (power 80%, alpha level of 0.05). We would argue that the power of the study was adequate as identifying errors of under 1 degree has no clinical relevance.

This is the first study to our knowledge to report on the effect of navigation during reaming the acetabular cavity.

The cup position has received great attention in recent years due to the understanding that the surgeon is unable to adequately control the final position of the uncemented stem [2,14]. When using a cemented stem, the anteversion of this can be controlled, therefore one can aim for “safe zones” during implantation of the cup. Due to the variability of the stem version in uncemented hip arthroplasty, the cup position may need to be adjusted further [15]. The concept of combined anteversion has been introduced in the 1990s and its importance on stability as well as impingement and edge loading, such as in metal on metal hip resurfacing, have been described [8,16,17]. The combined anteversion concept can be further modified to optimise the component orientation with respect to offset, cranial/