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Independent Evaluation of a Mechanical Hip Socket Navigation System in Total Hip Arthroplasty

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A B S T R A C T

Background: Acetabular cup malpositioning during total hip arthroplasty may lead to impingement, instability, wear-induced osteolysis, and increased rates of revision surgery. The purpose of this study was to independently evaluate the accuracy of acetabular cup orientation using a novel mechanical navigation device.
Methods: An adjustable, reusable mechanical navigation device was used in a consecutive series of patients. Angles (inclination and anteversion) were measured by 2 independent reviewers with a validated 2-dimensional/3-dimensional matching application using a preoperative computed tomographic scan and a postoperative plain film.
Results: There were no outliers for inclination or anteversion for errors within 10° of the preoperative plan. There were 6 (12.8%) outliers for inclination and 11 (23.4%) for anteversion for errors within 5° of the preoperative plan. All patients simultaneously met both targets when an outlier was considered 10°, whereas 30 (63.8%) simultaneously met both targets when the criteria was tightened to 5°. The absolute errors for both inclination and anteversion were significantly less than both 5° and 10° ($P < .001$).
Conclusion: This device reliably navigates acetabular cup inclination and anteversion individualized for each patient to within 10° of a preoperative plan. Outliers increased when this criteria is tightened to 5° but still appears to be more accurate than conventional acetabular cup component placement. Further research is warranted to assess the clinical impact of reducing outliers using this device.

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Acetabular cup malpositioning during total hip arthroplasty (THA) may lead to impingement, instability, wear-induced osteolysis, and increased rates of revision surgery [1–6]. Reported rates of outliers using conventional alignment methods vary, but may be greater than 50% [7–9]. The frequency of error is reduced through the use of computer-assisted surgical navigation, but its use has not been widely accepted due to complexity and cost [4].

Recently, a novel mechanical navigation device (HipSextant; Surgical Planning Associates, Medford, MA) was developed to assist with cup orientation [10]. We began using this device at our institution in an attempt to create reproducible acetabular cup orientation. The accuracy of this system is validated by the design surgeon [10], but has not been evaluated by others. The purpose of this study was to independently evaluate the accuracy of acetabular cup orientation using this mechanical navigation device.

Materials and Methods

We retrospectively assessed planned preoperative vs postoperative cup orientation in a series of 50 patients (54 hips) who underwent primary THA using a mechanical navigation device (HipSextant; Surgical Planning Associates) between January 2013 and October 2013. Inclusion criteria were all patients who had a primary THA with the HipSextant mechanical navigation device to assist with cup orientation and had appropriate follow-up radiographs to allow for preoperative and postoperative comparisons as defined below. Exclusion criteria were those patients without appropriate follow-up radiographs. In addition, in an attempt to limit measurement error, we only analyzed one acetabular cup in our series. The institutional review board at our institution approved this study. There was no source of external funding for this study.

This unique mechanical navigation device is an adjustable, reusable frame that is applied to specific points on the pelvis during surgery.

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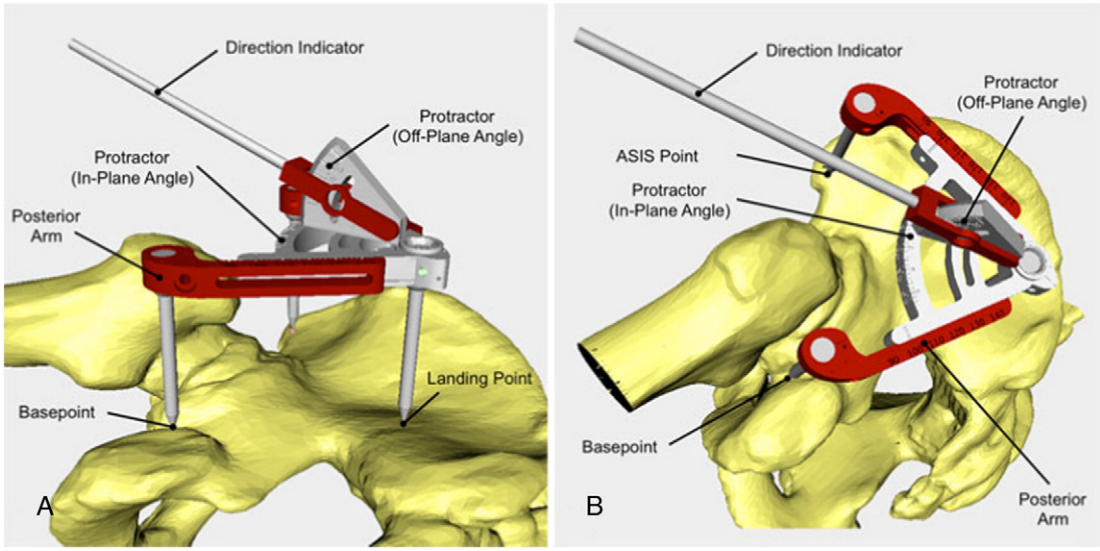

Fig. 1. A and B, The mechanical navigation system is defined by 3 points: the base point, the ASIS point, and the landing point. Permission granted from Steppacher et al [10].

The planes and anatomic landmarks for this mechanical navigation device have previously been described [10]. The first point (base point) is just outside the posterior wall of the acetabulum 20 mm above the infracotyloid notch. A distance guide is used to help define this point intraoperatively. The second point (ASIS [anterior superior iliac spine] point) is located on the lateral ilium just adjacent to the ASIS. The final point (landing point) is on the surface of the ilium, anterior to the sciatic notch, and equidistant from the first 2 points (Fig. 1A, B).

Preoperative Evaluation

All patients had a preoperative computed tomographic (CT) scan using a specific protocol that limits radiation, which includes the pelvis and a portion of the knees. A virtual model of the pelvis is constructed, and based on the patients individualized anatomy, a default ideal acetabular socket position is established by the vendor. This position is adjustable by the surgeon either before or during surgery by use of a Web-based computer application.

Surgical Procedure

A single surgeon performed all of the cases through a posterior approach in the lateral decubitus position. Appropriate exposure and preparation of the acetabulum was performed in the standard fashion. The base point was then identified as previously described [10] using a calibrated drill guide and threaded guide wire. The base point leg of the HipSextant was then placed over the guide wire. The ASIS was then identified and percutaneously insertion using the designed trocar was performed through the lateral aspect of the ASIS. Lastly, another trocar was placed through a third cannula percutaneously onto the surface of the ilium to determine the landing point. The surgeon then impacted the acetabular component with the insertion handle aligned visually with the direction of the indicator (Fig. 2). The same cementless, press-fit, fully hemispheric titanium alloy acetabular component was used in all patients.

Postoperative Evaluation

To determine cup inclination and anteversion, 2 independent readers compared the preoperative planned values with the postoperative measured cup orientation using a 2-dimensional/3-dimensional matching application [11] (HipMatch; Institute for Surgical Technology and Biomechanics, Bern, Switzerland) and the average of the 2 measures were used for statistical comparisons. This application uses a fully automated registration procedure that can match the 3-dimensional model of the preoperative CT scan with the projected pelvis on a postoperative radiograph that includes the ASIS and iliac crest superiorly. Validation of this software has previously been described [12]. For the purpose of this study, an outlier was defined outside of a range of $\pm 10^\circ$ of inclination and/or anteversion from the planned orientation based on the original publication of this navigation system [10]. In addition, we also evaluated outliers outside of $\pm 5^\circ$ of inclination and/or anteversion because this tighter range of error has been used with other navigation studies [13,14].

Statistical Analysis

Data are presented using standard methods for continuous (n, mean, SD, minimum, and maximum) and categorical variables (counts and percentages).

A 1-sample *t* test was used to determine if the mean values of the absolute error for anteversion and inclination were less than both 5°

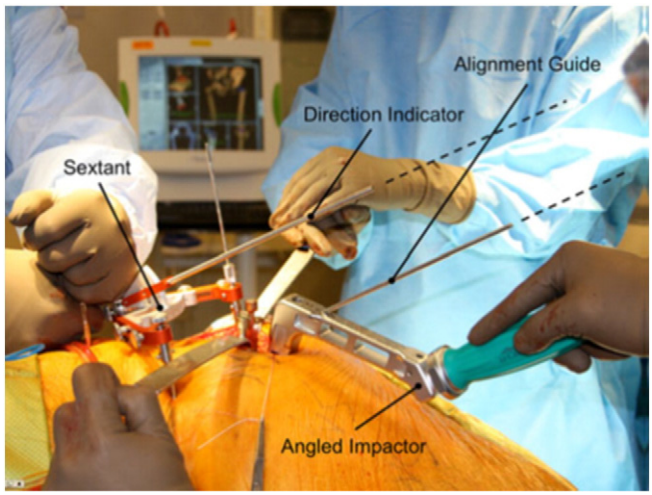

Fig. 2. Intraoperatively, the surgeon visually aligns the cup impactor handle or the alignment guide with the direction indicator to implant the cup in the desired orientation. Although this figure depicts an angled cup impactor, a straight cup impactor may be used as well. Permission granted from Steppacher et al [10].