Reliable Acetabular Cup Orientation With a New Gravity-Assisted Guidance System

Santiago Echeverri, MD, Pierre-Francois Leyvraz, MD, Pierre-Yves Zambelli, MD, and Brigitte M. Jolles, MD, MSc

Abstract: Acetabular cup orientation is a key factor determining hip stability, and standard mechanical guides have shown little help in improving alignment. An in vitro study was carried out to compare the accuracy and precision of a new gravity-assisted guidance system with a standard mechanical guide. Three hundred ten cups were impacted by 5 surgeons, and the final cup orientation was measured. With the new guide, the average error in anteversion was 0.4°, compared with 10.4° with the standard guide and 0.3° and −4.7°, respectively, for abduction angles. The average time required for orienting the cups was similar for both guides. The accuracy and reproducibility obtained with the new guide were better ($P < .0001$). These good results would require a clinical validation. **Key words:** precision, accuracy, cup orientation, total hip arthroplasty, alignment guides, navigation.

Inadequate orientation of the components in total hip arthroplasty (THA) is one of the major factors responsible for early wear, loosening, and dislocations [1-3]. Clinical studies in THA have shown increased wear rate in cups exceeding 50° of abduction [4,5], a clinical observation that has been confirmed by mechanical studies [4,6,7]. Inadequate orientation leads to wear due to impingement [4,5,8,9] and leads to early loosening due to the transmission of considerable torque forces [10]. Case-control and mathematical modeling studies have also shown the cause-effect relationship of component orientation and dislocation [11-13]. Despite an increased understanding of the physiopathology of THA dislocation and technological improvements of prostheses, the incidence of dislocation has been reported between 2% and 10% according to a review by Turner in 1994 and has not decreased since then [1,11,14-16]. Assuring consistently an adequate cup orientation in THA is therefore the key to obtain maximum head coverage and range of motion before impingement [5,7,8,10,14,15,17].

D'Lima et al [6] have shown, with a computer model, the range of possible orientations of both the acetabular cup and stem needed to assure maximum range of motion before impingement. However, clinical and laboratory studies [18-21] have demonstrated the lack of current practices, precision, and consistency in cup orientation and strict positioning of the pelvis in lateral decubitus even among experienced hip surgeons. This laboratory conclusion was clinically confirmed by Hassan et al [14]: the postoperative radiograph measurements showed that 50% of the cups placed by experienced surgeons were outside the desired "safe zone" of Lewinneck [14,19,22,23], defined as a cup abduction angle of 40° ± 10° and a cup anteversion angle of 15° ± 10°. Di Gioia et al [20] and Jaramaz et al [21] also found a large variability with 78% of their cups outside this safe zone, using a computer-assisted navigation measurement intraoperatively.

Sources of error leading to lack of precision (due to random error) and accuracy (due to systematic

From the Hôpital Orthopédique de la Suisse Romande, Centre Hospitalier Universitaire Vaudois, University of Lausanne, Lausanne, Switzerland.
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Reprint requests: Brigette Jolles, MD, MSc, Hôpital Orthopédique de la Suisse Romande, 4 avenue Pierre Decker, 1005 Lausanne, Switzerland.

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error) in cup orientation can be patient-related, surgeon-related, or instrument-related [23-26]. Standard mechanical guides have been shown in both clinical and in vitro studies to be inaccurate and imprecise [11,12,21,24] mainly because they assume a strict lateral decubitus of the pelvis throughout the operation, failing to control pelvic roll and yaw [21,24]. In addition, they assume that every patient in lateral decubitus (for posterior or anterolateral surgical approach) has the same pelvic flexion or pitch and, thus, parallel orientation of the anatomic plane with the axis of the surgical table. Finally, adequate use of standard mechanical guides implies visual control of precise alignment in 2 planes at the same time (parallelism to the floor level for cup abduction and perpendicular alignment with the longitudinal axis of the table for cup anteversion). In practice, this implies looking at the guide from 2 different angles at the same time, which is certainly a source of errors. In addition, they do not use an anatomic reference within the pelvis to control for changes in pitch position on the operating table, a fact that has been recognized as important to improve accuracy according to McCollum and Gray [2]. Many studies have focused on implant design such as head size and acetabular liners to compensate for error in cup orientation [14,24,27-31]. However, cup orientation continues to be one of the most important factors under the surgeon's control, having a larger effect on range of motion than changes in head-to-neck ratio [1,2,32,33]. For this task, there is currently no simple-to-use, cost-effective tool, which would help assure accuracy and precision of component orientation, particularly cup anteversion.

The purpose of this study was to compare the accuracy, precision, and ease of use of a new gravity-assisted guidance system and technique for cup orientation with the standard mechanical guide (Müller's). Such alignment guides have been used extensively since the 1970s, most surgeons are familiar with them, and their performance has been compared with computer navigation and freehand techniques in recent studies [14,19,21,34].

Materials and Methods

A new gravity-assisted guidance system was designed to take advantage of the constant direction of the force of gravity as a reference (Fig. 1) for cup orientation in anteversion and abduction, with respect to the anatomic plane of the pelvis. It uses bull's-eye bubble levels, circular flat-bottomed devices with liquid, and a bubble under a slightly convex glass face that indicates the center clearly. They serve to level a surface in 2 perpendicular directions (perpendicular to the direction of gravitational force) (Fig. 1).

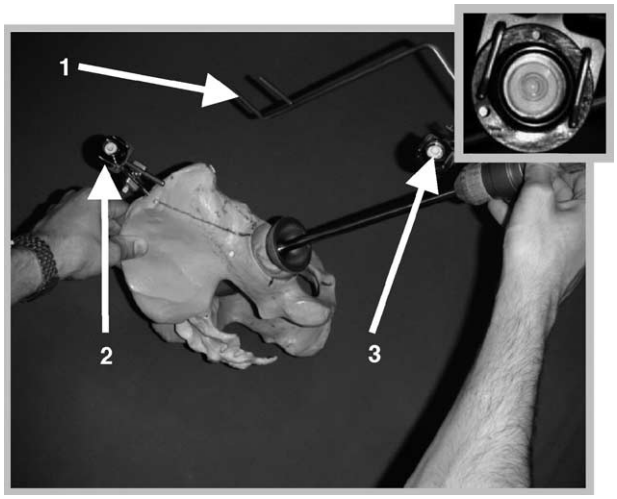

Fig. 1. Description of the gravity-assisted guidance system. The number 1 indicates the pitch pointer to be aligned to ASIS for pitch control (anatomic reference point); 2, first bubble level control of pelvic position (roll and yaw); 3, second bubble level calibrated for 45° abduction and 15° anteversion.

Following the concept of intraoperative augmented reality, it provides real-time information to control the pelvic position in either lateral or dorsal decubitus and then cup orientation [2,13,30,35]. It consists of 1 bull's-eye bubble level on 2 different items. The first bubble level, fixed to a Shanz pin, is placed in the iliac crest (Fig. 1). A standard clamp allows zero setting once pelvic position has been determined using the pelvic positioning device to align the anterosuperior iliac spines in strict lateral decubitus (Fig. 2) and before submitting the patient to maneuvers that may modify the pelvic position [1,12,24]. It acts as a witness, identifying the initial yaw and roll positions throughout the operation [1,24]. The second bull's-eye level is fixed to a simple device that is adapted to the positioning shaft (Fig. 1). It is designed in such a way that any desired cup orientation (eg, abduction of 45° and anteversion of 15°) can be reproduced with respect to the anatomic plane of the pelvis. The gravity-assisted guide uses 2 anatomic points of reference within the pelvis (the hip joint center and the anterior superior iliac spine [ASIS]) and the direction of gravitational force identified by the bubble level to precisely orient the cup, provided the pelvis is in strict lateral decubitus. The use of a second reference point