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Using Intraoperative Pelvic Landmarks for Acetabular Component Placement in Total Hip Arthroplasty

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Abstract: Dislocation after total hip arthroplasty is frequently due to acetabular malpositioning. Positioning of the acetabular component using anatomical landmarks may reduce the incidence of dislocation from improper acetabular orientation. The pelvis provides 3 bony landmarks (ilium, superior pubic ramus, and superior acetabulum), which, when used to define a plane, allows cup orientation in abduction and version. Landmarks evaluated in 24 cadaveric acetabuli allowed slightly increased abduction and anteversion of the cup, compared with native acetabuli. Six hundred seventeen primary total hip arthroplasties were performed between 1996 and 2003 using this technique. Mean cup abduction was 44.4° with 13.2° of anteversion. This technique allows satisfactory reproducible cup orientation based on individual pelvic morphology. Review of patient outcome data suggest high patient satisfaction and lower dislocation rate without additional equipment, time, or cost. **Key words:** pelvic landmarks, acetabular component, total hip arthroplasty.

Hip dislocation after total hip arthroplasty occurs with a reported incidence ranging from 1% to 11% [1-3]. Dislocations have been associated with an increase in age, female sex, certain medical conditions, cognitive dysfunction, surgical approach, implant orientation, implant type, revision procedures, and patient postoperative compliance. Of these factors, the surgeon directly controls implant choice, implant orientation, and surgical approach. Component orientation, specifically acetabular orientation, is responsible for most dislocations [2-5], although head sizing, leg length, offset, and patient compliance can play important roles.

Proper orientation of an acetabular implant can be obtained by careful consideration of abduction and version angles. Most manufacturers recommend placement of the acetabulum within a so-called safe zone [6]. This safe zone is based upon studies showing that the optimal radiographic orientation of the acetabulum is an abduction angle of 40° ± 10° and an anteversion angle of 15° ± 10° [7]. Lewinnek et al [8] reported a 6% rate of instability when either the abduction angle or the anteversion angle fell outside this safe range and a significantly ($P < .05$) lower dislocation rate of 1.5% when implants were within the safe range.

Many current intraoperative techniques recommend placement of the acetabular component using reference guides in relation to the longitudinal and coronal axis of the patient's body or the floor of the operating room. These techniques of measurement are subject to numerous problems including inaccuracies based on the variability of the patient's pelvic position on the operating table [9,10] and difficulty in application of preoperative templating to intraoperative decisions on radiographic

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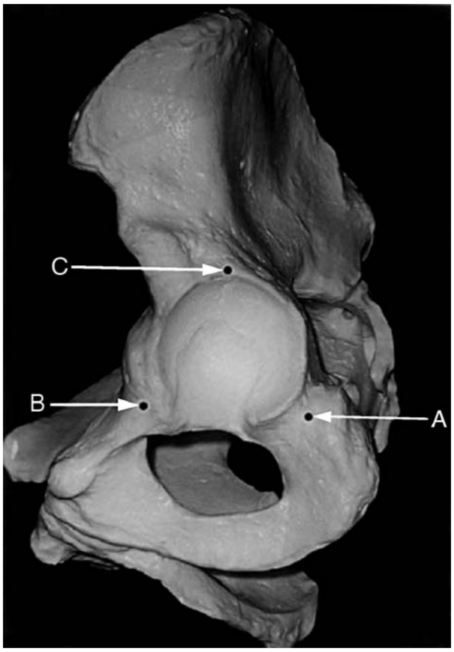

Fig. 1. Photograph of pelvis defining anatomical landmarks: the lowest point of the acetabular sulcus of the ischium (point A), the prominence of the superior pelvic ramus (point B), and the most superior point of the acetabular rim (point C).

landmarks. McCollum and Gray [9] attempted to improve the intraoperative accuracy of component placement by using a line determined by the anterior superior iliac spine (ASIS) and the sciatic notch, reducing dislocations to 1.14%. Their technique still required judgment and did not assess the orientation of the acetabulum anatomy. Recently, computers have been suggested as an alternative combining preoperative radiographic data to intraoperative component orientation. DiGioia et al used computed tomographic (CT) scans and computerized component guidance to minimize dislocation in a small group of patients [11]. Although this technique demonstrates promise, the high financial costs and limited availability restricts the usefulness in routine daily application in all centers performing hip arthroplasty. Currently, no system is universal or allows reproducible accurate placement of the acetabular component.

The use of osseous pelvic landmarks was derived from considerations in elementary geometric relationships. The outer rim of the acetabular component defines a single plane in space. The planes of abduction and version describe the positioning of this component within the acetabulum. Likewise, 3 bony landmarks on the patient's pelvis form a plane that can be used to position the component in abduction and version. These landmarks, described in more detail below, are the prominence of the lateral aspect of the superior pelvic ramus, the lowest point of the acetabular sulcus of the ischium, and the most superior point of the acetabular rim (Fig. 2A). These landmarks can be readily identified intraoperatively. Furthermore, the landmarks are easily discerned from osteophyte formation and, in most circumstances, are still present with erosive bone defects secondary to osteolysis. The purpose of this work is to describe the surgical application of these landmarks, to establish the topology described by these landmarks, and to document the clinical success of acetabular positioning.

Clinical and laboratory investigations were undertaken to prove the efficacy of these landmarks in placement of acetabular components. The clinical investigation involved surgical application of the landmark use with careful tracking of the patient. The laboratory investigation used in vitro measurement to establish a relationship between the native anatomical orientation of the acetabulum and the resulting component orientation.

Materials and Methods

Use of Landmarks in Cup Placement: Geometric Details

Adequate placement of the acetabular component demands orienting the prosthesis within the confines of the acetabulum after reaming. The position must approximate the pelvic and femoral anatomical relationships to provide coverage of the femoral head. The relationship avoids dislocation by maintaining stability within the physiological arc of motion. The orientation of the acetabular component is based upon the prosthetic rim guiding planes of reference. The outer rim of the component forms a plane, and any 3 points on the rim define the plane. The reamed acetabulum confines the component location. However, once the component is within the acetabulum, specification of any 2 points on the rim completely defines cup orientation provided they do not lie on a line through the center. Thus, 2 bony landmarks in combination with the prosthetic rim location can define acetabular component orientation. The method of component placement in this study uses the acetabular confines and bony landmarks in conjunction with preoperative templating. The method allows consistent component orientation, thereby decreasing the possibility of dislocation secondary to malposition [9].

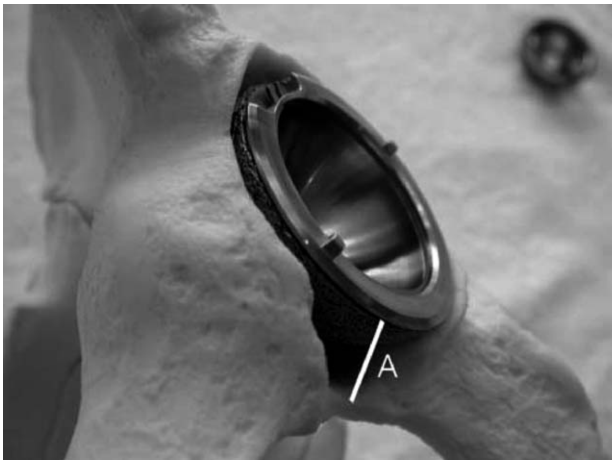

Fig. 2. Photograph demonstrating incorrect vertical orientation of the acetabular component. The vertical position is represented by the overhanging of the component distal to the acetabular notch at the inferior aspect of the acetabulum (A). If the inferior acetabular fovea is located, no component overhang should be present inferiorly.

The landmarks used in this study to orient the cup are shown in Fig. 1. The first point, A, is on the ischium and is the lowest point in the sulcus or groove between the acetabulum and the ischeal tuberosity. Intraoperative identification of this point can be accomplished by sliding a Cobb elevator over the acetabular rim along the ischium until reaching the lowest point of the sulcus. The second point, B, is located on the lateral portion of the superior pubic ramus. The point is located at the confluence of the inferior aspect of the iliopectineal eminence and the pubic rami. This point is readily distinguishable although not an eminent osseous landmark. In following the ridge of the ramus toward the acetabulum, the point can be clearly seen or palpated and is approximately 5 mm from the acetabular rim. In 24 pelvises measured in the laboratory, the prominence was 5.2 $\pm$ 1.0 mm from the reamed edge of the acetabulum. Should the surgeon have any doubts regarding correct identification of the prominence, a point on the ridge approximately 5 mm from the reamed acetabulum will suffice.

After identification of the first 2 landmarks, the acetabulum is serially reamed to the measured templated diameter. The orientation of the reamer and component is positioned according to the plane defined by the rim of the component passing through the 2 landmarks and medialized to the acetabular fossa. An important principle of this technique is the inferior portion of the acetabular component must be positioned to avoid inferior overhang of the acetabular notch.

This is represented by component templating superior to a horizontal line at the inferior aspect of the acetabular teardrop on the anteroposterior (AP) pelvis radiograph. Intraoperatively, confirmation can be determined by placement of a Homan's retractor at the inferior aspect of the acetabular notch. The component rim must be placed at the level of the retractor. If the acetabulum is appropriately reamed to diameter, any evidence of inferior component overhang will orient the component in a more vertical position than anticipated in the preoperative template (Fig. 2). Conversely, if bone is visible inferior at the acetabular notch and the inferior aspect of the cup, malorientation in a more horizontal position will occur (Fig. 3).

Although the 2 landmarks in conjunction with reamed acetabular relationship to the acetabular notch will suffice to orient the component, a third point, point C in Fig. 1, is used to confirm correct component placement. The third point is the most superior point of the acetabulum, which intraoperatively is equivalent to establishing the overhang of the acetabular cup; when viewed radiographically, the most superior point is also the most lateral. Once the component is correctly placed in the reamed socket, the amount of component overhang is measured from this point. If the component has been placed correctly, the intraoperative measured distance of overhang will be consistent with the templated assessment, as measured in millimeters.

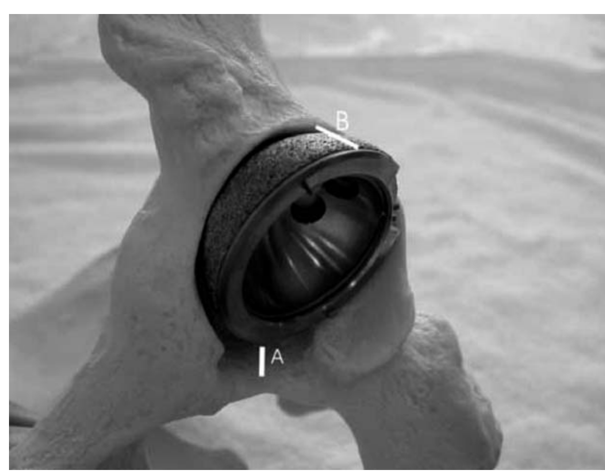

Fig. 3. Photograph demonstrating horizontal orientation of the acetabular component. The horizontal position is represented by the ability to visualize acetabular bone inferior to the rim of the component (A) and overhang superiorly (B), as referenced via preoperative templating.

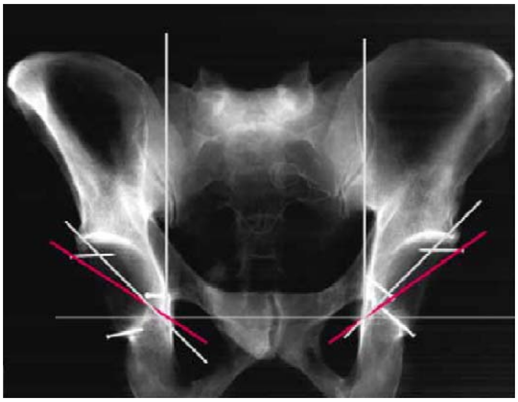

Fig. 4. Abduction angles associated with position of the superior lateral landmark and corresponding x-ray of the pelvis.

The component orientation is completely defined by the 2 points inside the reamed socket in combination with the confines imposed by acetabulum and the notch. The final amount of the component overhang of the bony acetabulum should agree with preoperative templating.

Component placement is templated on preoperative radiographs by using standard landmarks, as shown in Fig. 4. Using a standard AP film, a horizontal line is drawn connecting the inferior points of the teardrop for both acetabuli. Using this line as a reference, a perpendicular line is then drawn along the lateral border of the teardrop representing the amount of cup medialization.

Using standard templates provided by the implant manufacturer, the acetabulum is first sized. Then, the inferior corner of the acetabular template is placed on the horizontal line with the backside of the cup touching the vertical line such that the cup face forms a 40° angle with the horizontal. The new hip center of rotation is marked, and the amount of cup that is uncovered over the superior-lateral acetabulum is noted; this is defined as *overhang*.

The templating concludes with the femoral implant. The change in hip center of rotation will reduce the offset from the patient's inherent offset length, and this change must be considered in planning the femoral neck resection and choosing the type of femoral implant. The x-rays are used intraoperatively to confirm the position of the cup. The component should be placed on the inferior portion of the teardrop, and the extent of the lateral overhang should match the templated films. If the templated and intraoperative component placements do not agree, then repositioning of the cup is necessary until intraoperative landmarks and preoperative templates match.

Clinical Investigation

Between 1996 and December 2003, 617 consecutive primary total hip arthroplasties were performed by the senior physician (NGS). Criteria for inclusion were advanced degenerative joint disease, rheumatoid arthritis, ankylosing spondylitis, avascular necrosis, inflammatory arthritis, and posttraumatic arthritis. Femoral fixation was based on the patient's age, bone quality, and underlying medical comorbidities. A Morse taper, 28-mm head segment, with variable neck length was used to adjust soft tissue tension. Acetabular fixation was achieved in all patients using a cementless component. The acetabular shells were titanium alloy with porous coating and cluster holes (Trilogy; Zimmer, Warsaw, Ind). Exclusion criteria included previous hip surgery.

Preoperative templating was performed in all patients. On the AP pelvic radiograph, standard measured templates were used to approximate the circumference and estimated size of the acetabulum. The acetabular component was templated in reference to the acetabular teardrop. The inferior medial portion of the component was positioned lateral and not inferior to the teardrop. The superior cup overhang from the lateral aspect of the acetabulum was measured in millimeters (Fig. 4). All surgeries were performed using a modified Hardinge approach. The hip was dislocated, and neck osteotomy was preformed. The acetabulum was exposed, followed by a capsulotomy to identify specific bone landmarks: the prominence of the superior pubic ramus, the lowest point of the acetabular sulcus of the ischium, the superior acetabular rim, and the acetabular notch. These points were used to conceptualize a plane of the acetabular orientation in abduction and version. Acetabular reaming was performed in relation to the conceptualized acetabular orientation. The acetabular implants were placed in accordance to the template and bony landmark identification. No other utilities were used for acetabular orientation intraoperatively. After implantation of the femoral component, stability tests through out full range of motion were done during surgery.

The 2 points on the inside of the reamed surface at the levels of the 2 inferior bony landmarks can be readily visualized (Fig. 1A and B). The rim of the component must pass through these 2 visualized points, and the cup will overhang the acetabulum by the amount determined as measured in millimeters during preoperative planning (Fig. 4). In effect, the line connecting the 2 inferior points assures the appropriate anteversion, whereas the

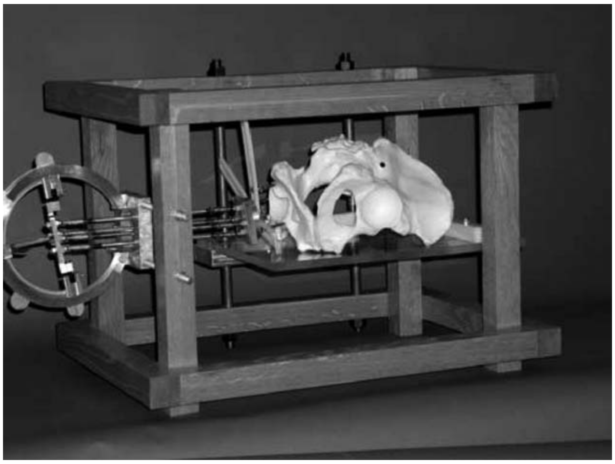

Fig. 5. The device for the measurement of acetabular orientation. The 3 prongs were used to determine the acetabular plane. The scales used to read the orientation are at the left end of the device.

measured overhang derived from templating assures the appropriate abduction. Intraoperatively, there were no jigs or other devices used to check the cup positioning. No postoperative abduction pillows were used.

Physical therapy was initiated on postoperative day 1. The weight-bearing status was determined by femoral fixation. All patients with cemented femoral components were weight-bearing as tolerated and cementless implants were partial weight-bearing. Physical therapists instructed all patients in hip precautions limiting hip flexion to less than 90°. Follow-up occurred at 2 weeks, 1 month, 3 months, 6 months, 12 months, and each year.

All of the patients were examined both clinically and radiographically at each follow-up visit by the senior author. The patients were evaluated using the Harris Hip Score at the 1-year evaluation.

Laboratory Investigation

To determine the accuracy of this new positioning method, in vitro measurements of the native and implanted acetabulum were performed. Twelve cadaveric pelvises without arthritic degeneration and acetabular osteophytes were analyzed in the laboratory using a special measuring apparatus to determine abduction and anteversion angles (Fig. 5). The orientation of each acetabulum was performed in a plane defined by the 3 relevant bony landmarks (Fig. 1). This definition satisfactorily identifies acetabular orientation because the pelvises were free of osteophytes.

The soft tissue of each pelvis was removed to allow accurate assessment of bony anatomy and to optimize radiographic visualization of bone. Upon completion of the soft tissue removal, small metallic tacks were placed in the prominence of the superior pubic ramus, the lowest point of the acetabular sulcus of the ischium, and the most superior point on the acetabular rim of each acetabulum. These tacks represent the described anatomical landmarks, and the radiographic location is shown in Fig. 6. These tacks were used as the points to obtain measurements of the abduction and anteversion and suggest orientation of the native acetabulum. Radiographs were obtained for each of the pelvises including an AP view of the pelvis, an individual hip AP view, and shoot-through lateral hip. Each pelvis was preoperatively templated to determine a radiographic abduction and the overhang of the implant at the superior acetabular rim.

The ASISs and the pubic tubercles of each pelvis were drilled and secured with wood screws to a flat 10-mm-thick polymethylmethacrylate plate. This fixation placed the pelvis in a reference position referred to as the anterior pelvic plane [12]. Each pelvis was placed in the 3-dimensional coordinate measuring device. The orientation of the plane parallel to the acetabulum was ascertained by touching the tip of a prong to the head of each tack. This plane was labeled as the acetabular plane and was taken as the preoperative measurement of acetabular orientation. The angles describing the orientation of the plane defined by the plane were read directly from the device, and these angles were converted into anatomical abduction and anteversion. Therefore, the abduction angle was

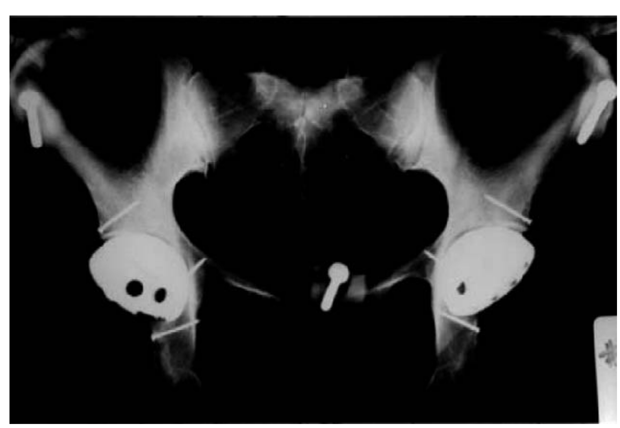

Fig. 6. Radiograph of a pelvis used in the laboratory study demonstrating tacks to mark the bony landmarks and the radiographic orientation of the cups after implantation. The larger screws hold the pelvis to the measurement device.

Table 1. Postoperative Radiographic Data of 150 Primary Total Hip Arthroplasties

Cup abduction angle* (degree)	44.4 (24-58)
No. (%) of cups with abduction of 30° to 50°	139 (96.0)
No. (%) of cups with abduction angle <30°	2 (1.3)
No. (%) of cups with abduction angle >50°	4 (2.7)
Cup anteversion angle* (degree)	13.2 (1-25)
No. (%) of cups with anteversion of 5° to 15°	136 (90.7)
No. (%) of cups with anteversion <5°	2 (1.3)
No. (%) of cups with anteversion >15°	12 (8.0)

*The values are given as the average and the range in parentheses.

recorded as the elevation of the acetabular axis from the transverse plane, and anteversion was the rotation of the component about the superior-inferior axis of the pelvis.

All 24 acetabuli were reamed to the size deemed appropriate by the senior physician (NGS). Each acetabular shell was pressed into place in accordance with the technique described above. Measurements were performed with the custom apparatus of the postoperative component orientation on the 24 postoperative acetabuli using the 3 prongs on the device to touch the rim of the cup. Statistical analysis of the measurements was conducted using paired *t* tests with a Bonferroni correction for 2 measures, setting the level of significance at .05.

Results

Clinical Investigation

In 150 hips, we measured the cup abduction and version postoperatively. The measured mean cup abduction angle, using the method described by Widmer [13], was 44.4° (range, 24° to 58°). Components were defined as outliers when the cup abduction angle was out of the range of 30° to 50°. In only 4 (2.7%) of 150 procedures were the measured cup abduction angles greater than 50°. In 2 (1.3%) of 150 the measured cup abduction angle was lower than 30° (Table 1). The measured mean cup anteversion, using the method described by Widmer, was 13.2° (range, 1° to 25°). Components were defined as outliers when the cup was out of the range 5° to 15°. In only 12 (8.0%) of 150 were the measured cup anteversion angle greater than 15°, and in only 2 (1.3%) of 150 were the measured cup anteversion angles lower than 5°(Table 1). Five patients suffered dislocation. One posterior dislocation occurred at 4 months while the patient was using a recumbent bicycle during a physical therapy session. The second, a posterior dislocation occurred during a seizure during extubation in the operating room. Both cases were reduced with conscious sedation and treated with hip abduction orthosis for 12 weeks. There was 1 late dislocation at 2 years, which was treated in an abduction orthosis. The other 2 dislocations occurred in the first 3 months after surgery were treated in abduction orthosis with no further dislocations. There were no subsequent dislocations and no revision surgeries for all dislocations. At an average follow-up of 4.5 years, the dislocation rate was 0.81% (5/617).

Of the 617 patients, 10 were lost to follow-up and 6 died. Of the 6 deaths, contacted family members reported no dislocations before death. The average postoperative Harris hip score for all patients was 84, ranging from 34 to 97.

Laboratory Investigation

In the cadavers, 24 acetabuli were measured preoperatively and postoperatively to determine the abduction and anteversion angles. These angles were measured using the anterior pelvic plane, as defined by the 2 ASISs and the 2 pubic tubercles. In

Table 2. Native Cadaver Acetabulum Orientation and Postoperative Cadaver Acetabulum Orientation with Acetabular Implants Inserted

		Native cadaver acetabulum		Postoperative cadaver acetabulum	
Pelvis	Hip	Abduction	Anteversion	Abduction	Anteversion
1	Left	45.3	23.9	30.0	21.4
	Right	44	22.8	32.5	24.9
2	Left	45.9	21.6	32.0	22.4
	Right	49.5	25.0	30.7	24.9
3	Left	53	20.1	30.9	23.1
	Right	50.5	21.4	33.4	24.8
4	Left	56.1	20.3	32.9	21.8
	Right	49.1	22.8	34.3	24.7
5	Left	52.8	22.0	24.7	45.7
	Right	47.7	23.8	26.8	44.1
6	Left	44.7	20.7	31.0	24.8
	Right	45.5	21.5	30.8	23.5
7	Left	49.3	17.7	30.9	25.0
	Right	45.5	20.0	31.6	26.7
8	Left	45.8	20.7	30.1	19.7
	Right	42.1	18.2	31.1	23.0
9	Left	34.6	16.9	25.8	20.9
	Right	32.3	14.3	24.1	25.1
10	Left	30.8	23.4	30.4	24.6
	Right	35.1	22.1	32.9	25.1
11	Left	25.1	32.0	30.1	23.1
	Right	23.4	32.1	23.8	23.3
12	Left	45.9	21.6	30.1	25.8
	Right	53.7	20.9	30.2	24.6
Mean		43.6	22.0	30.0	26.6
SD		7.9	4.1	9.3	9.7

the preoperative pelvis, the acetabular plane was measured by a plane defined by the 3 tacks, and the acetabular component plane was recorded in reference to the rim of the component. Results for all acetabuli and cups are recorded in Table 2. The postoperative abduction results were 13.6° less than the preoperative native values, showing less anatomical abduction of the component. The postoperative anteversion angle was 4.6° greater than the native. The paired t test comparisons including Bonferroni correction showed statistical significance in both abduction and anteversion angular differences.

Discussion

Dislocations are disturbing for both the patient and physician and involve a significant expense. Preventive strategies are the appropriate remedy and can be divided into 3 broad categories: preoperative, intraoperative, and postoperative. Preoperatively, important steps include a thorough history, a complete physical exam, radiographic evaluation, and templating.

Intraoperatively, the surgical approach, implant orientation, soft tissue tension, and implant selection affect rates of dislocation [2,3]. Postoperatively, patient education and hip motion precautions can also prevent dislocation.

This study reviews the single variable of acetabular component position in hip dislocation. The study reports excellent clinical results and defines laboratory measurements with the use of local anatomical bone landmarks to position the acetabular component. The overall dislocation rate was 0.81% (5/617), without consideration of the etiology. When the case of the intraoperative seizure resulting in a dislocation was not included, only 4 patients (0.64%) suffered a dislocation.

There is currently no method in total hip arthroplasty using the patient's visible bony landmarks as an intraoperative reference for acetabular implant placement without the need for additional equipment or extensive preoperative imaging. Recently, Jaramaz et al [14] combined preoperative CT imaging with intraoperative application of specialized computerized equipment to standardize acetabular component orientation. Unfortunately, this method requires additional equipment, time, cost, and resources. The proposed method described in this paper can be used effectively in any setting in which hip arthroplasty is performed.

The laboratory measurements suggest the implanted component anteversion and abduction would provide greater posterior and superior coverage than the native orientation of the acetabulum. The difference in the abduction and anteversion angle was statistically significant. The component abduction was substantially less than the native abduction and indicates an increase in superior coverage of the femoral head. This relationship between the prosthetic femoral head and acetabular joint surface may be beneficial in establishing greater functional arc of stability because the reconstructed hip geometric relationships are a smaller diameter than the native hip joint. The abduction reflects the resulting overhang of the acetabular component in the pelvis, as could be expected from the preoperative template placement. This is demonstrated in the postoperative radiograph of a laboratory test (Fig. 4). The SDs between the implanted component orientations were greater than the SDs of the native acetabular orientations. This was interpreted to reflect the technical difficulties in reproducible seating of the cementless component. Further investigation of the variability with additional laboratory study would be beneficial in application to the index arthroplasty methodology.

The measured values in the current study are expressed in anatomical terms. The recommendations for component placement can be expressed in operative, radiographic, or anatomical reference [15]. An acceptable value of anteversion in radiographic terms is approximately 15° [7] and must not be directly compared with values determined in the anatomical frame. Using published conversions [15], the current anatomical results have a radiographic equivalent of 13° of anteversion and 28° of inclination. In comparison to the "safe-zone" of orientations presented by Lewinnek et al [8], the current method of component placement leads to an average orientation with anteversion and inclination angles, just outside the suggested range of 15° ± 10° of anteversion and 40° ± 10° of inclination. However, the combination resulting from the current use of bony landmarks could be considered quite conservative and less likely to dislocate because all the dislocations in the study of Lewinnek et al occurred at considerably higher anteversion and inclination angles. McCollum and Gray [9] observed the safest range of acetabular component placement was 30° to 50° of abduction and 20° to 40° of flexion. In their review, the hip remained stable and allowed a physiological range of motion. The current laboratory evaluation of acetabular component abduction measurement suggests an increase in superior and posterior coverage. A possible criticism of this position may include that the increased anteversion could result in a decrease in hip extension. The lack of this motion could result in posterior neck impingement with subsequent anterior dislocation. In addition, the decreased inclination could limit abduction causing lateral impingement resulting in an anterior or inferior dislocation. Neither of these concerns has been apparent in the clinical review. The suggested position, as described in this method, may increase the coverage of the femoral head during the functional arc of motion and may result in a more physiological stable orientation. Further evaluation is necessary to evaluate this hypothesis.

Placement of an implant outside prescribed abduction and anteversion ranges has been shown to increase dislocation rate [14]. Manufacturers provide intraoperative guides for acetabular implant placement in an attempt to align the implant with respect to the longitudinal and coronal axes of the patient [6]. These may be highly inaccurate, and the difference in orientation between the patient's pelvis and the whole body is the most likely cause for variation [11]. The use of radiographic assessment of acetabular component orientation also has pitfalls. As described by Herrlin et al [5], radiographic anteversion must consider the relationship of the radiographic plate to the source. This requirement is well known but also means that plane film radiographs must be used carefully in operative decisions. The need for consistent acetabular placement has led to development of systems such as the HipNav [11], which guides acetabular component alignment through comparison of preoperative CT images with intraoperative measurements of the patient's pelvis. Although future advances in technology and reductions in cost should permit computer assisted methods to aide all surgeons, simpler techniques can provide alternatives. The proposed method for intraoperative placement determines the abduction and anteversion of the acetabular implant based strictly on the local pelvic anatomy and can be used effectively in all operating rooms. Degenerative changes may obscure the acetabular rim as a consistent landmark for component placement. The adjacent landmarks of the pelvis are less likely to be altered by degenerative changes. The superior rim of the acetabulum, the prominence of the superior pubic ramus, and the acetabular sulcus of the ischium form a triad of bony landmarks that can be identified consistently in most patients. In our experience, minimal additional dissection is required, and the landmarks are usually unaffected by osteophytic growth. In certain instances, the superior landmark may be obscured by an osteophyte, but this should be expected from the preoperative template. The osteophyte may be removed or used to measure the lateral overhang of the acetabular component. These landmarks will form a plane specifying the location of the component rim within the reamed acetabulum. This technique produces consistent anteversion and superior coverage.

The recorded dislocation rate of 0.81% is less than the reported rates commonly associated with primary total hip arthroplasty [16]. The follow-up period for this study was, on average, 4.5 years, ranging from 2.5 to 7 years. Although this study is shorter than optimal, most dislocations after total hip arthroplasty occur within the first few months after surgery. Dorr et al [1] reported that 54% of dislocations occur within the first 3 months and 85% within 2 years. Late dislocations are often the result of polyethylene wear and component malposition [1]. The short follow-up is a weakness of this study. At this interval, it is unclear if satisfactory initial component placement may improve femoral head coverage and late dislocation.

We conclude that the anatomical bony pelvis landmarks in combination with preoperative templating are a successful method in assuring proper acetabular component orientation. The landmarks obviate the need for mechanical guides, alleviate the need for expensive navigation equipment, and lead to a low dislocation rate. These landmarks may be useful in the standardization of the cup positioning with new approaches in minimally invasive total hip arthroplasty. Along with intraoperative range of motion testing, this technique shows result in dislocation rates less than 1%.

We don't recommend this method in cases of hip dysplasia or after fractures of the acetabulum. Continued follow-up and application of the landmark technique in multiple centers should be conducted to further evaluate the method in the hands of multiple surgeons.

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