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Operative Techniques in
Orthopaedics

The Importance of Proper Acetabular Component Positioning and the Challenges to Achieving It

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The importance of proper cup placement cannot be overemphasized, regardless of the bearing material or diameter. Unsatisfactory acetabular component position has been associated with instability, increased wear, and pain. Pelvic, acetabular, and femoral anatomy are all variable, so it is illogical to have the same fixed target position for all patients. The hip arthroplasty surgeon actually faces 2 challenges: (1) determining the desired acetabular component position for each patient (the target), and (2) how to reasonably obtain that position in surgery (hitting the target). An abduction angle of 40° ± 10° is generally satisfactory. Anteversion is more complex. The desired amount of anteversion is influenced by (a) the amount of femoral anteversion and (b) the cup abduction angle. A combined anteversion of 25° ± 10° is generally satisfactory. A combination of internal and external landmarks can be used to assess the relative component position. Routine evaluation of intraoperative range of motion is an additional check. When in doubt, we try to obtain a quality intraoperative image.
Oper Tech Orthop 19:132-136 © 2009 Elsevier Inc. All rights reserved.

KEYWORDS total hip, acetabular component, wear, surgical technique

Debate continues on the relative strengths and weaknesses of the available bearings for total hip arthroplasty (THA). One feature common to all, however, is that the clinical outcomes are dependent on proper component positioning. The importance of proper cup placement cannot be overemphasized, regardless of the bearing material or diameter. Acetabular component position influences the forces on the hip joint, the range of motion and stability, and the amount of bearing and nonbearing wear. It should be recognized that pelvic, acetabular, and femoral anatomy are all variable, so it is illogical to have the same fixed target position for all patients. The hip arthroplasty surgeon actually faces 2 challenges: (1) determining the desired acetabular component position for each patient (the target), and (2) how to reasonably obtain that position in surgery (hitting the target).

Femoral-acetabular impingement (FAI) (either intra-articular or extra-articular) is a cause of poor outcomes after hip arthroplasty. It can lead to instability, increased wear, and pain.[1] Impingement is influenced by patient variables (ie, anatomy and laxity), component position, and prosthetic design variables [ie, acetabular component center of rotation (COR) and the femoral head–neck diameter ratio]. Data from a large administrative database indicates that hip instability at 22.5% is the most common indication for revision of total hip replacement in the USA, and this revision burden has a significant personal and economic effect.[2] Increased lateral opening (abduction) angles have been associated with higher wear of polyethylene,[3] fractures of crosslinked polyethylene components,[4] neck-socket impingement and rim wear,[5] stripe-wear and squeaking of ceramic–ceramic bearings[6,7] as well as with higher wear, and ion levels with metal–metal bearings.[8,9]

What is the Target?

Acetabular component position is generally described in medial-lateral position (relative to the acetabular teardrop),[10] the abduction or lateral opening angle (relative to the interteardrop line), and the degree of anteversion (Fig. 1). For most cases, cephalad-caudad positioning is a resultant of the medial-lateral position (depth of the socket) and the diameter of the native acetabulum, given that it is desirable not to remove excessive bone (over-ream). Medializing the hip COR decreases the moment arm for body weight and increasing the femoral offset lengthens the lever arm for the abductor muscles. These changes in hip biomechanics have a double benefit: a reduction in required abductor forces and lower

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1048-6666/09/$-see front matter © 2009 Elsevier Inc. All rights reserved.
doi:10.1053/j.oto.2009.09.008

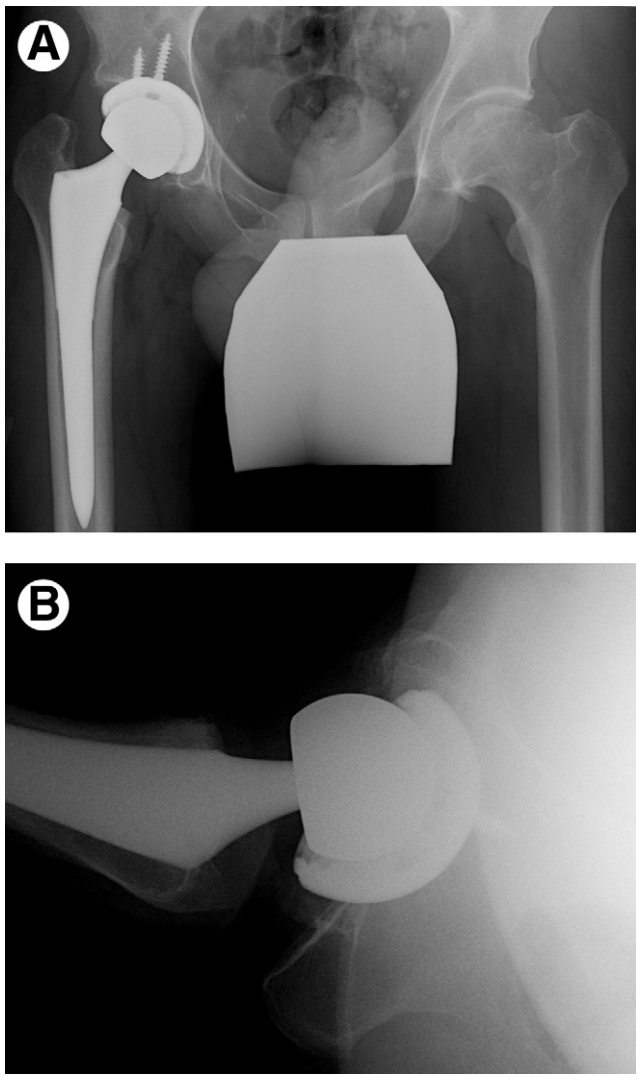

Figure 1 (A) This anterior-posterior (AP) radiograph of the pelvis was taken with the beam center on the pubis. The acetabular component is positioned close to the medial wall, the lateral opening angle is in the 40-45 degree range, and it is clearly anteverted. The component is well contained by the native acetabulum. The limb length and offset of the prosthetic hip is similar to that of the contralateral hip. (B) Shoot-through lateral radiograph of the hip taken as described by Danelius and Miller (1936).[11] The acetabular component is clearly forward facing, which reduces the potential for anterior femoral-acetabular impingement but increases the potential for posterior femoral-acetabular impingement with extension and external rotation. It is not possible to determine the amount of femoral anteversion on conventional radiographs.

joint reaction forces.[12] Application of these biomechanical principles improves clinical outcomes and reduces wear.[13-15] On this basis, it is generally recommended to position the acetabular component within a few millimeters of the medial wall of the acetabulum. In few cases, it may be desirable or necessary to place the cup right on the medial wall to obtain sufficient component coverage in a shallow socket.

Historically, the desired abduction or lateral opening angle (synonyms) was that which insured a satisfactory range of motion with a low risk of dislocation. Lewinnek et al[16] correlated the dislocation rate of THA with cup position and what was termed the "safe zone," defined as a lateral opening angle of 40 ± 10°, and an anteversion of 15 ± 10° (calculated from the ratio of the lengths of the minor and major axes of the ellipse on the anteroposterior [AP] radiograph; radiographic or planar version). It has been subsequently recognized that this relatively tight acetabular position target is associated with low wear and a low occurrence of other bearing-related complications, such as polyethylene liner fracture and dissociation, squeaking of ceramic–ceramic bearings, and high wear and ion levels with metal–metal bearings. Unfortunately, it is recognized that even experienced surgeons cannot guarantee that the cup will be implanted within a defined safe zone when using conventional techniques (ie, without intra-operative imaging or navigation), and navigation cannot insure that the functional position of the cup will be optimal.[17] Accumulating experience indicates a generally higher risk of bearing complications when the cup abduction angle exceeds 55 degrees.

Consistently obtaining satisfactory anteversion is challenging. The issues start with the definition of version. Murray (1993)[18] describes 3 distinct definitions of acetabular anteversion. Anatomical anteversion is defined as the angle between the transverse axis and the acetabular axis in the transverse plane or true anteversion. Radiographic anteversion is defined as the angle between the acetabular axis (passing through the center of the socket and perpendicular to the plane made by the rim of the socket) and the coronal plane. This measurement is sometimes called planar version. Similarly, as described by Lewinnek et al,[16] edge detection software (Einzel-Bild-Roentgen-Analyze, University of Innsbruck, Innsbruck) can be used to obtain this quantitative measure of anteversion on an AP pelvic radiograph. The relationship between anatomical anteversion and radiographic anteversion depends on the lateral opening angle of the cup as observed on AP radiographs. Operative anteversion is the angle between the longitudinal axis of the patient and the acetabular axis as measured in the sagittal plane.

The author also uses a cross-table or a shoot-through lateral, as described by Danelius and Miller (1936),[11] where the patient is supine and the contra-lateral hip is flexed. The x-ray beam is parallel to the table and effectively "shoots through" the groin without dorsal angulation. The hip to be imaged is internally rotated 15-20° for visualization of the femoral neck and the trochanters. This view displays the hip at 90 degrees from the AP radiograph and shows the degree of "forward facing" of the acetabulum (Fig. 1).

Determining the desired amount of acetabular anteversion needs to consider the version of the femoral component (or native femur in resurfacing), which is highly variable. In other words, for cementless stems with a fixed neck (and for resurfacing) the version of the native femur influences the version of the femoral component. The surgeon generally has more latitude with the version of the socket, which should compliment with that of the femur. A combined operative anteversion (femur plus socket) "safe zone" of 25-50 degrees has been suggested (Dorr et al 2009),[19] which seems relatively broad. The satisfactory range will be, at least in part,