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Original Research

The Direct Anterior Approach Total Hip Arthroplasty Reliably Achieves "Safe Zones" for Combined Anteversion

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ABSTRACT

Background: In total hip arthroplasty (THA), component position is critical to avoid instability and improve longevity. Appropriate combined femoral and acetabular component anteversion is important for improved THA stability and increased impingement-free range of motion. In direct anterior THA (DA-THA), concern has been expressed regarding the accuracy of femoral component positioning. This study seeks to quantify acetabular, femoral, and combined component orientation relative to the accepted "safe zones" in patients who have undergone DA-THA.
Methods: Twenty-nine patients who had THA performed via direct anterior approach had postoperative computerized tomography scans done to assess femoral anteversion. Stem rotational alignment was measured relative to the transepicondylar axis (TEA) and the posterior condylar axis (PCA) of the femur at the knee. Acetabular abduction and version were recorded on anteroposterior pelvis radiographs.
Results: The mean stem anteversion was 17.5° (standard deviation = 10.8°) from the TEA and 21.7° (standard deviation = 11.3°) from the PCA. Ten of 30 cups were appropriately anteverted; however, all the cups had appropriate abduction. Combined version when using the TEA resulted in 79% (23/29) of patients within the "safe zone" of 25°-50°. Pearson correlation coefficients were high for both stem anteversion from the TEA (R = 0.96) and PCA (R = 0.98); however, interobserver reliability for combined component anteversion was greater for the TEA (kappa, 0.83 vs 0.65).
Conclusions: Combined anteversion within the "safe zone" was achieved 79% of the time with DA-THA. Interestingly, most of the "excessive" combined anteversion appears to be related to increased anteversion of the acetabular component with only 10 patients within the acetabular cup "safe zone" of 5°-25°.

Introduction

In total hip arthroplasty (THA), optimum component position is critical for long-term success of the operation by decreasing rates of wear, aseptic loosening, and dislocation [1-4]. Recognizing the importance of acetabular component position, Lewinnek et al published a "safe zone" of 5° to 25° for anteversion and 30° to 50° for acetabular abduction based on their experience with dislocations after posterior THA [5]. This still serves as the standard for ideal acetabular component position but has been called into question given the importance of the spinopelvic relationship [6,7]. In addition to acetabular component position, emphasis has also been placed on femoral component positioning.

Historically, surgeons have identified the importance of keeping the femoral component out of varus because of increased rates of failure with varus cemented femoral stems [8,9]. With the use of cementless femoral fixation, varus positioning of the femoral stem has not been shown to lead to the same increased failures [10]. However, as compared with cemented femoral stems, many cementless femoral stems provide less ability to adjust the version of the component as a stable press-fit requires the stem to adapt to

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the proximal geometry of the native femur. Consequently, recent attention has been given to the combined version (CV) of the acetabular and femoral components, with the goal of improving impingement-free range of motion and decreasing instability [11-13]. The concept of CV was originally introduced by Ranawat, and he described the use of the "Ranawat sign" to determine CV intraoperatively when using the posterior approach [14]. While no optimum femoral version has been described, Dorr proposed a CV safe zone of 25°-50° based on previous anatomical studies and his experience with decreased instability in this range [15]. More recent studies have attempted to quantify a combined anteversion that minimizes impingement [16,17].

Native femoral anteversion can vary a great deal, and intraoperative judgment of femoral component version can be difficult. Using preoperative computerized tomography (CT) scans of a group of 46 patients scheduled for primary THA, Bargar et al [18] found a large range of native femoral version from 6° of retroversion to 33° of anteversion. Dorr et al compared the surgeon's estimate of femoral component anteversion in the posterior approach with the postoperative CT measurement of version and found a poor precision of the surgeon's estimate with a correlation coefficient of only 0.688 [19]. In addition, this study found that only 45% of the femoral stems landed within the desired range of 10°-20° of anteversion.

In direct anterior total hip arthroplasty (DA-THA), femoral component broaching and insertion occurs while the patient is positioned supine with the leg fully extended, and the leg below the knee is often draped from the surgeon's view. Despite published results of comparable patient outcomes from the DA-THA with other THA approaches, some have questioned the ability to appropriately orient the femoral component with respect to femoral anteversion, via this approach [20-23]. Previous studies have reported on improved acetabular component positioning in DA-THA [24,25]. However, no prior study, to our knowledge, has examined the combined anteversion of the femoral and acetabular components in DA-THA. This study aims to analyze the combined femoral and acetabular anteversion with cross-sectional imaging and quantify this relative to the CV "safe zone" described by Dorr.

Materials and methods

After obtaining institutional review board approval, patients were approached for enrollment in the study. An patient who was undergoing a primary DA-THA from the senior author (JBM) was a candidate for enrollment. Patients with femoral or acetabular hardware were excluded from this study. Thirty consecutive patients were enrolled in the study. Four blinded observers independently recorded the measurements (2 fellowship-trained arthroplasty surgeons, one hip and knee fellow, and one orthopaedic resident). All implants were positioned using intraoperative fluoroscopy based on preoperative templating. A CORAIL femoral stem (DePuy, Warsaw, IN) and a PINNACLE acetabular cup (DePuy, Warsaw, IN) were used for all the cases. The senior author standardized intraoperative images by matching the anteroposterior (AP) pelvis fluoroscopic view with the preoperative AP pelvis standing radiograph.

One month after surgery, all patients had a standing AP pelvis and a cross-table lateral radiograph taken, which were used for acetabular component position measurement. Abduction and anteversion measurements of the acetabulum were made from the digital radiograph using the TraumaCad (Voyant Health, Columbia, MD) hip abduction measurement tool. Femoral component position measurements were taken from limited supine CT scan of the hip and knee with 2.5-mm cuts (General Electric BrightSpeed, Fairfield, CT). CT was not selected for acetabular component position to minimize patient radiation exposure. Angular measurements were calculated using the axis of the top of neck of the femoral stem relative to both the posterior condylar axis (PCA) and the transepicondylar axis (TEA).

The CV was then calculated for the TEA and the PCA by adding the femoral anteversion calculated from the CT scan with the anteversion measured from the standing AP pelvis radiograph.

Statistical analysis

Measurements from the 4 observers were combined, and the mean and standard deviation were calculated. The Pearson correlation coefficient was also measured for each observer, with the kappa values reported, and compared with the group for all measurements. The mean for each measurement was used to determine the number of components placed in the "safe zone." Statistical analysis was performed with the use of SAS software (SAS Institute, Raleigh, NC).

Results

Of the 30 enrolled patients, 29 had an appropriate CT scan obtained. One patient had a CT scan performed without adherence to the protocol precluding reference of femoral version to the axes of the knee and was excluded from the results.

The mean acetabular abduction and anteversion were 39.3° (standard deviation [SD] = 4.2°) and 27.2° (SD = 4.7°), respectively. The mean stem anteversion was 17.5° (SD = 10.8°) from the TEA and 21.7° (SD = 11.3°) from the PCA. Ten of the 30 cups were placed inside of the "safe zone" of Lewinnek for acetabular anteversion, but all cups were within the "safe zone" for abduction (Fig. 1).

Combined femoral and acetabular component anteversion from the TEA resulted in 79% (23 of 29) of patients within the "safe zone" of 25°-50° with accurately oriented components (Fig. 2).

Pearson correlation coefficients were high for both stem anteversion from the TEA (R = 0.96) and the PCA (R = 0.98); however, the kappa coefficient for interobserver reliability for combined component anteversion was greater for the TEA (kappa = 0.83 vs 0.65).

Discussion

Component positioning has been recognized as an important factor in the long-term survival of THA [5,12,26]. Muller et al. [27] suggested a cup anteversion of 10°-15° and femoral anteversion of 10° to be ideal. Lewinnek et al. [5] followed with their study that found a lower dislocation rate when the acetabular components were positioned in a safe zone of 30°-50° of inclination and 5°-25°

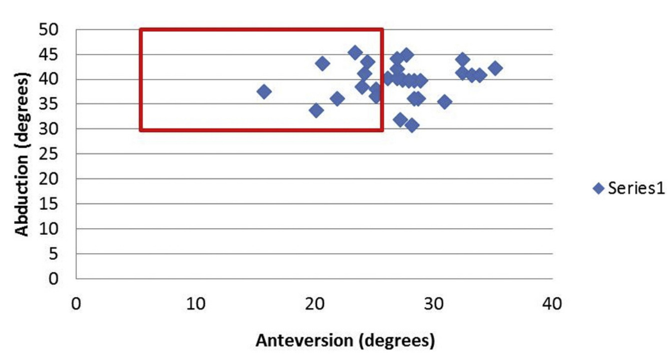

Figure 1. The Lewinnek "safe zone." Ten of the 30 cups were placed inside of the "safe zone" of Lewinnek for acetabular anteversion, but all cups were within the "safe zone" for abduction.

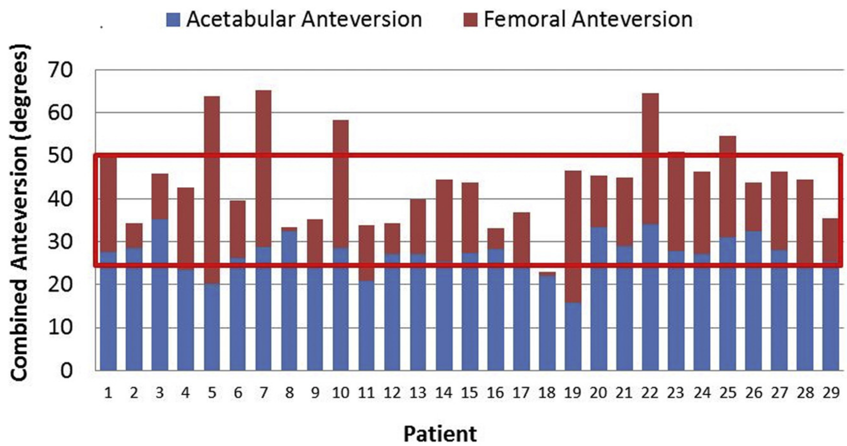

Figure 2. Combined anteversion. Combined femoral and acetabular component anteversion.

of anteversion. A study by Biedermann et al. [28] found the lowest dislocation rates with acetabular components positioned at 45° of inclination and 15° of anteversion. More recently, Dorr proposed a CV safe zone of 25°-50° based on previous anatomical studies and his experience with decreased instability in this range [15].

Many authors have begun to appreciate the importance of the combined femoral and acetabular anteversion on dislocation rates and impingement [3,11,12,29]. Ranawat and Maynard [6] suggested the importance of the combination of femoral and acetabular anteversion and recommended 45° for women and between 20° and 30° for men. Jolles et al. [12] found that when the combined anteversion was outside of a range of 40°-60°, the patient's dislocation was 6.9 times higher. Hisatome and Doi [29] examined combined anteversion in a mathematical model to find the optimum positions to avoid neck impingement with different sized components. They recommended an ideal position, while not accounting for patient's pelvic inclination, of 45° of cup abduction, 25° of cup anteversion, and 25° of stem antitorsion.

Other studies have examined the combined component anteversion after lateral or posterior approach THA. Reikerås and Gunderson [30] utilized postoperative CT scans in 91 patients after either posterior or lateral approach THA and found that only 60.4% of their patients had a combined anteversion within the acceptable safe zone. Wassilew et al. [31] evaluated THAs performed using an anterolateral approach with navigation, and they found that 88% of their patients were within the CV safe zone of 25°-50°.

A study by Nogler et al. [24] examined the ability of the DA approach to position the femoral and acetabular components with and without navigation. However, the present study is the first to analyze CV in the DA-THA. We used the TraumaCad (Voyant Health, Columbia, MD) software tool, which was found to have good intraobserver and interobserver reliability but can underestimate acetabular anteversion by as much as 12° [32]. Despite the potential for underestimation of anteversion, we believe that a standing radiograph more accurately represents the patient's functional anteversion and accounts for the patient's lumbar or pelvic tilt because of the difficulties in the estimation of tilts with supine radiographs [33-35]. This notion is supported by the work of Hayakawa et al that found a statistically significant difference between intraoperative and postoperative radiographs in 100 consecutive patients for both anteversion and vertical tilt [35].

Impingement can lead to abnormal wear patterns or dislocation. Our study found that 17% of patients had CV greater than 50°, outside of the safe zone. However, when the femoral and acetabular components were analyzed independently, 20 of 30 patients had "excessive" anteversion of the acetabular component. Intraoperative stability assessments did not identify any impingement. There was less variability in acetabular component version than in femoral version. With uncemented femoral components, femoral anteversion is largely dictated by proximal femoral geometry. Therefore, some surgeons have recommended a femur-first technique to better address this variability and "fine-tune" version on the acetabular implant [36]. Our results are comparable with those of similar series that included the posterior or lateral approach THA with and without navigation, with 88% and 60.4% of the components within the safe zone for CV, respectively [30,31]. We are unable to conclude that our results are superior based on the small sample size in our study, but this should be investigated further with a larger series.

We used both the PCA and the TEA for measurements to determine femoral component anteversion. Interestingly, we found a slightly higher interobserver reliability with the TEA measurements than with the PCA. This may reflect the difficultly of locating the point of maximal posterior bone in the condyle with a fine-cut CT scan. The differential radii of the femoral condyles and the extremity orientation relative to the CT scanner may influence the appearance of the most posterior projection of the condyles. This could cause the most posterior condylar projection to be on separate cuts of the CT scan. Authors may consider using the TEA primarily for femoral version measurements with axial imaging or 3-dimensional imaging techniques.

There are several potential limitations for this study. First, the number of patients in this study was 30. A small sample size may not reflect the variability of patient anatomies. The single-surgeon cohort may limit the generalizability of these results. The use of plain radiographs instead of CT to assess acetabular component position may be a limitation. The CT may be more accurate in determining acetabular anteversion and abduction. However, most surgeons who perform the DA-THA utilize the standing AP pelvis radiograph to position the acetabular component. It has been previously shown that the supine position of the acetabular component varies from supine to standing radiographs, and therefore, we chose to utilize a standing pelvis AP radiograph to determine the implant position. Many accepted modern studies have relied on AP radiographs to determine both anteversion and abduction angles for acetabular components [37-39]. Finally, this study did not assess the spinopelvic relationship. Abdel et al. recently demonstrated that most dislocations occurred within the "safe zone" [39] and it is possible that other factors are as important for stability as implant position.

As this study represents the first to examine CV in DA-THA with postoperative axial imaging, we found that the DA approach allowed for placement of components with CV within the acceptable range for most patients. In this study, excessive anteversion of the acetabular component based on Lewinnek's "safe zone" was the most common component orientation error. However, this may simply represent a single surgeon's component orientation preference and may not necessarily be generalizable. Even with limited visualization of the proximal femur, the DA approach can reproducibly yield a high percentage of THA components in the "ideal" position for CV.

Conflict of interest

J.B. Mason receives royalties from DePuy and A Johnson & Johnson Company, is a paid consultant for DePuy and A Johnson & Johnson Company, receives other financial or material support from DePuy and A Johnson & Johnson Company, receives royalties, financial or material support from the Journal of Arthroplasty, and is a board member for the Publication Committee AAHKS; J.R. Martin is a paid consultant for DePuy and A Johnson & Johnson Company; J.L. Masonis receives royalties from Medacta, Smith & Nephew, and Zimmer, is a paid consultant for Smith & Nephew and Zimmer, holds stock or stock options in Orthogrid, receives research support a principal investigator from DePuy, A Johnson & Johnson Company, Smith & Nephew, and Zimmer, receives royalties, financial or material support from Medacta, and is a board member for the Anterior Hip Foundation; J.B. Jackson is a board member for AAOS and AOFAS committee.

References

[1] Kennedy JG, Rogers WB, Soffe KE, Sullivan RJ, Griffen DG, Sheehan LJ. Effect of acetabular component orientation on recurrent dislocation, pelvic osteolysis, polyethylene wear, and component migration. J Arthroplasty 1998;13:530.

[2] Ng VY, McShane MA. Understanding acetabular cup orientation: the importance of convention and defining the safe zone. Hip Int 2011;21:646.

[3] Wang L, Trousdale RT, Ai S, An K-N, Dai K, Morrey BF. Dislocation after total hip arthroplasty among patients with developmental dysplasia of the hip. J Arthroplasty 2012;27:764.

[4] Little NJ, Busch CA, Gallagher JA, Rorabeck CH, Bourne RB. Acetabular polyethylene wear and acetabular inclination and femoral offset. Clin Orthop Relat Res 2009;467:2895.

[5] Lewinnek GE, Lewis JL, Tarr R, et al. Dislocations after total arthroplasties *. J Bone Joint Surg Am 1978;60:217.

[6] Ranawat C, Maynard M. Modern technique of cemented total hip arthroplasty. Tech Orthop 1991;6:17.

[7] Bedard NA, Martin CT, Slaven SE, Pugely AJ, Mendoza-Lattes SA, Callaghan JJ. Abnormally high dislocation rates of total hip arthroplasty after spinal deformity surgery. J Arthroplasty 2016;31:2884.

[8] Munuera L, Garcia-Cimbrelo E. The femoral component in low-friction arthroplasty after ten years. Clin Orthop Relat Res 1992:163.

[9] Jaffe WL, Hawkins CA. Normalized and proportionalized cemented femoral stem survivorship at 15 years. J Arthroplasty 1999;14:708.

[10] Min BW, Song KS, Bae KC, Cho CH, Kang CH, Kim SY. The effect of stem alignment on results of total hip arthroplasty with a cementless tapered-wedge femoral component. J Arthroplasty 2008;23:418.

[11] Renkawitz T, Haimerl M, Dohmen L, et al. The association between femoral tilt and impingement-free range-of-motion in total hip arthroplasty. BMC Musculoskelet Disord 2012;13:65.

[12] Jolles BM, Zangger P, Leyvraz P-F. Factors predisposing to dislocation after primary total hip arthroplasty: a multivariate analysis. J Arthroplasty 2002;17:282.

[13] Widmer K-H, Zurfluh B. Compliant positioning of total hip components for optimal range of motion. J Orthop Res 2004;22:815.

[14] LUCAS DH. The Ranawat sign. A specific maneuver to assess component positioning in total hip arthroplasty. J Orthop Tech 1994;2:59.

[15] Dorr LD, Malik A, Dastane M, Wan Z. Combined anteversion technique for total hip arthroplasty. Clin Orthop Relat Res 2009;467:119.

[16] Ohmori T, Kabata T, Kajino Y, et al. The optimal combined anteversion pattern to achieve a favorable impingement-free angle in total hip arthroplasty. J Orthop Sci 2019;24:474.

[17] Weber M, Woerner ML, Sendtner E, Völlner F, Grifka J, Renkawitz TF. Even the intraoperative knowledge of femoral stem anteversion cannot prevent impingement in total hip arthroplasty. J Arthroplasty 2016;31:2514.

[18] Bargar WL, Jamali AA, Nejad AH. Femoral anteversion in THA and its lack of correlation with native acetabular anteversion. Clin Orthop Relat Res 2010;468:527.

[19] Dorr LD, Wan Z, Malik A, Zhu J, Dastane M, Deshmane P. A comparison of surgeon estimation and computed tomographic measurement of femoral component anteversion in cementless total hip arthroplasty. J Bone Joint Surg Am 2009;91:2598.

[20] Kennon RE, Keggi JM, Wetmore RS, Zatorski LE, Huo MH, Keggi KJ. Total hip arthroplasty through a minimally invasive anterior surgical approach. J Bone Joint Surg Am 2003;85-A:39.

[21] Taunton MJ, Trousdale RT, Sierra RJ, Kaufman K, Pagnano MW. John charnley award: randomized clinical trial of direct anterior and miniposterior approach THA: which provides better functional recovery? Clin Orthop Relat Res 2018;476:216.

[22] Watts CD, Houdek MT, Wyles CC, Sierra RJ, Trousdale RT, Taunton MJ. Direct anterior versus posterior simultaneous bilateral total hip arthroplasties: no major differences at 90 days. Am J Orthop (Belle Mead, NJ) 2016;45:E373.

[23] Taunton MJ, Mason JB, Odum SM, Springer BD. Direct anterior total hip arthroplasty yields more rapid voluntary cessation of all walking aids: a prospective, randomized clinical trial. J Arthroplasty 2014;29:169.

[24] Nogler M, Mayr E, Krismer M, Thaler M. Reduced variability in cup positioning: the direct anterior surgical approach using navigation. Acta Orthop 2008;79:789.

[25] Anterior Total Hip Arthroplasty Collaborative Investigators, Bhandari M, Matta JM, Dodgin D, et al. Outcomes following the single-incision anterior approach to total hip arthroplasty: a multicenter observational study. Orthop Clin North Am 2009;40:329.

[26] Del Schutte H, Lipman AJ, Bannar SM, Livermore JT, Ilstrup D, Morrey BF. Effects of acetabular abduction on cup wear rates in total hip arthroplasty. J Arthroplasty 1998;13:621.

[27] Müller M, Abdel MP, Wassilew GI, Duda G, Perka C. Do post-operative changes of neck-shaft angle and femoral component anteversion have an effect on clinical outcome following uncemented total hip arthroplasty? Bone Joint J 2015;97-B:1615.

[28] Biedermann R, Tonin A, Krismer M, Rachbauer F, Eibl G, Stöckl B. Reducing the risk of dislocation after total hip arthroplasty: the effect of orientation of the acetabular component. J Bone Joint Surg Br 2005;87:762.

[29] Hisatome T, Doi H. Theoretically optimum position of the prosthesis in total hip arthroplasty to fulfill the severe range of motion criteria due to neck impingement. J Orthop Sci 2011;16:229.

[30] Reikerås O, Gunderson RB. Components anteversion in primary cementless THA using straight stem and hemispherical cup: a prospective study in 91 hips using CT-scan measurements. Orthop Traumatol Surg Res 2011;97:615.

[31] Wassilew GI, Perka C, Koenig C, Janz V, Asbach P, Hasart O. 3D CT analysis of combined cup and stem anteversion in cases of cup navigation in hip arthroplasty. Orthopedics 2010;33:48.

[32] Westacott DJ, McArthur J, King RJ, Foguet P. Assessment of cup orientation in hip resurfacing: a comparison of TraumaCad and computed tomography. J Orthop Surg Res 2013;8:8.

[33] Wan Z, Malik A, Jaramaz B, Chao L, Dorr LD. Imaging and navigation measurement of acetabular component position in THA. Clin Orthop Relat Res 2009;467:32.

[34] Kalteis TA, Handel M, Herbst B, Grifka J, Renkawitz T. In vitro investigation of the influence of pelvic tilt on acetabular cup alignment. J Arthroplasty 2009;24:152.

[35] Hayakawa K, Minoda Y, Aihara M, Sakawa A, Ohzono K, Tada K. Acetabular component orientation in intra- and postoperative positions in total hip arthroplasty. Arch Orthop Trauma Surg 2009;129:1151.

[36] Loppini M, Longo UG, Caldarella E, Rocca AD, Denaro V, Grappiolo G. Femur first surgical technique: a smart non-computer-based procedure to achieve the combined anteversion in primary total hip arthroplasty. BMC Musculoskelet Disord 2017;18:331.

[37] Poehling-Monaghan KL, Kamath AF, Taunton MJ, Pagnano MW. Direct anterior versus miniposterior THA with the same advanced perioperative protocols: surprising early clinical results. Clin Orthop Relat Res 2015;473:623.

[38] Lin TJ, Bendich I, Ha AS, Keeney BJ, Moschetti WE, Tomek IM. A comparison of radiographic outcomes after total hip arthroplasty between the posterior approach and direct anterior approach with intra-operative fluoroscopy. J Arthroplasty 2017;32:616.

[39] Abdel MP, von Roth P, Jennings MT, Hanssen AD, Pagnano MW. What safe zone? The vast majority of dislocated THAs are within the Lewinnek safe zone for acetabular component position. Clin Orthop Relat Res 2016;474:386.