Original Article

Difference in the acetabular cup orientation in standing and supine radiographs

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ABSTRACT

Acetabular orientation changes with that of the pelvis during lying and standing. This study was designed to measure these changes. We assessed 17 BHR replacements using EBRA software. The mean acetabular anteversion was more ($p = 0.02$) on erect than supine radiographs. Linear regression analysis showed that anteversion and inclination increased in some while decreased in others, and Bland and Altman analysis showed wide limits of agreement. The changes in acetabular orientation are thus subject to significant variations between the patients. We suggest studying the factors affecting acetabular orientation in standing to help reduce joint reaction forces and improve outcomes.

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1. Introduction

Acetabular component orientation is determined routinely on an AP pelvic radiograph, which is taken in the supine position. There is a difference in orientation of the pelvis (pelvic tilt) between lying and standing positions and consequently that of the acetabulum. The orientation of the pelvis is measured by calculating sacral slope, which decreases from supine to standing position.¹ This overall movement is related to the flexibility of the lumbo-sacral junction, and therefore pelvic tilt varies between individuals. As a result of the pelvic tilt the acetabular anteversion has been reported to increase from supine to standing position.¹ These pelvic movements allow for good range of hip movements by positioning the acetabulum in such a manner that impingement and instability of the hip joint are avoided in various range of movements including standing, sitting and lying positions.² On average, the pelvic tilt changes by approximately 49° (-22° to 27°) during lying, sitting and standing positions.^{3–6} The effect of these pelvic movements is relatively more on anteversion than the inclination of acetabulum.^{7,8}

Metal on metal bearings are very sensitive to malalignment. Their wear primarily occur in activities that are carried out in the standing position. It is therefore logical to know the orientation of

acetabular cups in standing position, which is the position of function.

2. Material and methods

A local risk analysis was performed and a local ethics approval was obtained for this study. Sample size was calculated from data obtained previously, of first 75 Birmingham hip replacements performed by the senior author of this study, using EBRA software. The standard deviation of the cup inclination and anteversion was 6.5° and 6.46° , respectively. We calculated that a minimum of 16 hips would be required to show a difference of 5° in anteversion and inclination, with a power of 80%.

2.1. Inclusion/exclusion criteria

The senior authors' care team from outpatient clinics identified the patients. We aimed to include the first sixteen Birmingham resurfacing hip arthroplasty patients from the clinic, who were completely asymptomatic. Patient's radiographs were taken in both supine and standing position and both the positions were standardized, to obtain reproducible results.

2.2. Measurements of acetabular cup orientation

Measurements of cup inclination and anteversion angles were performed using EBRA (Einzel-Bild-Röntgen-Analyse, University of Innsbruck, Austria) software from a single AP pelvic radiograph.⁹

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This software measures the precise positioning of prosthetic components on two-dimensional digitized imaging with error of less than 1° . It is a validated tool, and there are many reports in the literature on its good to excellent inter- and intra-observer reliability.^{10,11} This software has been shown to reliably assess the version of resurfacing cups, when¹² the radiographs are of sufficient quality. An independent person, who was not involved in the clinical care of the patients at any stage, took all measurements in this study.

2.3. Statistically analysis

Paired samples *t*-test was used to analyze the difference between the supine and lying acetabular component orientation. The null hypothesis was that there is no difference. *p*-Value of <0.05 was considered statistically significant. Moreover, agreement between the measurements was analyzed by using Bland and Altman plot and calculating the interclass correlation coefficient (ICC) for mixed model effects. Finally, linear regression was performed to check for proportional bias between the calculated difference in the measurements and the mean difference, i.e. to check if the difference between the measurements is positive or negative.

We used SPSS version 21 for analysis.

3. Results

We recruited fourteen (three with bilateral joint replacements) patients with Birmingham MoM hip resurfacings replacement, who were asymptomatic, at the time of annual follow-up. All patients were provided patients information leaflet and signed the consent form.

The patient's median age was 58. There were seventeen hips in 14 patients. There were 10 male and 4 female patients. The average time to implantation of the prostheses was 5 years. The average femoral head prostheses diameter was 46 mm (range 42–46 mm). The difference between the supine (43.4°) and the erect (44.5°) cup inclination angles was -1.08° (range 3.3° to -6.5°); and approaching but not significantly different ($p = 0.05$). The difference between the erect (16.9°) and the supine (15.07°) cup anteversion angles was -1.84° (range 6.7 to -6.4°), and was a statistically significant ($p = 0.02$) (Table 1).

The interclass coefficient for perfect agreement between the supine and erect cup orientation parameters was excellent, 0.93 and 0.92 for inclination and anteversion, respectively. Bland and Altman analysis, however, showed that the limits of agreement were quite wide (Figs. 1 and 2). Finally, the results of linear regression showed that the difference in the cup anteversion ($B = 0.04$, $p = 0.7$) and inclination ($B = 0.09$, $p = 0.4$) in supine and standing positions did not have a proportional bias, which indicates that there is no particular direction of change. In other words, we the cup inclination and anteversion had increased in some, while decreased in other patients, in the standing position.

Table 1

Data on cup orientation in lying and standing position. The value marked with “*” has *p* value < 0.05 .

	Mean ($^\circ$)	Range	St. Dev.
Supine inclination	43.3	35.4 to 49.8	4.8
Supine anteversion	15.1	4.2 to 28.2	6.8
Erect inclination	44.4	37 to 51.1	4.4
Erect anteversion	16.9	4.5 to 29.5	6.5
Difference in inclination	1.08	3.4 to -6.6	2.2
Difference in anteversion	1.84*	6.7 to -6.4	3.2

Fig. 1. Bland and Altman chart of difference between the cup inclination in supine and erect positions.

Fig. 2. Bland and Altman chart of difference between the cup anteversion in supine and erect positions.

4. Discussion

This study reports the effects of the pelvic movements on acetabular orientation. The effect was seen more on anteversion of the acetabular cup with a net increase of 1.84° . We know that standing leads to posterior pelvic tilt and resulting increase in the anteversion of the acetabulum. This phenomenon has been reported in other studies,^{5,13–15} however, our study data showed that standing may result in an increase or decrease in the anteversion as well as inclination. This can be seen very well on Bland and Altman analysis (Fig. 2) showing wider limits of agreements (-8° to 4.4°), as well as on linear regression as an absence of proportional bias. The effect could be related to variation in the pelvic tilt of individual patients, or due to compensatory postural correction by patients in response to underlying subclinical degenerate changes in the spine or lower limb joints.

Metal on metal bearings are more sensitive to the cup positioning. A high acetabular inclination angle in hip resurfacing is associated with high serum metal ion levels and pseudotumor formation due to an increase in the wear rates, as a result of edge loading.^{11,16–18} Excessive anteversion is an equally important factor.^{11,19,20} Anteversion below ten degrees and above 20° – 25°

has been reported to be associated with extremely high circulatory cobalt and chromium levels.^{11,12,17,21} Moreover, incorrect version can cause iliopsoas irritation,²² impingement, decrease range of motion, and increase rate of dislocation and loosening.^{23,24} Accurate assessment of the acetabular orientation is, therefore, of a key importance in assessing the outcome of hip resurfacing arthroplasty, and diagnosis of pain following hip arthroplasty.

In the past, changes in the acetabular orientation in reference to the pelvic tilt have been indirectly calculated in the native hips and cadavers, and recently in patients with metal-on-polyethylene hips.^{8,25,26} Most of those studies used CT scan, which involves high dose of ionizing radiations. Our study is novel because we performed direct measurements in lying and standing positions in patients with metal-on-metal bearing hip replacements; and we used EBRA software, which can be used to perform measurements from two-dimensional digitized radiographs. We did not study the effect of change in the acetabular orientation on circulatory metal ion levels, but we believe that without power analysis such calculations would not have provided meaningful results.

Acetabular positioning is of paramount importance in optimal functioning of the metal on metal hip arthroplasty. Higher inclination and anteversion angles lead to very high contact pressures and loss of lubricating regimes, because of proximity of wear patch to the rim.²⁷ This phenomenon is now increasingly recognized and reported to cause high wear rates in high polyethylene wear,²⁸ and squeaking²⁹ and fractures in ceramic bearings.³⁰ The effects of malaligned anteversion become significantly important in cups positioned in optimal inclination and hence apparently looking normal on AP radiographs. The importance of this study is in highlighting the fact that acetabular anteversion as well as inclination may change in either direction in standing position and hence individuals' pelvis orientation need to be taken into account at the time of arthroplasty. We suggest that changes in acetabular orientation of patients requiring hip arthroplasty shall be studied with such simpler methods like EBRA for better understanding. This will result in lower wear rates of metal on metal bearings in hip arthroplasty, as well as improved longevity of polyethylene bearing due to less wear, and less risk of squeaking and fractures in ceramic bearings.

Conflicts of interest

The authors have none to declare.

References

- Lazennec JY, Boyer P, Gorin M, Catonne Y, Rousseau MA. Acetabular anteversion with CT in supine, simulated standing, and sitting positions in a THA patient population. *Clin Orthop Relat Res.* 2011;469(April (4)):1103–1109.
- Lewinnek GE, Lewis JL, Tarr R, Compere CL, Zimmerman JR. Dislocations after total hip-replacement arthroplasties. *J Bone Joint Surg Am.* 1978;60(March (2)):217–220.
- Dowson D, Hardaker C, Flett M, Isaac GH. A hip joint simulator study of the performance of metal-on-metal joints: Part I: the role of materials. *J Arthroplasty.* 2004;19(December (8 suppl 3)):118–123.
- DiGioia AM, Hafez MA, Jaramaz B, Levison TJ, Moody JE. Functional pelvic orientation measured from lateral standing and sitting radiographs. *Clin Orthop Relat Res.* 2006;453(December):272–276.
- 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(January (1)):32–42.
- Zhu J, Wan Z, Dorr LD. Quantification of pelvic tilt in total hip arthroplasty. *Clin Orthop Relat Res.* 2010;468(February (2)):571–575.
- van Bosse HJ, Lee D, Henderson ER, Sala DA, Feldman DS. Pelvic positioning creates error in CT acetabular measurements. *Clin Orthop Relat Res.* 2011;469(June (6)):1683–1691.
- Dandachli W, Ul Islam S, Richards R, Hall-Craggs M, Witt J. The influence of pelvic tilt on acetabular orientation and cover: a three-dimensional computerised tomography analysis. *Hip Int.* 2013;23(January–February (1)):87–92.
- Stoeckl B, Biedermann R, Auckenthaler T. Ante- and retroversion measurement of cups by EBRA. *J Bone Joint Surg Br.* 2001;83-B(suppl II):179.
- Ochsner P. Measurement of the acetabular migration by using standard A.P. radiographs (EBRA): technique, results and practical application in clinical work. *J Bone Joint Surg Br.* 1998;80-B(suppl I):33.
- Langton DJ, Jameson SS, Joyce TJ, Webb J, Nargol AV. The effect of component size and orientation on the concentrations of metal ions after resurfacing arthroplasty of the hip. *J Bone Joint Surg Br.* 2008;90(September (9)):1143–1151.
- Langton DJ, Sprowson AP, Joyce TJ, et al. Blood metal ion concentrations after hip resurfacing arthroplasty: a comparative study of articular surface replacement and Birmingham Hip Resurfacing arthroplasties. *J Bone Joint Surg Br.* 2009;91(October (10)):1287–1295.
- 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(January (1)):152–157.
- Lazennec JY, Charlot N, Gorin M, et al. Hip-spine relationship: a radio-anatomical study for optimization in acetabular cup positioning. *Surg Radiol Anat.* 2004;26(April (2)):136–144.
- Lembeck B, Mueller O, Reize P, Wuelker N. Pelvic tilt makes acetabular cup navigation inaccurate. *Acta Orthop.* 2005;76(August (4)):517–523.
- Hart AJ, Buddhdev P, Winship P, Faria N, Powell JJ, Skinner JA. Cup inclination angle of greater than 50 degrees increases whole blood concentrations of cobalt and chromium ions after metal-on-metal hip resurfacing. *Hip Int.* 2008;18(July–September (3)):212–219.
- Hart AJ, Ilo K, Underwood R, et al. The relationship between the angle of version and rate of wear of retrieved metal-on-metal resurfacings: a prospective, CT-based study. *J Bone Joint Surg Br.* 2011;93(March (3)):315–320.
- Kwon YM, Glyn-Jones S, Simpson DJ, et al. Analysis of wear of retrieved metal-on-metal hip resurfacing implants revised due to pseudotumours. *J Bone Joint Surg Br.* 2010;92(March (3)):356–361.
- De Haan R, Campbell PA, Su EP, De Smet KA. Revision of metal-on-metal resurfacing arthroplasty of the hip: the influence of malpositioning of the components. *J Bone Joint Surg Br.* 2008;90(September (9)):1158–1163.
- Grammatopoulos G, Pandit H, Glyn-Jones S, et al. Optimal acetabular orientation for hip resurfacing. *J Bone Joint Surg Br.* 2010;92(August (8)):1072–1078.
- Langton DJ, Jameson SS, Joyce TJ, Hallab NJ, Natsu S, Nargol AV. Early failure of metal-on-metal bearings in hip resurfacing and large-diameter total hip replacement: a consequence of excess wear. *J Bone Joint Surg Br.* 2010;92(January (1)):38–46.
- Cyteval C, Sarrahere MP, Cottin A, et al. Iliopsoas impingement on the acetabular component: radiologic and computed tomography findings of a rare hip prosthesis complication in eight cases. *J Comput Assist Tomogr.* 2003;27(March–April (2)):183–188.
- Klues D, Zietz C, Lindner T, Mittelmeier W, Schmitz KP, Bader R. Limited range of motion of hip resurfacing arthroplasty due to unfavorable ratio of prosthetic head size and femoral neck diameter. *Acta Orthop.* 2008;79(December (6)):748–754.
- Malik A, Maheshwari A, Dorr LD. Impingement with total hip replacement. *J Bone Joint Surg Am.* 2007;89(August (8)):1832–1842.
- Siebenrock KA, Kalbermatten DF, Ganz R. Effect of pelvic tilt on acetabular retroversion: a study of pelves from cadavers. *Clin Orthop Relat Res.* 2003;(February (407)):241–248.
- Ross JR, Tannenbaum EP, Nepple JJ, Kelly BT, Larson CM, Bedi A. Functional acetabular orientation varies between supine and standing radiographs: implications for treatment of femoroacetabular impingement. *Clin Orthop Relat Res.* 2015;473(April (4)):1267–1273.
- Underwood RJ, Zografos A, Sayles RS, Hart A, Cann P. Edge loading in metal-on-metal hips: low clearance is a new risk factor. *Proc Inst Mech Eng H.* 2012;226(March (3)):217–226.
- Tezuka T, Inaba Y, Kobayashi N, et al. Influence of pelvic tilt on polyethylene wear after total hip arthroplasty. *Biomed Res Int.* 2015;2015:327217.
- Chevillotte C, Trousdale RT, An KN, Padgett D, Wright T. Retrieval analysis of squeaking ceramic implants: are there related specific features? *Orthop Traumatol Surg Res.* 2012;98(May (3)):281–287.
- Sariali E, Klouche S, Mamoudy P. Ceramic-on-ceramic total hip arthroplasty: is squeaking related to an inaccurate three-dimensional hip anatomy reconstruction? *Orthop Traumatol Surg Res.* 2014;100(June (4)):437–440.