

Changes of center of rotation and femoral offset in total hip arthroplasty

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Background: It is a challenge to reconstruct the center of rotation (COR) and femoroacetabular offset anatomically in total hip arthroplasty (THA). We addressed the controversy how we manage to preserve the COR and femoroacetabular offset with an uncemented total hip prosthesis implanted with free hand technique.

Methods: We analyzed a prospective series of 73 patients who underwent primary THA. The series was composed of 40 females and 33 males, mean age 64 years (range, 35–90 years). The reasons for THA were primary osteoarthritis (n=63) and developmental dysplasia of the hip (n=10). Pre- and postoperative X-rays were done in a standardized format for anterior-posterior (AP) radiographs of the pelvis, and digitalized measurements were done using SectraTM. We compared preoperative measurements with the final outcome to determine changes in COR and femoral offset.

Results: We found that 40 patients had their COR and 34 patients had their femoral offset preserved within preoperative 5.0 mm limits. Twenty-three patients had both their values of COR and femoral offset preserved within 5.0 mm limits. While a significant correlation was found between changes of femoral and global offset ($r=0.786$, $P<0.001$), there were no correlation between changes of acetabular and femoral offset ($r=-0.027$, $P=0.822$).

Conclusions: Using an uncemented THA and free hand technique, there is a fair reproducibility of anatomy. The variations were mostly minor, but our results indicate a potential for better restoring the location of COR and femoral offset when planning and implanting an uncemented THA.

Keywords: Acetabular offset; center of rotation (COR); femoral offset; global offset; total hip arthroplasty (THA)

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Introduction

During single-leg standing the body weight is counterbalanced by the abductor muscles strength (1). Any variation in the hip joint center of rotation (COR) after total hip arthroplasty (THA) influences the lever arm and tension of the abductor muscles as well as the lever arm of the body weight, and thus the force required by the muscles to balance the pelvis. Medialization of COR with reduced lever arm of the body weight positively affects hip function (2) and has been associated with increased survival of THA (3-6). Also, the height of COR determines the tension of the abductor muscles (7),

and superior and lateral relocation after THA has been connected with an increased rate of aseptic loosening (8,9). Therefore medialization of the cup with a respective increase in femoral offset has been advocated (10,11). However, medialization of the COR in THA may have negative effects on joint reaction forces, and may cause bone loss and changes in proprioception.

Increased femoral offset improves the hip abductor strength, and, thereby, reduces limping and the patients need of crutches (12-16). It also increases hip range of motion (10,17,18) and reduces the risk of dislocation and polyethylene wear (19-21). Correspondingly, patients

with reduced femoral offset perform lower on functional tests (22,23). For some reason, however, it seems that patients with a low femoral offset experience the greatest improvement on pain scores after THA (24).

Thus, we have performed a prospective radiological study in patients receiving an uncemented THA to address the controversies:

- (I) How do we manage to preserve the hip COR;
- (II) How do we manage to preserve femoral and global offset;
- (III) How are femoral, acetabular and global offsets correlated.

Methods

Patients

The study was not interventional, the patients followed ordinary routines and they could not be identified. Specific ethics approval therefore was not needed. It was prospectively performed in 100 patients (hips) who underwent primary THA with an uncemented prosthesis in accordance with the ethical standards of the 1975 Declaration of Helsinki as revised in 2008. The reasons for THA were primary osteoarthritis (n=63) and developmental dysplasia of the hip (n=10). We followed our ordinary practice, so there was no need for patient consent. We excluded 27 patients who suffered from distorted anatomy like developmental dysplasia of the hip (n=19), Calve-Legg-Perthes disease (n=4), avascular necrosis of the hip (n=2) and protrusion of the acetabulum (n=2). The following 73 patients to be included: 40 were females and 33 were males with a mean age of 64 years (range, 35–90 years). We intended a descriptive analysis, so we did not perform power calculations for statistics.

Four senior surgeons at our hospital operated the patients with a lateral approach. In all patients we used an uncemented prosthesis with a porous coated hemispherical press fit cup (Trilogy, Zimmer, Warsaw, USA) and a hydroxyapatite coated straight and rectangular press fit stem (Corail, DePuy, Saint Priest, France). The stem had a standard neck with modular lengths. The cup was inserted first, and then the stem. We used cup sizes from 48 to 60 and stem sizes from 9 to 14. As a standard we aimed to obtain femoral anteversion of 10 to 30°, acetabular anteversion of 10 to 30° and a combined anteversion of 25 to 55°. Cup position was obtained with the aid of an acetabular cup impactor-positioner provided with the

implant manufacturer. Stem position was obtained with the knee flexed 90° and the leg as the reference for anteversion. In all cases we used elevated liners to provide optimal femoral head coverage and we used a ceramic head with diameter of 28 mm.

Methods of assessment

All radiological examinations were performed at the same radiological center. We used a standardized format for anterior-posterior (AP) radiographs of the pelvis with the patients in the supine position with the lower limbs parallel with each other as the patella was pointing frontally. We considered radiographs to be standardized if there were symmetric appearances of the obturator foramina and the tip of the coccyx pointed toward the symphysis pubis (25). Two reference lines were used to establish the body axis; one inter-ischial line and one vertical body line drawn perpendicular to the inter-ischial line through the centre of pubic symphysis (*Figure 1*). With help of PACS circles superimposed on the femoral head and the acetabular border, the best fitting circle was used to determine the femoral head COR and the rim of the acetabulum, respectively.

Preoperatively and postoperatively we measured five variables of biomechanical interest: (I) Distance between vertical midline—medial rim of acetabulum. (II) Distance between vertical midline proximal lateral femoral cortex (global offset). The end of the proximal lateral femoral cortex is defined as where cortical bone thickening ends beneath the trochanter area of the femoral metaphysis. (III) Distance between vertical midline and COR (acetabular offset). II subtracting III gives femoral offset. (IV) Distance between horizontal line and roof of acetabulum. (V) Distance between horizontal line and COR.

Statistical analysis

The distances were automatically calculated in PACS. Measurements were done twice and the mean value used in our data. Image magnification was accounted for by measuring the size of a metal ball with a known diameter. In a previous study we found this method to be applicable with intraclass correlation coefficient above 0.98 for all measurements (26). As there are sparse relevant data in the literature and our data are presented descriptively rather than statistically, we did not perform power analyses before the study. Data are expressed by mean \pm standard deviations

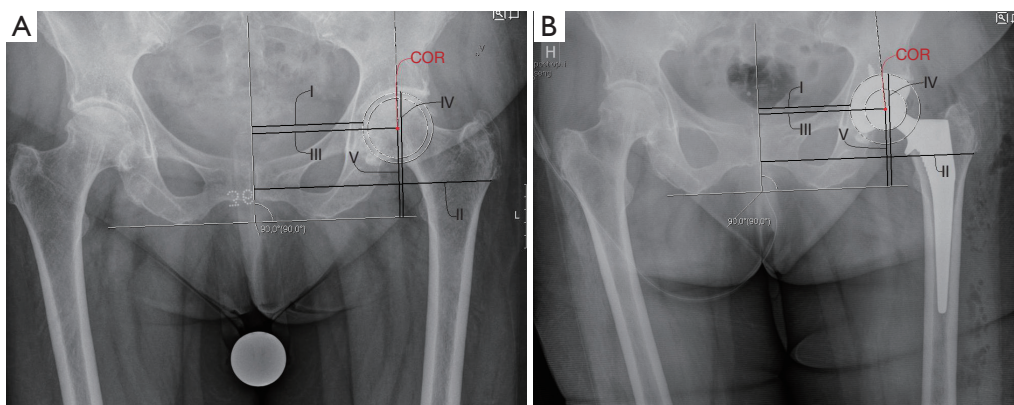


Figure 1 Pre- (A) and postoperative (B) measurements. Horizontal inter-ischial line and vertical body line perpendicular to the inter-ischial line pubic symphysis. Reference lines in bold black perpendicular to each other (90°). I, distance between vertical midline and medial rim of acetabulum. II, distance between vertical midline proximal lateral femoral cortex (global offset). The end of the proximal lateral femoral cortex is defined as where cortical bone thickening ends beneath the trochanter area of the femoral metaphysis. III, distance between vertical midline and COR (acetabular offset). II subtracting III gives femoral offset. IV, distance between horizontal line and roof of acetabulum. V, distance between horizontal line and COR. COR, center of rotation.

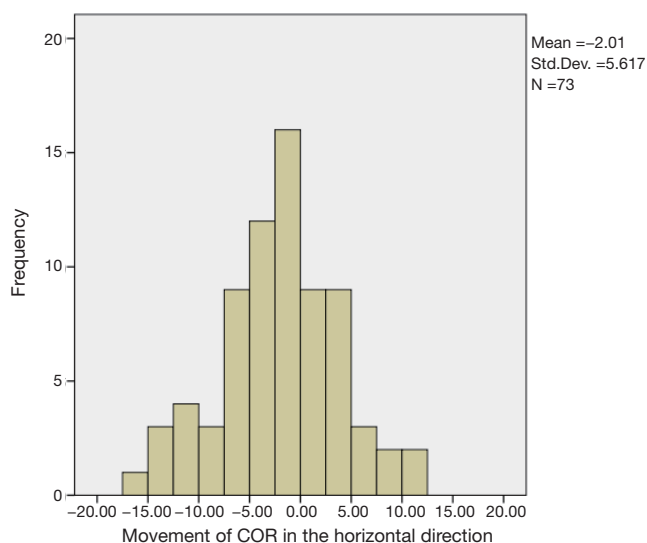


Figure 2 Distribution in horizontal movement of center of rotation (COR) in patients operated with primary total hip arthroplasty.

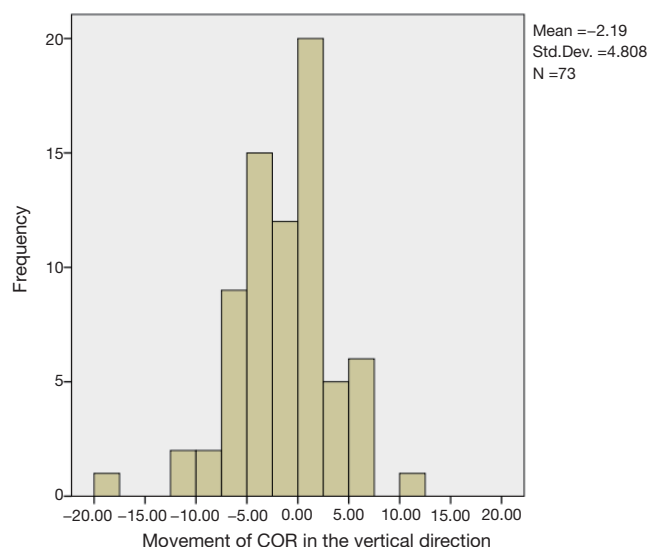


Figure 3 Distribution in vertical movement of center of rotation (COR) in patients operated with primary total hip arthroplasty.

(SD), and we calculated Pearson's correlation coefficient (r). P value equal 0.05 or smaller was considered significant. For statistical analysis the SPSSTM software of the 12th version was used.

Results

The changes of COR in horizontal direction (acetabular offset)

ranged from -15 to $+11$ mm with a mean of -2.0 ± 5.6 mm (Figure 2). In 20 of 73 cases there was a medial shift of COR by more than 5.0 mm, and in 7 cases there was a lateral shift by more than 5.0 mm. The changes of COR in the vertical direction ranged from 18 mm in proximal direction to 11 mm in distal direction with a mean of 1.3 ± 4.8 mm in proximal direction (Figure 3). In 14 cases COR was moved more than 5.0 mm proximally, and in 6 cases it was moved

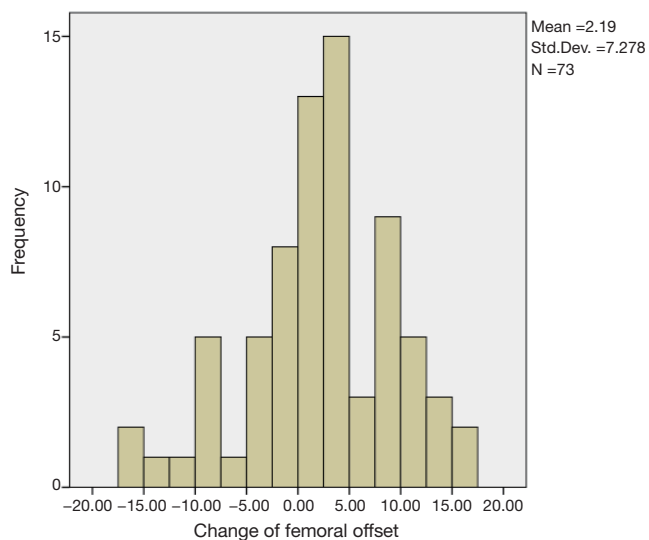


Figure 4 Distribution in change of femoral offset in patients operated with primary total hip arthroplasty.

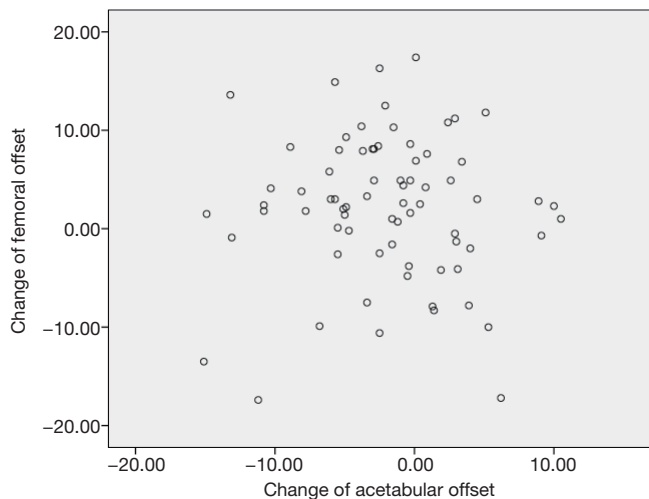


Figure 5 Scatter plot of correlations between changes of acetabular and femoral offset in patients operated with primary total hip arthroplasty.

more than 5.0 mm in distal direction.

The change of femoral offset ranged from -17 to +17 mm with a mean of $+2.2 \pm 7.3$ mm (Figure 4). In 10 cases the femoral offset was reduced by more than 5.0 mm, and in 22 cases the femoral offset was increased by more than 5.0 mm.

The change in global offset ranged from -29 to +18 mm with a mean of $+0.2 \pm 9.1$ mm. In 17 cases global offset was reduced by more than 5.0 mm, and in 22 cases the global offset was increased by more than 5.0 mm.

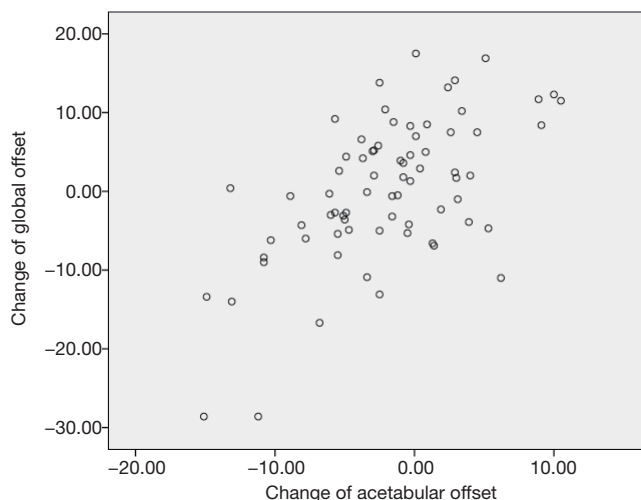


Figure 6 Scatter plot of correlations between changes of acetabular and global offset in patients operated with primary total hip arthroplasty.

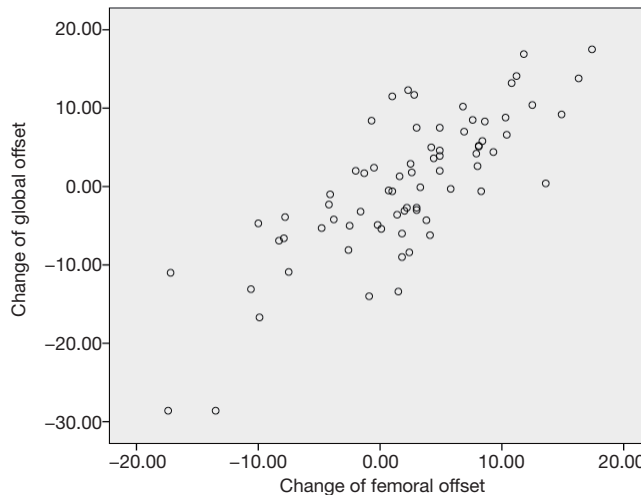


Figure 7 Scatter plot of correlations between changes of femoral and global offset in patients operated with primary total hip arthroplasty.

The correlation between changes in acetabular and femoral offset was not significant ($r = -0.027$, $P = 0.822$), while the correlation between changes in acetabular and global offset ($r = 0.598$, $P < 0.001$), and the correlations between changes in femoral and global offset ($r = 0.786$, $P < 0.001$) were significant (Figures 5–7 respectively).

The postoperative course was uneventful in all patients, and at follow-up at 12 months they all had gluteal stability as evaluated by clinical testing (Trendelenburg sign).

Discussion

In this study we addressed the controversy how we manage to preserve the COR to the anatomic position with an uncemented total hip prosthesis implanted with free hand technique. In the literature there is agreement that an optimal reconstruction of COR in THA is within 5 mm from the anatomic location (8,27,28). We found that in 40 of 73 patients (hips) the COR was preserved within 5 mm from the preoperative anatomy. In all except one case with acetabular reaming of more than 10 mm in medial or proximal direction, COR was relocated more than 10 mm medially of proximally to the anatomic location. This finding supports the logical conclusion that the degree of acetabular reaming affects relocation of COR.

There are limitations to our study: it was restricted to patients with a well-defined femoral head and acetabular cavity. In patients with a deranged hip joint, relocation of the acetabular cavity can be necessary, and consequently the relocation of COR in a medial and/or superior direction can be even larger. Second, we relied on proper standardization of radiographs and measurement techniques, but radiographic interpretation relies heavily on the clinicians experience with reading radiographs. To minimize shortcomings, we calibrated with a ball of known size, and in a previous study this method proved to have high reliability and agreement of both within the same observer and between observers (26). Third, frontal X-rays only represent two-dimensional change of distances between the object of interest. When measuring the change of femoral offset, the possible change of femoral neck version might be a confounder (28). We did not measure the femoral neck angles, but compared the physiological femoral offset with the patella facing frontally.

In our series femoral offset was preserved within 5 mm in 34 cases. The optimal outcome in terms of stress has been observed when COR is medialized, but with an equivalent increase in femoral offset to restore global offset. This was obtained in 15 of our cases. Medialization of the cup decreases stress on the head-cup interface and on the abductor muscles (10,11). On the other hand, any increase of femoral and global offset significantly increases the length and the tension in the anterior bundles of the abductor muscles, and an increased expression of pain has been linked to increased femoral offset (27). The contribution of an offset increase is larger in a patient with little femoral torsion. Large femoral antetorsion and an increased femoral offset move the insertion of the abductor

muscles on the greater trochanter more posteriorly and less laterally compared with a patient with little femoral antetorsion (29). Due to this a shift of femoral offset has been questioned. At least it seems that the effect of cup medialization is of less clinical importance than previously assumed.

A fair correlation was found between the changes of acetabular and global offset, and a better between femoral and global offset. This underlines that the surgeon has a greater influence on the femoral offset than the acetabular offset (8). The use of computer navigation may help to orientate the acetabular component in THA (30). Robotic computerized instrumentation that guides bone preparation and cup implantation was studied in 43 hips, and robotic instrumentation achieved precision of COR in 82% (31). However, the authors did not report how this affected offsets or clinical outcome.

Conclusions

In our study of the free hand technique, 40 patients (55%) had COR and 34 patients (47%) had femoral offset preserved within 5.0 mm limits after THA. Twenty-three patients (32%) had both their values of COR and femoral offset preserved within the preoperative 5.0 mm limits, as 15 patients (21%) had both their COR and femoral offset changed outside 5.0 mm limits. While a correlation was found between the changes of femoral and global offset, there was no correlation between the changes of acetabular and femoral offset that would have conserved the global offset. The variations had no influence on the function of the hip, but our results indicate a potential for better restoring the location of COR and femoral offset when planning and implanting an uncemented THA. The clinical consequences are, however, unknown.

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Footnote

Conflict of Interests: The authors have no conflicts of interest to declare.

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