The Journal of Arthroplasty 30 (2015) 1002–1007

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Reproduction of Hip Offset and Leg Length in Navigated Total Hip Arthroplasty: How Accurate Are We?

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ARTICLE INFO

Article history:
Received 29 July 2014
Accepted 16 January 2015

Keywords:
navigation
hip offset
THR
Orthopilot
leg length

ABSTRACT

This study assesses how accurately we can restore hip offset and leg length in navigated total hip arthroplasty (THA). 152 consecutive patients with navigated THA formed the study group. The contra-lateral hip formed control for measuring hip offset and leg length. All radiological measurements were made using Orthoview digital software. In the normal hip offset group, the mean is 75.73 (SD- 8.61). In the reconstructed hip offset group, the mean is 75.35 (SD - 7.48). 95.39% had hip offset within 6 mm of opposite side while 96.04% had leg length restored within 6 mm of contra-lateral side. Equivalence test revealed that the two groups of hip offsets were essentially the same. We conclude that computer navigation can successfully reproduce hip offset and leg length accurately.

The cornerstone of a successful total hip arthroplasty (THA) depends on restoring the biomechanics of the hip back to normal. This refers to restoring the offset of the hip joint and achieving limb length equality. Femoral offset restoration has been long recognized as an important part of THA procedure to improve joint stability and implant longevity [1]. Only recently has attention been focussed on hip offset, which is defined as perpendicular distance from tear drop through the femoral center of rotation to the axis of femur and is sum of femoral offset and acetabular offset (Hip offset = Femoral offset + Acetabular offset). According to Dastane, the acetabular center of rotation can be changed by reaming and cup implantation and hence femoral offset no longer quantifies the displacement of femur from pelvis [2]. Precise preoperative planning is essential to successfully reproduce the hip offset and limb length. Computer navigation in THA has recently claimed to be successful in the reproduction of leg length [3,4]. However, there is not much information in the literature regarding the reproduction of offset in computer navigated THA.

Computer assisted navigation in total hip arthroplasty aims to achieve good implant position with improved results. We have been using the Orthopilot navigation system (Aesculap, B. Braun, Tuttlingen, Germany) which is non-image-based system with infrared wave communication without preoperative additional imaging. With the use of Orthopilot, the cup position, femoral position, leg length and hip offset can be tracked intraoperatively.

The aim of our study was to test the hypothesis if navigation can successfully reproduce the hip offset in the replaced hip.

Materials and Methods

This study is a retrospective analysis of prospectively collected patient data. The data have been collected as a normal part of the patients' treatment and recorded in case notes, the departmental proprietary database, computer navigation data and radiographic images. We analyzed AP pelvic x-rays of 228 consecutive patients who underwent navigated THA at our institution between March 2009 and August 2012. These patients had a single uncemented implant combination — Plasma cup and Excia stem (Aesculap, B. Braun, Tuttlingen, Germany) with Orthopilot navigation system. The stem types included both standard and extended offsets which enabled us to change offsets without altering length. The exclusion criteria were bilateral hip OA (OA grade 2/3 by Tonnis classification [5]), inadequate pelvic x-rays and patients with hip arthroplasty on the other side. Radiographically the other hip was normal on the contra-lateral side which acted as a control for hip offset and leg length measurement. Of these 228 patients, 152 patients were found to be eligible for the study. Of the remaining 76 patients who were not eligible for the study, 40 patients had a prior hip arthroplasty on one side while 13 had bilateral hip osteoarthritis, thereby precluding measurement of contra-lateral hip offset and the other 23 had inadequate pelvis x-rays (rotational discrepancy)

One or more of the authors of this paper have disclosed potential or pertinent conflicts of interest, which may include receipt of payment, either direct or indirect, institutional support, or association with an entity in the biomedical field which may be perceived to have potential conflict of interest with this work. For full disclosure statements refer to http://dx.doi.org/10.1016/j.arth.2015.01.027.

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http://dx.doi.org/10.1016/j.arth.2015.01.027
0883-5403/

preventing correct measurements. There were 82 females and 70 males in the included patients. Mean patient age at the time of surgery was 66.17 ± 9.01 (Range: 43–89). Mean BMI was 29.66 ± 4.69 (Range: 19.15–42.03).

The statistical analysis was performed with SPSS 17.0 software (SPSS Inc., Chicago, IL). Intraclass correlation coefficient (ICC) was calculated to analyze the variability between observers. Our primary aim of the study was to prove that the two sets of hip offsets were essentially the same. Hence we used equivalence test where the null and alternative hypotheses are reversed from a standard 2-sample t-test. i.e. the null hypothesis (H_0) means the two sample means differ and the alternate hypothesis (H_1) is the two sample means are equivalent. We aim to prove the alternative hypothesis (H_1). We have defined our equivalence limits. Though it would be ideal to achieve the reconstructed hip offset same as the hip offset of the normal side, this would be practically impossible and it has been previously shown that the target of reconstructed hip offset should be within 6 mm of normal hip offset. Hence the upper equivalence limit (UEL) is +6 and lower equivalence limit (LEL) is −6. Thus any difference between the offsets that fall within this zone of +6 to −6 is considered unimportant. We used Two One-Sided Test (TOST) to test the above hypothesis (Table 1).

Navigation Technique in THA

Orthopilot navigation system for THA is non-image based system which uses a virtual data model supplemented by intra-operative registration [6]. We used THA Pro software module. The implants used were uncemented Excia stem and Plasma cup (Aesculap, B. Braun, Tuttlingen, Germany). The bearing material was ceramic on ceramic. Posterior approach was used in the exposure of all hips by the senior author (KD). The system required the placement of trackers on pelvis and femur with a pelvic pin and femoral clamp (Fig. 1). The reference frame used is anterior pelvic plane which is obtained by palpating the anterior superior iliac spines and pubic symphysis with a special tracked palpation pointer which was registered with the computer.

This is reproduced on the computer screen as 3D pelvic orientation which is taken as the reference position and the data are presented to the surgeon on screen. This plane provides the coordinate system to guide navigated cup placement. Femoral reference plane is made by the center of femoral head, knee center reference and ankle center. Original offset and leg length is registered before dislocation of the hip. Any change in this during different surgical steps can be tracked. Once the hip is dislocated and neck cut is made, the medial wall (true floor) of the acetabulum is palpated and registered with navigated stylus.

Navigated reamers are used to prepare the acetabulum. A navigated cup holder allows the positioning of the cup in desired orientation. This holder is used for final positioning of the implant. The new cup center is then registered and any change produced by the new cup is recorded by the computer and the position is computed and taken into account when doing the femoral side. The femoral tracker aids in orienting the desired femoral version.

Table 1
Statistics of Equivalence Test.

Null Hypothesis (H_0): Difference ≤ −6 or Difference ≥ 6
Alternative Hypothesis (H_1): −6 < Difference < 6
α Level: 0.05
95% Confidence Interval (−1.171 to 1.904)

Null Hypothesis	*P*-value
Difference ≤ −6	<0.0001
Difference ≥ 6	<0.0001

The femoral preparation broaches are tracked and can show on the screen version, virtual range of movement from that specific position, change of offset and leg length anticipated in that position. Once the best position and components are finalized the final check is made for achieved offset and leg length, version and range of movements achieved.

Radiography

The AP pelvic radiographs were performed in the standard manner with patient supine with x-ray tube to film distance of 120 cm with lower limbs placed in internal rotation and the big toes touching each other so that the patella is facing forward. This view allows femoral neck to be viewed in full profile thereby providing true femoral offset by negating the ante version. Further, the radiograph should be centered on the pelvis with no pelvic tilt in the coronal plane. The size of lesser trochanter and shape of obturator foramen was matched to avoid error in measurements caused by rotation. All the patients underwent standard AP view of the pelvis preoperatively with marker of known diameter to account for magnification. The hip offset and leg length difference between the two legs is calculated using Orthoview template on the AP pelvis x-ray taken preoperatively. This difference is used to correct the leg length discrepancy and restore hip offset in the reconstructed hip.

Postoperative x-rays were taken immediately after surgery and at 3 months.

All radiographs were accessed on Kodak Picture Archiving Communications System (PACS) (Eastman Kodak company, 10.1_SP1, 2006, Rocherster, NY, USA). All the radiographic measurements were made by a single author (PE), who was not involved in patient care or surgery, using Orthoview Digital Planning Software system (Orthoview LLC, Jacksonville, Florida) on PACS. The x-rays were corrected for magnification using the acetabular liner diameter.

To account for intra-observer and interobserver variability, 20 x-rays were randomly selected and the author (PE) measured them twice two weeks apart and they were also measured by another author independently (VM).

Radiographic Measurements

The intertear drop line (IT) was drawn as standard horizontal line reference and perpendiculars were erected to the top of trochanter to measure the leg length difference [7] (Fig. 2). The orthoview templating superimposes concentric circles over the femoral head. Further, the anatomical femoral axis is superimposed over the center of medullary canal which also gives the femoral offset. Perpendiculars are erected over the inter-tear drop (IT) line at pubic symphysis as well as at the two tear drops that help in measuring the amount of superior migration of the implanted hip. The distance calculated from the anatomical femoral axis to the perpendicular erected at the tear drop gives the hip offset.

Results

Intraobserver and interobserver variations were evaluated using the grouping recommended by Landis and Koch [8]. Values of 0.81–1.00 indicate excellent correlation; 0.61–0.80, substantial correlation; 0.41–0.60, moderate correlation; 0.21–0.40, fair correlation; and 0.00–0.20, poor correlation. Intra-observer variation (ICC) for hip offset and LLD was 0.85 and 0.89 respectively while interobserver variation (ICC) for hip offset and LLD was 0.87 and 0.91 respectively. All these values were greater than 0.8 demonstrating excellent agreement of the measurement methods.

In the normal hip offset group, the mean is 75.73 with Standard Deviation (SD) of 8.61 (Range: 55–99). In the reconstructed hip offset group, the mean is 75.35 with SD of 7.48 (Range: 53–94). The mean difference between the two groups was 0.38 with pooled SD of 8.05.