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Restoration of Global Offset and Limb Length in Primary Unilateral Total Hip Arthroplasty When Preoperative Templating is not Applied

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Abstract

Background: Preoperative templating is an essential step before performing any total hip arthroplasty (THA). Restoration of global offset (GO) and limb length (LL) were among the templating purposes. Thus, we aimed to perform THA without preoperative templating based on clinical examination and intra-operative anatomical landmarks to restore hip biomechanics. **Patients and methods:** This prospective observational study was conducted on 40 patients with primary THA through the posterior approach. The lesser trochanter was used to determine the level of femoral neck cut, the femoral component insertion depth, and version, along with adjusting the level of the center of the femoral head to the tip of the greater trochanter. The transverse acetabular ligament (TAL) was used as a reference for the acetabular component version and inclination. To optimize the LL, preoperative clinical assessment, intra-operative comparison with the normal side, soft tissue tension, and shuck test were used. GO was adjusted using the depth of acetabulum after reaming, placing the acetabular component fit or 10% overhang from the ridge and gluteus medius muscle tension. Postoperatively, computed tomography (CT) scan was used for measuring the GO (acetabular offset (AO) + femoral offset (FO)) and limb length discrepancy (LLD) and compared to the sound side. Pre and postoperatively, LL was measured using a tape measure from the anterior superior iliac spine (ASIS) to the medial malleolus. **Results:** Depending on postoperative CT measurements, there was no significant difference between the mean normal and operative GO (P=0.894). The mean LL difference between the two sides was 0.38 cm (P=0.007). Clinically, the mean LLD (comparing the normal side with the operated side preoperatively) was 1.001 cm, while the mean LLD was 0.722 cm (P=0.0455). **Conclusions:** This study demonstrated that when the preoperative templating step is omitted, depending on intraoperative landmarks, neither the GO nor the AO and FO of the operated side were significantly affected. The mean radiological and clinical postoperative LLD was almost consistent, and the mean difference was < 1 cm, which is within the acceptable range. Do not use abbreviations in abstract and conclusions

Introduction

Termed as operation of the century, total hip arthroplasty (THA) was the salvation of the arthritic hip joints. Wiles first developed the first prosthetic hip implants in 1938 and laid the foundation for today's modern implants. It was Charnley who later revolutionized this modality by introducing the low friction arthroplasty, the use of acrylic cement, and high-density polyethylene bearings ***[1]***. The main indication of THA is degenerative osteoarthritis. It's also a good option for femoral neck fracture in the younger population. There are many other indications like rheumatoid arthritis, fractures around the hip joint, bone tumors, whether benign or malignant, arthritis associated with Paget's disease, and unreduced hip dislocation ***[2]***. However, like any other procedure, complications in this line of treatment are common, and studies have shown that

unplanned arthroplasty resulted in a longer hospital stay and increased complication rate ***[3]***. To alleviate these adverse effects, it is crucial to have good preoperative planning. Preoperative templating is an important step in the preoperative planning, and many studies have shown that it can predict the size of the components, Limb length discrepancy (LLD), restoration of the center of rotation (COR), implant loosening, reduction in periprosthetic fracture risk rate, and to predict the tools that might be needed for the success of the procedure ***[4, 5]***.

There are two methods for applying preoperative templating: acetate and digital. Pre-drawn implant shapes usually do acetate templating on transparent papers that are applied on a correctly magnified anterior-posterior (AP) and lateral radiographs of the hip and pelvis, and the digital method is a computer-based application ***[6]***. Some studies favour acetate templating when facilities are unavailable, and others argue for a more accurate prediction of the sizes with digital software templating to be within one size in 78% of the acetabular and 90% of the femoral implants. Hence, manually templated plain radiography accuracy was found to be within one size in 67% of the acetabular and 82% of the femoral components ***[7]***.

LLD and global offset (GO) (the sum of femoral offset (FO) and acetabular offset (AO)) is another matter that affects the outcome of THA, and it was shown that reduction of GO > 5 mm is associated with less abductor muscle strength and poorer outcomes after THA ***[8]***. FO is measured from the COR of the femoral head to the anatomical axis of the femur ***[9]*** and the AO; the distance from the COR of the femoral head to the perpendicular line passing through the medial edge the ipsilateral teardrop ***[10]***. In a study done by Judge et al., 2011; increasing FO resulted in a better Oxford hip score, but they didn't confirm that it is solely related to increased offset ***[11]***; this theory was later backed up by a study done by Clement et al., 2016 showing the same results ***[10]***. However, increasing FO increases lateral hip pain due to more friction on the greater trochanter ***[12]***. LLD is another complication with an incidence of 1-27% that causes back pain, disturbance of gait, and implant loosening, and it's a common concern of the patient during follow-ups ***[13, 14]***.

Various clinical methods are used to measure the LL, but it has been proven that it's not as accurate as the radiological measurement using a full-length standing AP radiograph ***[15]***. Thus, this study aimed to conduct THA without preoperative templating based on a clinical examination and intra-operative anatomical landmarks to restore hip biomechanics.

Patients and methods

A. Study setting

This prospective observational study was conducted on 40 patients who underwent THA at Shar Hospital and High-Quality Hospital in Sulaimaniyah, Kurdistan Region of Iraq, from Jan 10th, 2020, to Jan 10th, 2022.

B. Inclusion criteria

Patients with primary degenerative osteoarthritis, femoral head osteonecrosis, neglected Perth's disease, and femoral neck fracture were included in this study.

C. Exclusion criteria

Any revision cases, or patients with developmental dysplasia of the hip (DDH), inflammatory arthritis**,** pelvic obliquity, and other cases of LLD were excluded from this study.

D. Patient preparation

After preoperative medical optimization, all patients were examined clinically for LLD using the tape measure method, from the anterior superior iliac spine (ASIS) to the ipsilateral medial malleolus in the supine position, adjusting both limbs symmetrically. In addition, the assessment of the range of motion and gluteus medius power was performed. The preoperative radiological assessments were the AP weight-bearing radiographs of the pelvis showing both hips.

E. Methodology

The operations were done by one senior surgeon, and one implant design (Smith & Nephew Synergy Cementless system) with standard femoral offset and 131^0 neck angle and acetabular cup (Smith & Nephew reflection system) was used. For all patients, general or spinal anaesthesia was used, and the patient was placed in a lateral decubitus position and firmly stabilized. Then, a T-shaped capsulotomy was done, gentle dislocation of the hip was performed, and the femoral neck was marked with electrocautery and cut (using a cutting guide device for the cut), which was approximately 5-10 mm above the upper border of the lesser trochanter and the femoral head was taken out and measured.

Consequently, acetabular preparation then performed keeping in mind to restore the GO near normal as much as possible with inclination angle in the range of 30-50 ^{0} and anteversion within 15 - 20 ^{0} using the transverse acetabular ligament (TAL) as a landmark. Any osteophytes that protrude beyond the edge of the acetabulum were removed with an osteotome. Serially increased size acetabular reaming was then done. The medialization or the depth of acetabulum after reaming was evaluated by exposure of bleeding cancellous bone, fit or 10% overhang of the shell, and k wire used to measure the bone thickness left (at least 3 mm or more of bone in the medial wall was left). Cementless porous-coated acetabular shell was used after trials for sizing, size to size, or one size bigger with not > 10% overhang of acetabular component inserted with the edges being flush with the socket or less than 5 mm protruded and fixed by one or two 6.5 self-tapping screws.

Lastly, the polyethylene liner with a posterior lip was fitted in the acetabular cup. Then, femoral preparation was done, using a chisel box to target the opening of the proximal femur and canal finder to guide the femoral canal and then distal femoral preparation, followed by proximal femoral preparation using increasing size broaching till reaching the most fitted size. The femoral cut and the lesser trochanter were used to guide femoral anteversion. At the same time, the limb was maintained in a position where the leg was held perpendicular to the floor (transepicondylar axis) and the foot facing the ceiling. Trials for neck length were used on the last reamer intraoperative length, then judged by using the sound limb as a reference and offset assessment depending on regaining the gluteus medius tension, shuck test, dropkick test, TAL, and proper range of movement with stability without impingement. The closure was done starting with reattaching the short rotators, followed by fascia and skin closure. Postoperative clinical LL measurements for the normal and operated sides were performed and recorded.

Thereafter, postoperative CT scans were done after two months following the index operation (General electronics, 64 slices) for both the normal and operated sides and then evaluated. The CT measurements were interpreted on the Radiant software. One senior radiologist reviewed all the measurements. Coronal cuts were used for measuring the AO, from the medial wall of the teardrop to the COR of the femoral head. For FO, the anatomical axis of the femoral shaft to the COR of the head was used. Then, the sum of both AO and FO was used to get the GO (Figure 1). The LL was measured bilaterally using the distance between the bi-ischial line and upper border of the lesser trochanter ***[16]***, utilizing the 3D recon bone window images (Figure 2). For varying patient position levels, the multiplanar reconstruction (MPR) option was used in the software until optimal coronal images were obtained.

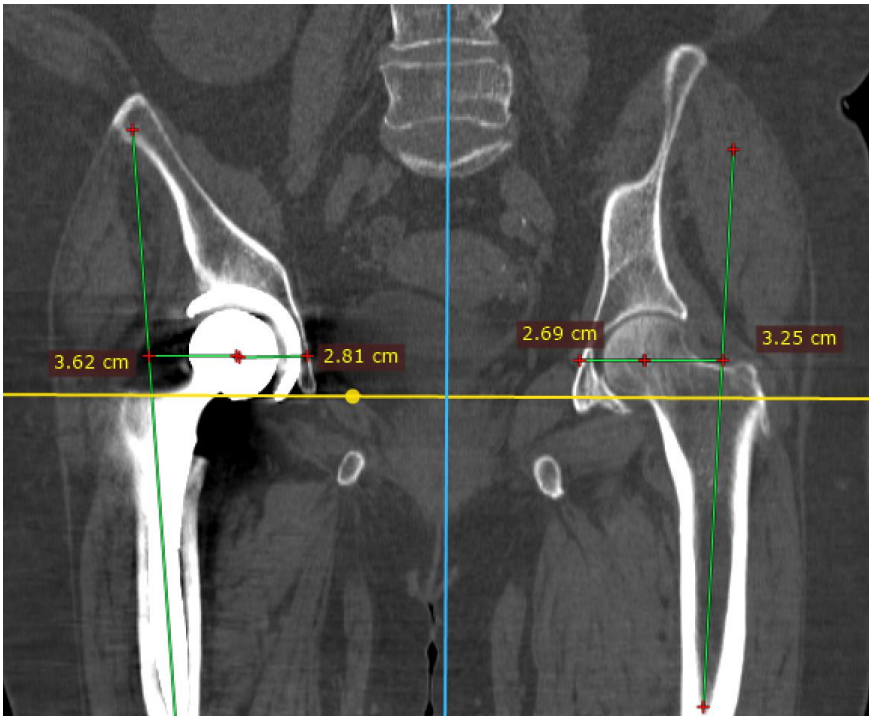

Figure- 1: Measuring the normal side and operated side femoral and acetabular offset using coronal section after adjusting with the MPR technique.

Figure- 2: The 3D recon image uses the bone window for measuring the limb length of both operated and normal sides.

F. Statistical analysis

SPSS (version 27.0) was used for descriptive statistical analysis. The mean, maximum/lowest values, and standard deviation (SD) were presented for continuous variables. The Kolmogorov-Smirnov test was used to check for normality before applying parametric testing. The independent t-test was used to analyze continuous variables, and a two-tailed paired t-test was used to test hypotheses concerning changes in pre-and postoperative outcome scores. A p-value < 0.05 was considered statistically significant in all tests.

Results

Enrolled patients (17 females and 23 males) aged 32-73 years (mean 52.5 years). Unilateral degenerative osteoarthritis was the main indication for arthroplasty in 25 patients (62.5%), while 13 patients (32.5%) had fractured femoral neck, and 2 cases (5%) had stage IV avascular necrosis (AVN). In Table 1, we realized that the mean GO of the normal side was 6.82 ± 0.79 cm, while for the operated side was 6.79 ± 0.79 cm. Parametric tests were conducted and revealed that there was no significant difference between the normal and operative sides (P=0.894). Also, the mean FO and AO of both operated and normal sides were measured. The results revealed no significant difference between the operated and the normal side for both measures (P-value for the FO and AO were 0.807 and 0.501, respectively).

Table- 1: Patient's Offset measures using CT postoperatively.

Variable	Minimum	Maximum	Mean ± SD
NFO	3.02	4.83	3.68 ± 0.49
NAO	2.48	4.08	3.14 ± 0.37
NGO	**5.51**	**8.7**	**6.82 ± 0.79**
OFO	2.64	4.75	3.70 ± 0.51
OAO	2.26	4.27	3.08 ± 0.43
OGO	**5.32**	**8.79**	**6.79 ± 0.79**

NFO: normal femoral offset, NAO: normal acetabular offset, NGO: normal global offset, OFO: operated femoral offset, OAO: operated acetabular offset, OGO: operated global offset

On the other hand, clinical LL measurement was done for both the normal and operated side via the tape measure method. The normal side had a mean LL of 88 cm, and the operated LL has then measured pre and postoperatively, with a mean length of 87 and 87.28, respectively. Clinically, we found that the mean preoperative LLD (comparing the normal side with the operated side preoperatively) was 1.001 cm (P=0.025) (Table 2).

Table- 2: Clinical measurement of the limb length between the normal and operated limb (preoperatively).

Variable	Normal Mean±SD	Normal range	Preoperative Mean±SD	Preoperative range	Mean Difference	P-value
Leg Length	88.0±1.93	85.3-94.6	87.0±1.99	85.05-94.07	1.001	0.025

On the other hand, the mean postoperative LLD (comparing the normal side with the operated side) was 0.722 cm, with a statistically significant difference (P=0.0455) (Table 3).

Table- 3: Clinical measurement of the limb length between the normal and operated limb (postoperatively).

Variable	Normal Mean±SD	Normal range	Postoperative Mean±SD	Postoperative range	Mean Difference	P-value
Leg Length	88.0±1.93	85.3-94.6	87.28±1.15	86-95	0.722	0.045

Radiologically, the mean LL of the normal side was 1.85 cm, while the postoperative side was 1.47 cm. The parametric test showed a difference of 0.38 cm between the two samples with a significant difference (P=0.007) (Table 4). Collectively, the outcomes of radiographic parameters in this study are presented in Table 5.

Table- 4: Radiological measurements of limb length (LL).

Leg Side	Minimum	Maximum	Mean±SD	Mean Difference	P-value
Normal side LL	1.12	3.22	1.85±0.54	0.38	0.007
Operated side LL	0.34	3.1	1.47±0.66		

Table- 5: Summary of postoperative hip parameters assessed by CT scan.

Radiographic Parameter	Normal Mean±SD	Normal range	Operative Mean±SD	Operative range	Mean Difference	P-value
FO	3.68±0.49	3.02-4.83	3.70±0.51	2.64-4.75	-0.027	0.807
AO	3.14±0.37	2.48-4.08	3.08±0.43	2.26-4.27	0.061	0.501
GO	6.82±0.79	5.51-8.7	6.79±0.79	5.32-8.79	0.033	0.894

FO: femoral offset, AO: acetabular offset, GO: global offset

Discussion

Restoration of hip biomechanics should be one of the main concerns in hip arthroplasty for a good functional recovery. On the other hand, maintaining the LL and GO is a vital component of a successful arthroplasty, and every attempt should be made to preserve joint stability ***[14]***. Preoperative templating is an integral part of the operation, and it is one of the keys to this success. Prediction of the size of the implants, restoration of biomechanics, reduction in operative time and cost, and foreseeing the difficulties encountered during the procedure ***[17, 18]***. Most centers use digital templating using computer software instead of the old on lay acetate method. In this regard, Petretta et al., 2015 showed that the acetate method can be as reliable as digital templating and more readily available ***[19]***. This study tried to depend on intraoperative landmarks and clinical assessment pre and intraoperatively to restore hip biomechanics as much as possible.

We identified the lesser trochanter in planning the neck osteotomy level and marked 5- 10 mm proximal to it. This outcome is supported by Floerkemeier et al., 2013 who studied the effect of femoral neck cut level on stem position and offset, the higher the level (> 10 mm), the more varus the stem will align, and the higher the strain will be on the bone ***[20]***.

The surgeon assessed the femoral stem anteversion (FSN), using the tibia as a guide by positioning it perpendicular to the transepicondylar axis and the direction of the lesser trochanter. This result is agreed with Lee et al., 2018 study ***[21]*** while controversial with Wines and McNicol, 2003 finding. According to their

postoperative CT calculations, only 71% of FSN were within the expected clinical version range when evaluated intraoperatively by the surgeon ***[22]***.

Moreover, we utilized the TAL for orienting the acetabular component, and it has been shown to be a reliable structure by other authors ***[23, 24]***. The inferior margin of the cup should be aligned flush with TAL. To minimize error in component positioning intraoperatively, we tried to keep the position of the pelvis unchanged, as even small changes in the place, either by forceful retraction or repeated dislocations occurred while trailing, might lessen the landmark's accuracy. This finding is supported by Hiddema et al., 2012 ***[25]***.

Furthermore, we attempted to ream the acetabulum until bleeding bone appeared, and there was proper coverage of the cup in all directions with achieving press-fit position, keeping at least 3 mm of bone in the acetabular floor intact by frequently checking with a wire for the depth of the remaining medial wall. Other researchers showed that the anatomical restoration of AO with many advantages, such as bone stock preservation, reduced impingement, and dislocation rates ***[26, 27]***. Also, the manipulation of these measures ranged from 5 - 10 mm of native or contralateral normal side, which is proved by Warnock et al., 2019, as results beyond that would have poor Oxford Hip Score and increased pain ***[28]***.

Additionally, when we tried to restore FO, we depended on abductor muscle tension, shuck test, and intraoperative stability tests with a motion range of the hip at 90^0 hip flexion and maximal internal rotation (sleep position) and full hip extension and maximal external rotation. This is also applied by other surgeons who depend on these intraoperative manoeuvres to restore femoral FO ***[29, 30]***. We used a stem standard offset (131^0 with 0 mm neck offset), so increasing horizontal offset (femoral offset) wasn't an option; instead, we tackled this problem by increasing the femoral neck length to restore the FO. The balance of restoring FO without increasing the LL can be solved by using a high offset femoral neck or a stem with a more varus neck-shaft angle ***[31]***. Manual assessment of GO was also performed by having at least one fingerbreadth clearance between the LT and the ischium in full extension, the greater trochanter (GT) and the ilium in the abduction and external rotation, and the anterior part of the GT and the ilium anteriorly in full flexion with internal rotation ***[32]***.

In the current study, the FO and AO values were closely comparable to the non-operated side, with only minor insignificant mean differences (0.02 cm and 0.06 cm). Various methods have been developed to overcome LLD. Preoperative templating being one of them, most had failed to match the correct implant size in 60% of cases hence, rendered unreliable ***[33]***. Although there are more than 20 intraoperative techniques and various callipers to minimize LLD, most have their limitations and difficulties applying them correctly to all circumstances ***[34]***. Although the most recent computer navigation systems give precise measures, they have their shortcomings as they are still controlled by the surgeon for applying the reference points ***[35]***.

In addition, in the present study, intraoperative comparison between the operated and the sound limb was made by flexing both the knees and hips 90 º and fitting the heels and knees together after ensuring that the patient is in pure lateral position without any forward or backward tilt. Although many surgeons have routinely done it, this test is subjective and affected by the surgeon's experience level. Its accuracy somehow is doubted, as displayed by Nossa et al., 2018, which showed that 31% of the patients had LLD > 5 mm ***[36]***.

We also implied the dropkick test, while another test for soft tissue balancing dictated by Bourne and Rorabeck, 2002 in which the hips were held in extension while the knees were held concomitantly in 90 º flexion; if the limb was over lengthened, the extensor mechanism becomes taut and the knee tends to extend spontaneously when released ***[37]***.

Our results also showed that the operated limb was shorter than the non-operated limb in 29 patients (72.5%), but the mean LLD was < 10 mm, which is within the acceptable range by another study ***[34]***. Moreover, Sarangi and Bannister, 1997 demonstrated that patients usually become aware of shortening only when LL exceeds 10 mm ***[38]***, even though Eden et al., 1995 advocate that even a small discrepancy in the LL can a be a source of discontent by some patients ***[39]***.

Conclusions

Restoration of the global offset to near normal without depending on preoperative templating in unilateral primary THA is possible depending on intraoperative landmarks and the surgeon's judgment. Attempting to restore the LL was more difficult without preoperative templating, although the difference in this series was not significant compared to the non-operated side.

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Conflicts of interest

The authors declare no conflict of interest.

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