

**Digital Templating of the Non-Affected Hip as a Means of Minimizing Leg-Length
Discrepancy after Primary Total Hip Arthroplasty**

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Abstract

We set out to determine the accuracy of templating the non-affected hip versus the operative hip as a means of minimizing leg-length discrepancy (LLD) after total hip arthroplasty (THA). Preoperative digital radiographs were obtained in 40 patients undergoing primary, posterior, single mini-incision THA for osteoarthritis. Radiographs were templated using the Sectra digital radiography system (Linköping, Sweden). Both operative and non-affected hips were templated in the usual fashion, and correction of pre-operative LLD was predicted by measuring the vertical distance from the tip of the greater trochanter to the shoulder of the femoral prosthesis on both sides (“Vertical GT-SFP Distance”). Pre-operative Vertical GT-SFP Distances were compared with the actual post-operative Vertical GT-SFP Distances for both operative and non-affected sides. Preoperative LLD was -4.7 ± 8.54 mm ($-25 - +11$ mm). Postoperative LLD was -0.35 ± 5.62 mm ($-11 - +14$ mm).. Templating of the non-affected hip better predicted correction of LLD compared to templating of the operative hip ($p < 0.0005$). While it is impossible to completely eliminate LLD, templating both operative and non-affected hips is highly effective in minimizing LLD after primary THA.

Key Words:

Digital templating, leg-length discrepancy, total hip arthroplasty

INTRODUCTION

Modern total hip arthroplasty (THA) has evolved considerably since Sir John Charnley established the key elements for its success in 1962. Continuous advancement in implant design and surgical technique have made THA both effective and safe; however, numerous pitfalls still exist, most notably during preoperative planning and implant templating. The precise templating of arthroplasty components is necessary in order to determine the size and type of implants needed, the relative position of the implants to bone, and to optimize postoperative hip biomechanics [1].

Perhaps the most widely used marker of postoperative hip biomechanics is the restoration of offset and leg length, errors which may lead to iatrogenic leg-length discrepancy (LLD) [2]. While the cutoff for significant LLD is debatable, leg-lengths within 5 mm of each other are well tolerated by most patients. Conversely, the deleterious effects of severe LLD are well documented and include sciatic nerve palsy, limp, hip instability and dislocation, the need for contralateral heel lifts, and revision arthroplasty [3-5]. Additionally, severe LLD is the leading cause of malpractice litigation in adult reconstructive surgery [6-7]. While multiple studies discuss intraoperative techniques for the correction of LLD, little mention is given to preoperative planning to minimize LLD [8-11].

Although it is impossible to completely eliminate LLD following total hip arthroplasty, we set out to minimize its occurrence by describing a preoperative planning technique based on digital imaging of both the operative side and the non-affected side.

MATERIALS AND METHODS

Following institutional review board approval, we retrospectively reviewed 403 THA procedures performed by the senior author between 2005 and 2007. Subjects were excluded from the present study if they were < 60 years of age, presenting for revision surgery, had significant degenerative disease of the non-affected hip, or had significant acetabular or femoral deformity. Of the remaining cohort, 40 patients with severe unilateral osteoarthritis who had undergone digital radiography of the hip with use of a magnification marker were randomly selected for this study. All templating was performed by one individual (JMB).

Demographic information was recorded for each patient (Table 1). Both the operative and non-affected hips were templated pre-operatively as described below to determine the best position of implants to equalize leg lengths. Component sizes, LLD, and femoral offset were recorded from the pre-operative radiographs. Vertical distance from the greater trochanter to the shoulder of the templated femoral component (“Vertical GT-SFP Distance”), were recorded. A negative Vertical GT-SFP Distance signified the shoulder of the femoral component being BELOW the tip of the greater trochanter, while a positive value signified the shoulder being ABOVE the tip of the greater trochanter. On the six-week postoperative radiographs, LLD and Vertical GT-SFP Distance were measured .

Digital Templating Technique

Images were accessed through the Sectra Picture Archiving Communication System (PACS) (Sectra, Linköping, Sweden). Calibration was performed using a 25.4 mm magnification marker taped to the thigh, roughly at the same distance from the film as the femur.

On pre-operative radiographs, the leg-length tool was used to measure LLD by measuring the vertical distance from a line connecting the bilateral acetabular teardrops to the most prominent point on each lesser trochanter. The offset tool was used to measure femoral offset between a line drawn collinear with the femoral shaft to the center point of the femoral head. Next, implants were placed using the automatic implant selection tool. Two points were selected on the acetabulum, one at the superior-lateral margin and one infero-medially near the teardrop. The program then recommended and placed the appropriate acetabular and femoral components in the appropriate location and orientation. Approximately 10% of the femoral components were sized and positioned manually using the “insert template” tool when the program was unable to locate the endosteal cortex of the femur. Leg-length discrepancy was corrected radiographically on the operative hip by vertical repositioning of the femoral component. (Figure 1A).

On post-operative radiographs, the LLD was again determined using the leg-length tool, and the Vertical GT-SFP Distance from the actual implant to the tip of the greater trochanter was measured digitally (Figure 1B). The recorded Vertical GT-SFP Distance was corrected to account for any residual leg length discrepancy so that the Vertical GT-SFP Distance which would result in equal leg lengths could be compared with the pre-operative Vertical GT-SFP Distances measured on the operative and non-affected sides. Theoretical correction of leg length discrepancy using both the operative and non-affected hips as the guidelines for correction was determined by applying the templated Vertical GT-SFP Distances to the post-operative radiograph

Surgical Technique

All patients received the SL-Plus femoral component with either standard or high-offset neck (Plus-Endoprothetik AG, Rotkreuz, Switzerland), and hemispherical, press fit, ingrowth acetabular component (EPF, Plus-Endoprothetik AG, Rotkreuz, Switzerland). The Plus stem comes in sizes 01, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10. It is a triple taper design with rectangular cross-sectional geometry. The difference between sizes is approximately 1 mm in the medio-lateral plane. The EPF cups come in even-numbered sizes from 44-68 mm. All surgeries were performed in the lateral decubitus position using a posterior, single incision, MIS surgical technique as previously described by the senior author [12].

Although pre-operative templating was used to guide correction of leg lengths in this study group, only the operative hip was templated prior to surgery. Additional correction of LLD was guided using intra-operative cues such as lax soft tissues or an overly tight anterior capsule or positive rectus test.

Data Analysis

Descriptive statistics are presented as mean \pm S.D. (range) or n (%). Paired Student's t-test was used for analysis of continuous variables. Both actual and absolute values of Vertical GT-SFP Distance were analyzed as continuous variables. Statistical significance was determined with an α of 0.05.

RESULTS

Preoperative Measurements

On pre-operative radiographs, the operative side was shorter than the non-affected side by a mean of 4.73 ± 8.54 mm. After correction for the measured LLD by shifting the operative side femoral component vertically, the mean Vertical GT-SFP Distance was -0.73 ± 9.54 mm for the operative hip and -5.95 ± 3.46 mm for the non-affected hip. Mean templated cup size on the operative side was 53.6 ± 5.07 mm and 52.5 ± 5.36 mm on the non-affected side. Mean templated stem size on the operative side was 5.6 ± 1.5 mm on the operative side and 5.3 ± 1.8 mm on the non-affected side (Table 2).

The mean Vertical GT-SFP Distance on the operative side was 5.23 ± 6.50 mm less than the Vertical GT-SFP Distance on the non-affected side ($p < 0.0005$). That is, the femoral component was templated 5.23 mm higher in the femoral intramedullary canal on the operative side than on the non-affected side.

Postoperative Measurement

On the post-operative radiograph, the operative hip was 0.35 ± 5.62 mm shorter than the non-affected hip. Mean postoperative Vertical GT-SFP Distance was -7.30 ± 4.72 mm (that is, the shoulder of the femoral component was 7.30mm below the tip of the greater trochanter). After correcting for equal leg lengths, the corrected Vertical GT-SFP Distance was -6.95 ± 6.50 mm. Mean operative cup size was 53.6 ± 3.46 , and mean operative stem size was 5.3 ± 1.8 with 15 hips (38%) utilizing a high-offset stem (Table 3).

Accuracy of Templating Operative vs. Non-affected Hip

Using operative hip measurements, the corrected post-operative Vertical GT-SFP Distance was 6.23 ± 9.56 mm lower than the templated pre-operative Vertical GT-SFP Distance. Using non-affected hip measurements, the corrected post-operative Vertical GT-SFP Distance was 1.00 ± 6.83 mm lower than the templated pre-operative Vertical GT-SFP Distance. Pre-operative templating measurements utilizing the non-affected hip provided more accurate restoration of leg lengths by 5.23mm ($p < 0.0005$). That is, using the templated Vertical GT-SFP Distance for the non-affected hip decreased post-operative LLD by a mean 5.23mm than using the Vertical GT-SFP Distance for the operative hip (Table 4).

Utilizing pre-operative templating measurements for the operative hip to correct leg length discrepancy resulted in a theoretical post-operative leg length discrepancy of 6.56 ± 10.16 mm while utilizing pre-operative templating measurements for the non-affected hip resulted in a theoretical post-operative leg length discrepancy of 1.35 ± 5.03 mm (Table 4). That is, utilizing pre-operative templating of the operative hip would have resulted in a mean leg lengthening of 6.56 mm while utilizing pre-operative templating of the non-affected hip would have resulted in a mean leg lengthening of only 1.35 mm.

DISCUSSION

The need for careful pre-operative planning in THA to achieve a satisfactory outcome has been well described in the orthopedic literature [1,2,11,12]. Several methods have been described to minimize LLD; however, most of these methods utilize intraoperative measurements rather than pre-operative templating [9,14,15]. Additionally, while the concept of templating the non-affected hip has been explored briefly in previous studies [11,16,17], its use is mentioned only in cases where a stable arthroplasty is present on the contralateral side. In the present study, we found that templating the non-affected hip in most cases led to a more predictable correction of LLD compared with standard templating of the operative hip only. To our knowledge, this study is the first to demonstrate more accurate restoration of leg lengths after THA using templating data from the non-affected hip.

The reasons for better correction of LLD utilizing templating of the non-affected hip is likely associated with the degenerative process itself and the secondary effects on the affected hip including soft-tissue contractures or muscle spasm. Patients with severe degenerative joint disease of the hip often develop flexion and external rotation deformities or develop muscle spasm due to pain resulting in malpositioning of the joint during radiography. Because the highest part of the greater trochanter is posterior, flexing or rotating the hip may artificially change the radiographic height of the tip of the greater trochanter. The radiographic position of anatomical landmarks used for preoperative templating, such as the greater and lesser trochanters, can easily be distorted due to malpositioning of the lower extremity leading to errors in leg length correction during templating [18-20]. Utilizing the normal, non-affected hip, which does not require correction for LLD and is usually positioned normally on radiographs, avoids

these potential sources of error and leads to more accurate restoration of equal leg lengths after THA.

In addition to its accuracy, another significant advantage of this technique is its simplicity. Many intraoperative methods for achieving leg length equality require use of special intra-operative measuring devices, use of non-standard landmarks, arithmetic formulas, and additional, sometimes complex, instrumentation[8,9,14]. In contrast, our strategy relies on a simple method of utilizing measurements taken from the non-affected hip during standardized preoperative radiographs in pre-operative planning of the operative hip.

As described in the technique by the senior author [12], the height from the shoulder of the femoral component to the tip of the greater trochanter can be used as a landmark for LLD correction. Utilizing this method combined with additional intra-operative cues, the mean LLD was corrected from -4.73 mm preoperatively to -0.35 mm postoperatively, with 29/40 (73%) < 5mm and 35/40 (86%) < 8mm. Were templating of the operative hip alone (without use of other intra-operative cues) be used to attain leg length equality, the leg would have been lengthened a mean 6.56 mm; however, utilizing the non-affected hip would have lengthened the operative leg only a mean 1.35 mm. These data compare favorably to previous studies, with both Ranawat et al. and Woolson & Harris demonstrating 87% < 7mm and 89% < 6mm, respectively [8,9]. Edeen and colleagues [7] determined that patients were unaware of LLD < 15 mm, and all of the patients in our cohort were within this measurement.

In summary, digital templating of the non-affected hip provided more accurate correction of LLD than templating of the operative hip. More thorough preoperative planning enables a surgeon to make better intraoperative decisions to correct hip biomechanics and improve

postoperative outcome. This is a simple method to minimize post-operative LLD utilizing standard pre-operative radiographs.

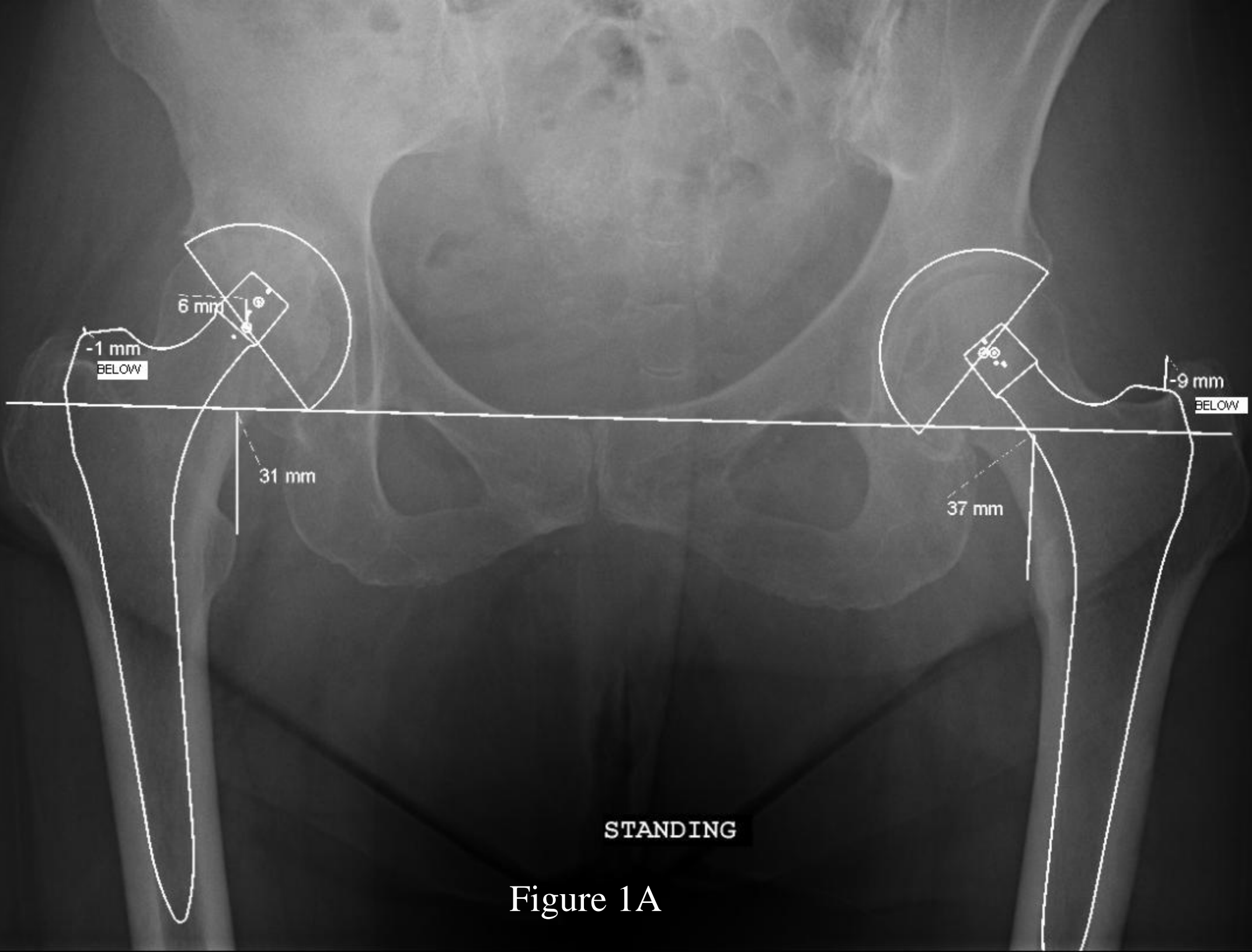


Figure 1A

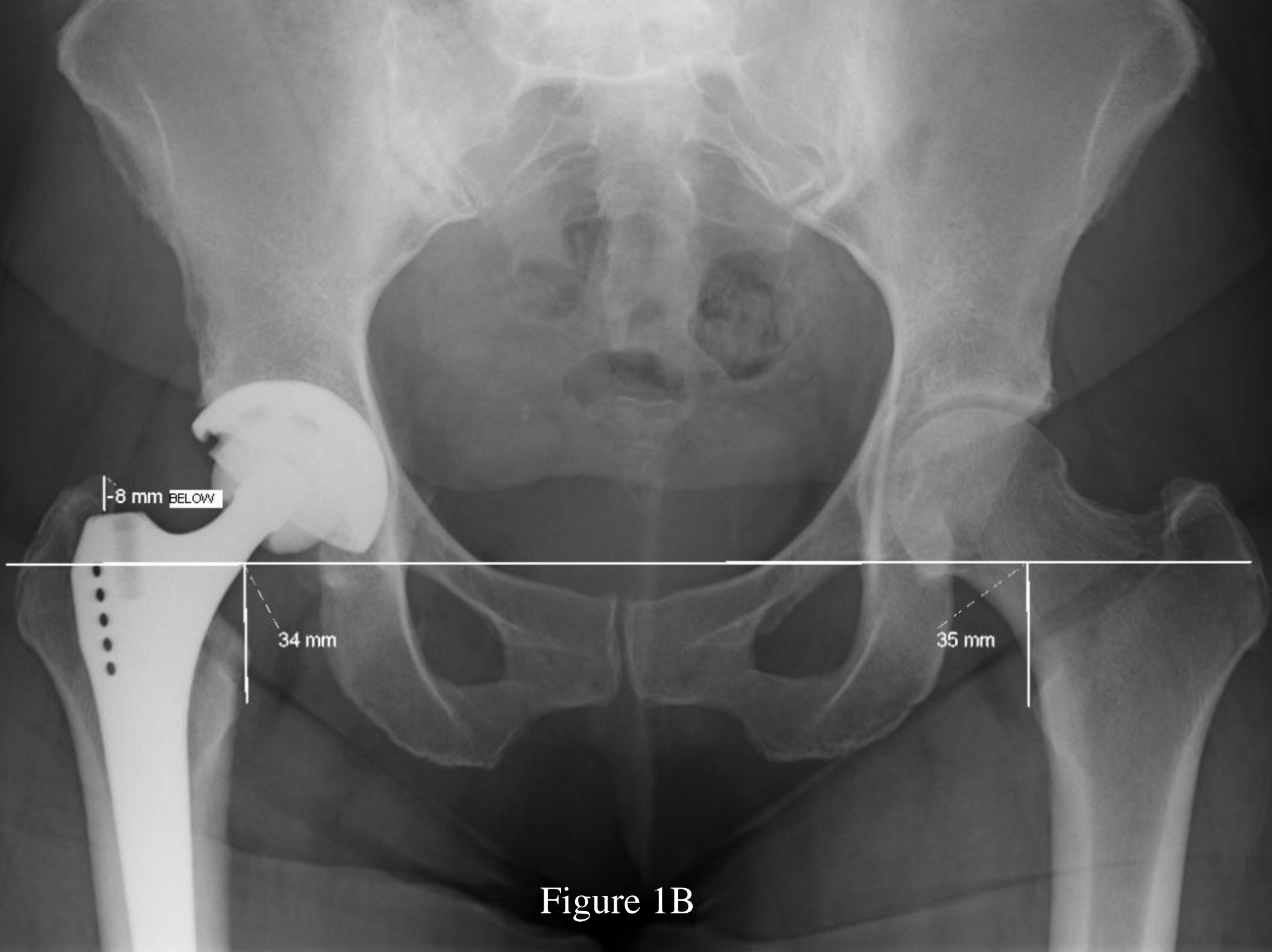


Figure 1B

Figure Legends

Figure 1. Preoperative and postoperative A/P pelvis radiographs.

A: Preoperative radiograph templated for total hip arthroplasty. Leg length discrepancy (LLD) was corrected by moving the center of rotation of the femoral component 6 mm vertically. Vertical GT-SFP Distance was 1mm below the tip of the greater trochanter on the operative side and 9mm below the tip of the greater trochanter on the non-affected side.

B: Postoperative radiograph shows Vertical GT-SFP Distance 8 mm below the tip of the greater trochanter.

TABLES

Table 1. Patient Demographics

Age (years)	70 ± 7.6 (60 - 88)
Gender [Male:Female]	[18:22]
Weight (kg)	82.3 ± 17.1 (47.7 - 131.8)
Height (m)	1.7 ± 0.1 (1.50 - 1.88)
BMI (kg/m²)	28.5 ± 5.7 (19.2 - 47.7)
Operative Hip [Left:Right]	[16:24]

Data presented as Mean ± SD (range)

Table 2. Preoperative Measurements

Pre-operative LLD (mm) (Operative Side Short)	4.73 ± 8.54 (-25 to +11)		
	Operative Hip	Non-Affected Hip	p-value
Vertical GT-FSP Distance (mm) (negative value signifies shoulder of prosthesis below tip of greater trochanter)	-0.73 ± 9.54 (-30 to +23)	-5.95 ± 3.46 (-12 - +2)	p < 0.0005
Cup Size (mm)	53.6 ± 5.07 (42-68)	52.5 ± 5.36 (44 - 62)	NS
Stem Size	5.6 ± 1.5 (2-8)	5.31 ± 1.8 (1 - 8)	NS

Data presented as mean ± SD (range).

Table 3. Postoperative Measurements

Post-operative LLD (mm) (Operative Side Short)	0.35 ± 5.62 (-11 - +14)
Vertical GT-SFP Distance (mm) (negative value signifies shoulder of prosthesis below tip of greater trochanter)	-7.30 ± 4.72 (-15 - +6)
Corrected Vertical GT-SFP Distance (mm) (to attain equal leg lengths)	-6.95 ± 6.50 (-22 - +4)
Cup Size (mm)	53.6 ± 3.46 (48-64)
Stem Size	5.3 ± 1.8 (1-8)
High Offset Stems	15/40 (38%)

Data presented as mean ± SD (range).

Table 4. Accuracy of Pre-Operative Templating: Operative Side vs. Non-Affected Side

	Operative Hip	Non-Affected Hip	p-value
Error in Pre-operative Vertical GT-SFP Distance (mm) (signifies distance that shoulder of prosthesis templated too high on pre-operative radiographs)	6.23 ± 9.56 (-32 - +29)	1.00 ± 6.83 (-14 - +13)	<i>p</i> < 0.0005
Theoretical LLD using pre-operative Vertical GT-SFT Distance Corrected for Residual Post-operative Radiographic LLD (mm) (operative leg longer than non-affected side)	6.56 ± 10.16 (-25 - +34)	1.35 ± 5.03 (-9 - +13)	<i>p</i> < 0.0005

Data presented as mean ± SD (range).

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