

# Intraoperative measurement of limb lengthening during total hip arthroplasty

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## ABSTRACT

**Background:** Limb length discrepancy (LLD) after total hip arthroplasty (THA) is a common problem which cannot be completely resolved. Many techniques have been described in order to minimize postoperative LLD, but most of these techniques are difficult to apply. Ideal technique must be simple and accurate. The most simple technique using a suture tied on the skin has well-known limitations, but its accuracy has not been evaluated before.

**Materials and Methods:** Sixty THAs in sixty patients (mean age 71 years, 1:1 male to female ratio) with hip osteoarthritis (37 cases in the right, and 23 cases in the left side) were studied in this prospective study. In all surgeries, the intraoperative measurement of limb lengthening was performed using a suture tied on the skin of the lateral pelvis. The accuracy of this technique and correlation between intraoperative and postoperative radiological measurements of lengthening were evaluated.

**Results:** The mean preoperative LLD was -7.5 mm while the mean postoperative LLD was 1.58 mm. The accuracy of this technique, defined as the mean difference between the intraoperative and postoperative measurements was 1.8 mm. A strong correlation between these two measurements was noticed ( $r = 0.86$ ).

**Conclusion:** The accuracy and correlation index of this simple technique were similar to those of other techniques. The studied technique is quite accurate when attention is given to certain details, such as the amount of tension applied on the suture, the position of the tied point on the skin, and the position of the leg during measurements.

**Key words:** Limb length discrepancy, suture technique, total hip arthroplasty

**MeSH terms:** Arthroplasty, replacement, hip, hip prosthesis, leg length inequality, sutures

## INTRODUCTION

Limb length discrepancy (LLD) after total hip arthroplasty (THA) is a main cause of poor functional outcomes and may result in sciatic pain, back pain, and abnormal gait.<sup>1</sup> It is also the most common cause of lawsuits against orthopedicians in USA.<sup>2</sup> In osteoarthritis, the involved limb is usually shorter. This is caused by (i) loss of cartilage thickness and bone loss (structural shortening), (ii) deformities due to soft

tissue contractures such as adduction and flexion deformity of the hip (apparent shortening), and (iii) compensatory pelvic obliquity (apparent shortening), with the affected hemipelvis being higher in order to avoid crossing of legs due to an adducted position. One of the aims of THA is to correct the LLD caused by structural shortening and soft tissue contractures and not the overall shortening which is the sum of these two and of the pelvic obliquity. The reason of this is because in most cases, pelvis alignment will return to normal by correcting simply the first two causes, except from those cases where pelvic obliquity is the result of fixed scoliotic deformity. In those cases, overall shortening cannot be managed because the oblique pelvis alignment cannot

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return to normal and the patient must be informed about this before hand.

Many methods have been described and studied in order to measure and evaluate LLD intraoperatively if the desired position of the components and the desired limb length have been achieved. The method of the suture tied on the skin of the lateral side of pelvis is one of the most simple technique, but it has well-known limitations and disadvantages. However, this method is used by many surgeons and its exact accuracy has never been evaluated before. The purpose of this study is to describe thoroughly this technique and to examine whether intraoperative measurements accurately represent postoperative radiological measurements or not.

## MATERIALS AND METHODS

Sixty consecutive patients planned to undergo THA due to osteoarthritis, were included in this prospective study. The study was approved by institutional review board. All surgeries were performed by one surgeon. An informed consent of all patients was taken. All acetabular components were Trilogy (Zimmer, Warsaw, IN, USA) and all femoral components were Spotorno (Zimmer, Warsaw, IN, USA) with modular heads. There were four variations of neck length (0, 3.5, 7.5, and 10). The first step was to assess the preoperative LLD. The preoperative evaluation of LLD included physical and radiological examination. The most common method of measurement of structural LLD is by measuring the distance from the anterior superior iliac spine to the medial malleolus. Although this method does not really measure the true structural LLD due to the fact that it is affected by soft tissue contractures and the position of the hip, it has the advantage that pelvic obliquity does not affect the measurements. It has been shown that this method measures the true structural LLD.<sup>3</sup>

The radiological examination included an anteroposterior view of the hips with the limbs in 15° of internal rotation, whenever this was possible, a lateral view of the hip and additional views of the lumbar spine in many cases, in order to examine if there was any rigid scoliosis. For LLD measurement, a reliable method is to measure the vertical distance from a line connecting the inferior margins of the two teardrops, to the most medial margin of the lesser trochanter [Figure 1]. The difference in these measurements between the two sides represents the LLD. To avoid and correct any magnification error, we used a round marker of a known diameter on x-ray plate. In all patients, the affected limb was either shorter or in a few cases equal to the contralateral leg. Subsequently, the aim usually was to lengthen the limb during THA, as much as the LLD which was measured preoperatively. In order to achieve the desired limb length during surgery, the



**Figure 1:** X-ray anteroposterior view of pelvis with both hip joints showing the technique of measurement of limb length discrepancy. On the affected side, the vertical distance from a line connecting the inferior margins of the two teardrops, to the most medial margin of the lesser trochanter is measured. The same is performed on the other side, and the difference between the two distances represents the limb length discrepancy

suture technique for the measurement of limb lengthening was used. All surgeries were done in a lateral position using the posterior approach. Before the dislocation of the hip, the limb was positioned in extension, aligned with the axis of the body, and parallel to the ground so that this position can be reproduced as closely as it can during the surgery. A suture (Ethibond No. 5) was tied on the lateral side of the pelvis, on a point in line with the long axis of the femur, about 10 cm proximal to the greater trochanter [Figure 2a and b]. The reason why this was done, was to avoid errors of measurement due to indirect, oblique measurements of lengthening. The limbs of the suture were clamped vertically by a straight forcep, at a distance approximately 10 cm away from the tied skin point. Applying a standard tension, in order to just straighten the suture but not to move the tied point of the skin and distort the skin area, the tip of the forcep was placed on the lateral greater trochanter area. The point where the tip of the forcep was touching the femur was marked by diathermy [Figure 2c]. A knot was tied in the clamped point of the suture, as an additional mark of the distance of the suture from the tied point of the skin to the clamped point. This distance must not change during the operation. The route of the suture as it crosses the subcutaneous tissue while the tip of the forcep touches the femur is marked by diathermy [Figure 2d]. This will assist to reproduce the same route of the suture during the subsequent measurements, so the same parameters of measurement can be reproduced as accurately as possible. After the placement of the acetabular component and the placement of the trial femoral component, measurement of the limb lengthening was performed. Using again the same technique and having the leg in extension, aligned



**Figure 2:** Intraoperative photograph showing (a) Position of the limb during measurements in line with the axis of the body and parallel to the floor (b) In order to have straight measurements, the suture is tied in a point in line with the axis of the femur (c) The limbs of the suture are clamped by a straight forcep in a distance about 10 cm away from the tied skin point. Applying a standard tension, the tip of the forcep is placed on the lateral greater trochanter area. The point where the tip of the forcep touches the femur is marked by diathermy (d) The marked route of the suture as it crosses the subcutaneous tissue while the tip of the forcep touches the femur

with the axis of the body and in horizontal position, the tip of the forcep was placed on the lateral greater trochanter area, applying the same amount of tension on the suture as before. Now the tip of the forcep was usually touching the femur in a new point, more proximal than the initial cauterized point. The distance from the initial marked point on the femur to the new point was measured. In order to avoid any measurement error due to the thickness of the diathermy marks, the center of the cauterized marks was used as the reference points. This distance represented the intraoperative lengthening [Figure 3]. The aim was to choose a combination of correct sizes of the femoral component and of the modular head, so this distance would be exactly equal or as close to equal as it can be to the preoperatively measured length of the discrepancy. In addition to the suture technique, palpation of leg lengths and leg-to-leg comparison was performed intraoperatively. If indicated by this assessment, adjustments were made to leg length. A followup including radiological and clinical evaluation was performed 6 weeks postoperatively. The next step of the study was to compare the final intraoperative measurement of lengthening to the radiological measurement of the true lengthening based on postoperative X-rays, 6 weeks after the surgery [Figure 4]. Statistical analysis consisted of Pearson correlation, in order to evaluate the correlation between these two measurements. The level of statistical significance was set at  $P < 0.05$ .

## RESULTS

There were 32 men and 28 women were included in this study. The mean age was 71 years (range 61-86 years). Although the radiological measurements were made 6 weeks after the operation, additionally none of the patients was lost during the routine 6-months followup.

There were four patients without any LLD. In patients whose limb was shorter, clinical and radiological examination revealed that in all these patients there was a true shortening, although in five patients there was an additional apparent shortening due to fixed scoliotic deformities. The goal in all patients was to correct only the true LLD. Preoperative LLD averaged  $-7.5$  mm (ranged from  $-23$  mm to  $0$  mm). Postoperative LLD averaged  $1.58$  mm (ranged from  $-8$  mm to  $+7$  mm) the mean intraoperative measurement of limb lengthening was  $7.21$  mm (ranged from  $0$  mm to  $20$  mm). The mean radiological measurement of limb lengthening was  $9.01$  mm (ranged from  $0$  mm to  $26$  mm). The mean difference between the two measurements was  $1.8$  mm (range  $-8$  mm to  $+7$  mm). The correlation between the two measurements was significant ( $r = 0.86$ ,  $P < 0.05$ ) [Figure 5]. In those patients with no LLD, although according to the intraoperative measurements there was no change in limb length, the postoperative mean radiological measurement revealed limb lengthening of  $0.4$  mm.

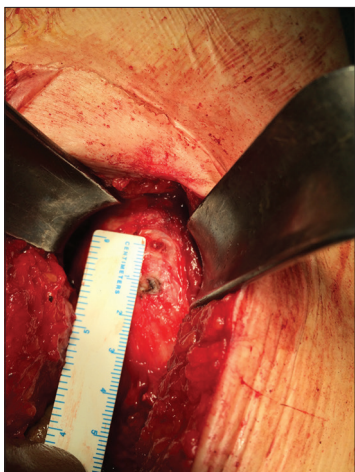


In two cases, the leg-to-leg comparison indicated that although intraoperative measurement of limb lengthening was similar to preoperative measurement of LLD, yet there was a significant discrepancy. In these two cases, difference between the final intraoperative measurement of limb lengthening and the postoperative radiological measurement was 7 mm and 8 mm, respectively.

## DISCUSSION

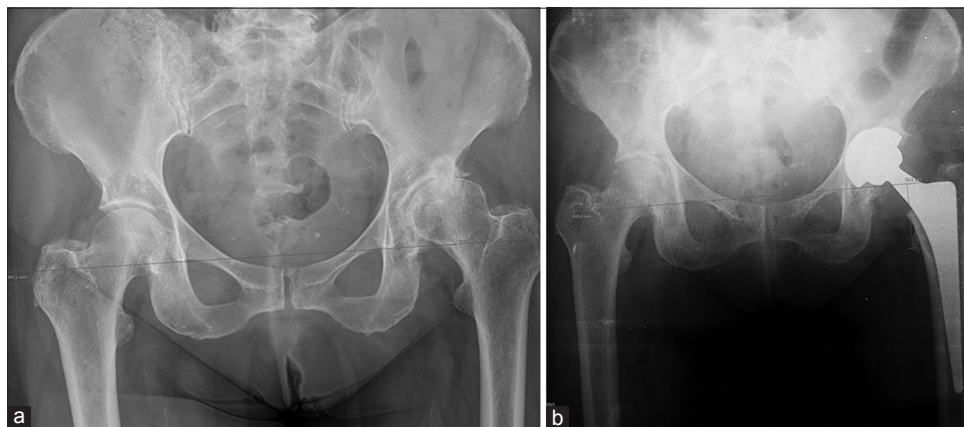
It is widely accepted that postoperative LLD after THA cannot be absolutely corrected. Postoperative LLD after THA ranges from 1 to 27%.<sup>4</sup> Many studies have been published, describing techniques about the management of LLD. These methods can be divided into four main categories: (1) Based on the preoperative templating to define the correct neck cut, the correct neck length of the femoral component (in case of a modular head) or the correct depth of insertion of the femoral component

(by measuring the distance of the tip of the greater trochanter to the shoulder of the femoral component),<sup>5-8</sup> (2) based on the usage of a standard pelvic reference point and of a femoral reference point, and measurement of the distance of these two points as the limb length changes intraoperatively [the marking of the pelvic reference point and the measurement can be performed with the aid of calipers,<sup>9-17</sup> bented K-wire,<sup>18</sup> suture (tied in the skin, in a K-wire, or in a pin),<sup>19</sup> Steinman pin in the infracotyloid groove or screw above the superior acetabular rim,<sup>20,21</sup> (3) based on clinical tests intraoperatively such as the shuck test, the drop kick test, and the leg-to-leg comparison,<sup>15,22,23</sup> and (4) based on navigation system's measurements.<sup>16,24-26</sup> In addition, some other techniques have been described, such as measuring the gap between the tenotomy limb edges of the abductor musculotendinous insertion on the greater trochanter<sup>15</sup> or evaluating the level of the center of the head in relation to the tip of the greater trochanter with the aid of a plate in a femoral head slot.<sup>27</sup>

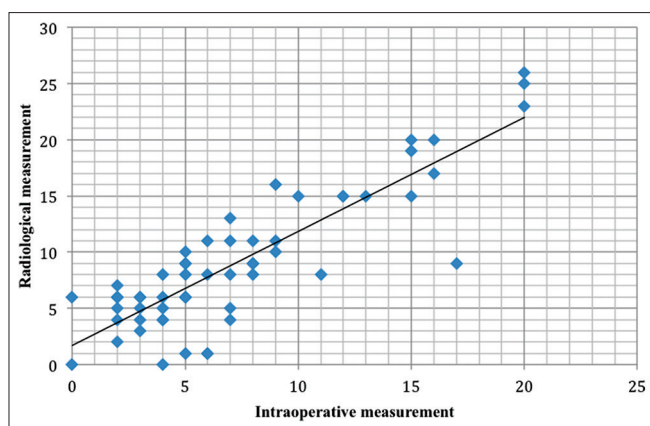


**Figure 3:** Intraoperative photograph showing the distance from the initial marked point on the femur to the new point, which is usually more proximal than the first one is measured. This distance represents the intraoperative limb lengthening

It has been shown that in up to 60% of cases, preoperative templating is not accurate in predicting the correct size of the implants.<sup>28</sup> Matsuda *et al.* and González Della Valle *et al.* described techniques about defining the correct neck length of the femoral component based on preoperative templating.<sup>6,7</sup> These techniques have the disadvantage that errors can occur due to the different final position of the acetabular cup. According to these techniques, the measurement of correct neck length during preoperative templating is affected by the templated position of the acetabular cup. Hence, when the final intraoperative position of the cup differs from that of the preoperative templating, the predicted correct neck length will be wrong. Another technique, based on preoperative templating, aims to assess the correct depth of insertion of the femoral component in the femur by measuring the distance from the tip of the greater trochanter to the shoulder of the femoral component, so this distance will be reproduced



**Figure 4:** Preoperative (a) and postoperative (b) anteroposterior views of pelvis with both hips showing the limb length discrepancy and the subsequent equalization of limb lengths



**Figure 5:** Scattergram. The diagram demonstrates the correlation between intraoperative measurements and radiological postoperative measurements ( $r = 0.86$ )

on the handle of the rasp intraoperatively. However, the osseous tip of the greater trochanter during the operation is not easily assessed and accurately defined, so mistakes can be made intraoperatively.<sup>5</sup>

Concerning the methods based on a standard reference pelvic point, use of calipers or any other device is a disadvantage of its own. Techniques for marking the reference pelvic point with the aid of a pin in the infracotyloid groove<sup>20</sup> or a screw in the pelvis above the superior acetabular rim<sup>21</sup> are invasive and are not easily applicable. Navigation systems are expensive and methods based on navigation measurements<sup>16,24-26</sup> cannot be widely used.

The limitations of this study are that first, there was only one study group, and this method was not compared with any other technique. Second, our series lacks functional assessment of the patients.

The obvious advantage of the simple suture technique is its simplicity. On the other hand, technical errors and disadvantages of this method are well known and accepted. One disadvantage is that the proximal fixation point is not bony or fixed in order to minimize the invasiveness of the method and make it more easy. For the proximal reference landmark, we use a point on the skin of the lateral side of the pelvis about 10 cm proximal to the greater trochanter. This point must be aligned with the long axis of the femur (while the femur is in extension and aligned with the axis of the body) and not posterior or anterior to the femur axis. If the proximal reference landmark is anterior or posterior to the femur axis, there will be indirect oblique measurements of lengthening which will not represent the true intraoperative lengthening. Due to the fact that we do not use a fixed bony proximal reference point, different tension on the suture may result in different measurements, especially in

older patients with loose skin. To reduce the possibility of measurement errors due to this fact, we applied as much tension as needed to just straighten the suture and not to move the tied skin point. Many times in order to achieve this, we are starting to tense the suture until the skin point is just starting to move, and then we slightly loosen the tension until the skin point returns to its previous position while the suture is still stretched and straight. Another disadvantage of the method is that it is subjective to three-dimensional (3D) error. It measures the distance between two reference points (one on the skin of lateral side of pelvis and one on the lateral trochanteric area) of the body which are in different height, especially in obese patients in whom excessive amount of fatty tissue on the lateral side of pelvis place results in a substantially higher position of the skin point compared to the trochanteric point. The line connecting these two points is not parallel to the limb lengthening axis but has an oblique trajectory in relation to this axis. For the same reason, due to the different height of these two points, the measurement of our technique is not only affected by the length of the leg, but also by the medial offset. Usually, the smaller the medial offset, the longer the distance between the two points. This 3D error can be overcome by use of calipers, but this will take away the main advantage of the technique, which is its simplicity. In addition, the differences in measurements due to this 3D error did not seem to result in high deviations as the mean accuracy of this method was similar to that of other published techniques using calipers.

Nevertheless, in obese patients, the differences between the intraoperative and radiological measurements were at the limits of the range of rates. Another limitation of the method is that the exact reproduction of the position of the leg during measurement is not possible, and slight differences in the position of the leg during measurements may affect the results.<sup>29</sup> This limitation also exists in all methods that use a proximal and distal reference point. As in those other methods, we try to minimize the error occurring by this factor by placing the limb during measurements in extension, aligned with the axis of the body, and parallel to the ground, which is a relatively stable and reproducible position.

In two cases, the intraoperative leg to leg comparison indicated that there was a significant limb length discrepancy, although the discrepancy had already been adjusted according to the preoperative measurement. In these two cases, the final differences between the intraoperative measurement and the postoperative radiological measurement were at the limits of the range of these difference values. The reason of this may be the fact that in these two obese patients there was an excessive apparent limb length discrepancy due to fixed scoliosis and hip contractures, and all these may led to slightly affected measurements.

The accuracy of this method has never been evaluated before. The mean difference between the intraoperative measurements and the postoperative radiological measurements, which represents the mean error and the accuracy of this method was 1.8 mm. The accuracy of this method seemed to be similar to that of other published techniques using a standard reference pelvic point, such as techniques based on a pin in the infracotyloid groove<sup>19</sup> (1.49 mm) or on calipers<sup>10</sup> (1.7 mm). Moreover, the absolute value of correlation between these two measurements was similar to that of other techniques, like those based on calipers ( $r = 0.89$ ,  $r = 0.93$ ), navigation systems ( $r = 0.88$ ), or a pin in the infracotyloid groove ( $r = 0.82$ ).<sup>10,15,19</sup>

The accuracy of this method proved to be similar to the accuracy of other more objective but more difficult techniques. This may be due to three factors (1) the amount of tension applied on the suture was such to just straighten the suture and not move the tied point on the skin, (2) the tied point on the skin was in line with the long axis of the femur in the extended and horizontal position, and (3) the position of the leg during measurement was similar to the leg aligned with the axis of the body and parallel to the ground.

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### Conflicts of interest

There are no conflicts of interest.

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