

# A simple method to minimize leg length discrepancy in hip hemiarthroplasty

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Guodong Wang<sup>1,2</sup>

Ai Guo<sup>1</sup>

Fei Yu<sup>1</sup>

Bo Yang<sup>1</sup>

Haomiao Yu<sup>1</sup>

Naicheng Diao<sup>1</sup>

Lifeng Ma<sup>1</sup>

Hua Qiang<sup>2</sup>

Erhong Zhao<sup>2</sup>

<sup>1</sup>Department of Orthopaedics, Beijing Friendship Hospital, Capital Medical University, Beijing 100050, People's Republic of China; <sup>2</sup>Department of Orthopaedics, Beijing Tongren Hospital, Capital Medical University, Beijing 100730, People's Republic of China

**Purpose:** We developed a simple method to minimize leg length discrepancy (LLD) during hip arthroplasty. The purpose of this study is to evaluate the accuracy of the method.

**Patients and methods:** A total of 47 patients who suffered from unilateral femoral neck fracture and underwent hip hemiarthroplasty between 2015 and 2018 were enrolled in this study. We measured the diameter of the contralateral femoral head (D) and the distance (L) between the center of the femoral head and the top of lesser trochanter in the antero-posterior pelvic X-ray view before the operation, the ratio (R) of D to L was calculated. During the operation, the diameter of the femoral head (d) was measured using a Vernier caliper. Then, the distance should be obtained from the center of the femoral head prosthesis to the lesser trochanter was calculated according to the contralateral ratio R.

**Results:** The mean LLD was  $4.4 \pm 3.2$  mm ( $-4.0$  to  $11.1$  mm), 80.9% of the patients had LLD  $< 6$  mm, 93.6% of the patients with LLD  $< 10$  mm, only 6.4%  $\geq 10$  mm LLD.

**Conclusion:** This method is a simple, cost-effective, fast and accurate way to reduce the postoperative leg length discrepancy.

**Keywords:** leg length discrepancy, hip arthroplasty, femoral neck fracture, contralateral side, measurement

## Introduction

With the progressive aging of the population, it is estimated that the incidence of hip fracture will reach 6.3 million all over the world by the year 2050.<sup>1</sup> Although hip arthroplasty has achieved significant pain relief and functional restoration of the hip-joint, it is still beset with defects like leg length discrepancy (LLD).<sup>2-6</sup> It is reported that the incidence of LLD after hip arthroplasty is as high as 62%.<sup>7</sup> Unequal leg length can lead to lower back pain, poor gait, dislocation of hip, neurological impairment and patient dissatisfaction or even revision surgery,<sup>3,8-10</sup> and 15-50% of the patients may require elevated shoes.<sup>4,11</sup> A survey enrolled 1114 patients undergoing total hip arthroplasties shows that LLD occurs in 30% of the patients, of which 49% are unsatisfied with the effect of operation and 4% regret having had the operation.<sup>12</sup> In addition, LLD is the second most common reason for hip arthroplasty-related litigations.<sup>13</sup> We developed a simple and effective new method to minimize LLD during such operations, with satisfactory accuracy.

## Patients and methods

### Ethical statement

This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Beijing Friendship Hospital (2019-P2-071-01). All patients provided written informed consent before participating.

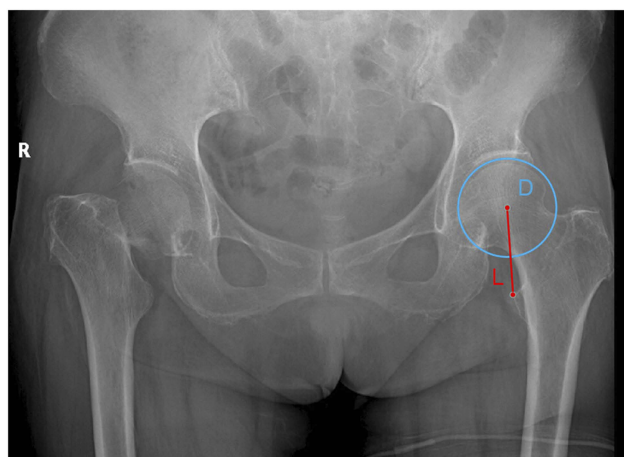
Correspondence: Ai Guo  
Department of Orthopaedics, Beijing Friendship Hospital, Capital Medical University, No 95, YongAn Road, Xicheng District, Beijing 100050, People's Republic of China  
Tel +86 106 313 8293  
Email guoaij@139.com

## Inclusion and exclusion criteria

Patients who underwent hip hemiarthroplasty (Tri-lock stem, Corail collarless standard offset/high offset stem, and bipolar femoral head; DePuy Orthopaedics, Inc, Warsaw, IN, USA and DePuy France SAS, Cedex, France) between 2015 and 2018 were retrospectively analyzed. The inclusion criteria for the patients were: 1) underwent bipolar femoral head replacement after unilateral femoral neck fracture and 2) received antero-posterior pelvic X-ray on both lower extremities at 10–15° internal rotation before and after the operation. The exclusion criteria were as follows: 1) developmental dysplasia of hip on the fractured or the contralateral side; 2) osteoarthritis, avascular necrosis of the femoral head, previous trauma or surgery, or other causes leading to a deformed femoral head that affected the accuracy of measurement; and 3) requiring increased off-set to ensure joint stability due to hemiplegia or other reasons. A total of 47 patients (19 males and 28 females) met the above criteria, with an average age of  $75.9 \pm 4.5$  years (68–89 years).

## Methods

The diameter of the contralateral femoral head (D) was measured in the antero-posterior pelvic X-ray view using the picture-archiving communication system, and the center of the femoral head was marked. Since cartilage could not be visualized by X-ray, the circle for measuring the diameter of the femoral head was drawn from the middle of the gap between the superior surface of the femoral head and the acetabulum (Figure 1). The distance (L) between the center of the femoral head and the top of lesser trochanter



**Figure 1** The diameter of the contralateral femoral head (D) and the distance between the center of the femoral head and the top of lesser trochanter (L).

was measured, and the ratio (R) of D to L was calculated. All operations were performed with the postero-lateral approach, with exposed lesser trochanter. During the operation, the diameter of coronal plane of the femoral head (d) was measured by a Vernier caliper, and the distance from the center of the femoral head prosthesis to the lesser trochanter was calculated according to the contralateral ratio R. Then, this distance was checked using a Vernier caliper after implanting the femoral component (Figure 2).

## Statistical analysis

SPSS V23 software (IBM, Armonk, NY, USA) was used for statistical analysis. Kolmogorov–Smirnov test was used for checking the normality of the data. The LLD results conformed to the normal distribution and were expressed by mean and SD.

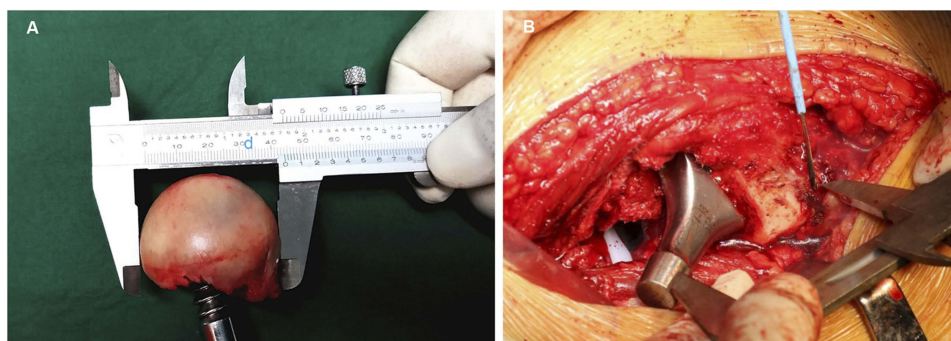
## Results

LLD was assessed according to Kim<sup>14</sup> and Yu Takeda,<sup>15</sup> by measuring the vertical distances from the lower edge of the teardrop line to the lesser trochanters in the post-operational antero-posterior pelvis X-ray view (Figure 3). The mean LLD between the fractured and the contralateral sides was  $4.4 \pm 3.2$  mm (–4.0 to 11.1 mm). We set the threshold of LLD at 6 mm according to Ranawat<sup>16</sup> and Woolson's<sup>17</sup> studies and 80.9% of the patients had LLD <6 mm. 93.6% of the patients with LLD <10 mm, only 6.4%  $\geq 10$  mm LLD.

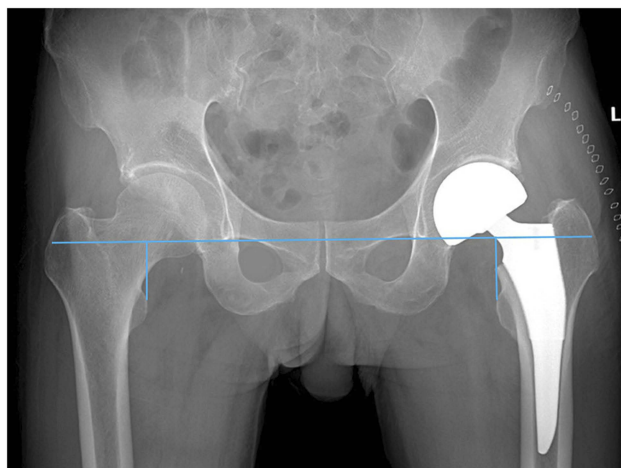
## Discussion

There are several ways to avoid LLD after hip replacement: (1) fix Kirschner wires on bones to serve as references points, and measure the distance before and after installation of the prosthesis by a ruler or similar device,<sup>5,16,18</sup> (2) use a navigation system during the operation,<sup>4,5,15,19</sup> (3) direct manual comparison of the positions of bilateral patellas or heels in surgery,<sup>9,20</sup> (4) similar to our method, measure the distance between the center of the femoral head and the top of lesser trochanter of the fractured side before femoral neck osteotomy and after the prosthesis implantation,<sup>21,22</sup> (5) template measuring on X-ray film before operation to confirm the osteotomy position according to the lesser trochanter or the fracture line,<sup>14</sup> and (6) compare the tip of the greater trochanter and the femoral head center during operation.<sup>14</sup>

Kirschner wires or other bone-fixed markers require drilling holes on the bones, which is invasive, can cause peripinhole fractures.<sup>9,16,23</sup> Furthermore, the accuracy of this method is significantly affected by the position of the lower extremities. A previous study indicates that 5 degrees of



**Figure 2** (A) The femoral head (d) was measured by a vernier caliper. (B) The distance should be obtained from the center of the femoral head prosthesis to the lesser trochanter during operation.



**Figure 3** Measurement of the postoperative LLD with reference to inter-teardrop line.  
**Abbreviation:** LLD, leg length discrepancy.

abduction/adduction mal-positioning can cause a measurement error of almost 8 mm in the leg length.<sup>24</sup> Intraoperative navigation is more accurate, but its fixation markers may require additional skin incisions, could cause pin sit pain and irritation, even increase the risk of peri-pinhole fractures.<sup>23,25,26</sup> Some pinless navigation systems<sup>4,27</sup> do not require bone-fixation markers, but still need additional equipment that can increase both operation time and costs. The accuracy of the manual comparison of the position of

bilateral patellas and heels is not high, which depends on the patient's position and surgical drapes.<sup>9</sup> This method could result in 27% of patients with LLD >10 mm.<sup>20</sup> Maybe pre-operative template measurement should be recommended, but its accuracy depends on the correct magnification of the X-ray film<sup>28</sup> and the surgeon's experience.<sup>29</sup> In addition, X-ray magnification can be approximately 15% less or 25% more in thin or obese patients, respectively.<sup>28</sup> For obese patients especially, the location of the marker may also be inaccurate.<sup>14</sup>

Although the accuracy of our method cannot be compared with navigation systems, but compared with previous studies (Table 1),<sup>5,16,18,21</sup> the accuracy is still quite satisfactory. In addition, our method is relatively simple, time-saving, cost-effective, does not require a particularly accurate preoperative magnification X-ray film and the corresponding template, or additional debugging of complex equipment. The time taken for each measurement using our method is <1 min.

There are however some limitations in our study. The actual diameter of the femoral head cannot be measured accurately by X-ray due to the presence of cartilage. The circle for measuring the diameter of the femoral head was drawn through the middle of the gap between the superior surface of the femoral head and the acetabulum.

**Table 1** Previous reports of LLD

Report	Mean LLD	Methods
Grosso P	1.3 mm	Navigation <sup>5</sup>
McGee and Scott	5.4 mm	Bone-fixed U shape K-wire <sup>18</sup>
Ranawat C S	7.4 mm	Bone-fixed K-wire <sup>16</sup>
Nam D	3.9 mm	Measuring the distance from the center of femoral head to lesser trochanter <sup>21</sup>
Our study	4.4 mm	The simple method

**Abbreviation:** LLD, leg length discrepancy.

According to Shepherd's study, the superior part of femoral head cartilage thickness is  $1.76 \pm 0.30$  mm, and that of the corresponding acetabular part is  $1.59 \pm 0.31$  mm, with mean difference of 0.17 mm.<sup>30</sup> We consider this difference is much smaller than 6 mm, and may not have a significant impact on the LLD.

Acetabular position has an impact on LLD,<sup>26</sup> which is a factor that needs to be excluded when judging the accuracy of our method. So unlike other studies,<sup>5,16,18,21</sup> we did not include total hip replacement cases in our study. But we believe that our method also helps to reduce LLD in total hip arthroplasty.

## Conclusion

The method is a simple, cost-effective, fast and accurate way to reduce the postoperative LLD. It is worth of using for reference in clinical practices especially in the absence of navigation system and other high-precision measurement equipment.

## Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Disclosure

The authors report no conflicts of interest in this work.

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