The effectiveness and influencing factors of the ‘Y’ line technique in reducing the leg length discrepancy after total hip arthroplasty

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Research Article

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Abstract

Objective: To introduce a surgical technique (the ‘Y’ line technique) which is to control the leg length discrepancy (LLD) after total hip arthroplasty.

Methods: A total of 350 patients were selected; 134 patients who were used the ‘Y’ line technique to control lower limb length were included in Group A and 166 patients treated with free hand methods to control lower limb length were included in Group B. 50 patients who were taken standard anteroposterior X-ray of bilateral hips preoperatively and used the ‘Y’ line technique during the operation were included in Group C.

Results: The postoperative LLD of the three groups was statistically significant ($p < 0.001$). There were significant differences statistically in comparison between any two groups ($P<0.01$). Severe unequal length rates of the lower extremities (LLD > 10 mm) were 5.97% (8/134) in Group A, 14.3% (24/166) in Group B and 0% (0/50) in Group C – the difference was statistically significant ($p < 0.001$). There were significant differences between Group A and Group B, Group B and Group C ($P < 0.05$), but there was no significant difference between Group A and Group C ($P = 0.078$).

Conclusion: The ‘Y’ line technique, which does not increase the operation time, can effectively reduce postoperative LLD. Insufficient internal rotation of the healthy lower extremity and the low projection position in the preoperative anteroposterior X-ray of bilateral hips were important factors affecting the accuracy of the ‘Y’ line technique.

Introduction

Leg length discrepancy (LLD) is a common complication after total hip arthroplasty (THA), and it is also the main reason why patients are dissatisfied with the operation [1]. Severe LLD can lead to gait disorders, lower back pain, hip dislocation, sciatica, prosthesis loosening and even early revision problems [2-5]. At present, there have been many methods to control LLD [6,7]but most of them have the disadvantages such as cumbersome to use, need additional equipment, increase operation time or cost, low accuracy, and et al. This paper introduced a new method (the ‘Y’ line technique) to control LLD by measuring the central height of the acetabulum and femoral head of the healthy hip on preoperative X-ray and adjusting the prosthesis height according to the preoperative measurement intraoperatively. Good results have been obtained and the factors affecting the accuracy of this method were also analysed.

Materials And Methods

I General Information

This single-centre retrospective study was approved by the Ethical Committee of the First Affiliated Hospital of Shandong First Medical University(IRB No. 2021-S943),The study was performed in accordance with the principles of the Declaration of Helsinki. The authors confirm that all methods were

carried out in accordance with relevant guidelines and regulations.The procedure, purposes, risks, and benefits associated with the study were explained, and written consent was obtained from the participants.

Inclusion Criteria: unilateral hip abnormality with normal contralateral hip; no obvious scoliosis or pelvic tilt.

Exclusion Criteria: intraoperative femoral osteotomy; appreciable dysplasia of the pelvis and lower limbs. The top of the greater and lesser trochanters, or the teardrop on plain radiographs were clearly unidentifiable.

According to the inclusion and exclusion criteria, a total of 350 patients from June 2017 to July 2020 in the First Affiliated Hospital of Shandong First Medical University were selected in this study. Group A (134 cases) was used the 'Y' line technique to control the length of the lower limbs. Group B (166 cases) was treated by free hand methods to control lower limb length. There were additional 50 patients formed Group C, who had a standard anteroposterior X-ray of bilateral hips for preoperative measurement. The standard photographing method was supine, the hips (at least the healthy hip) were full extended and internally rotated by 15–20°, the projection point was straight above the midpoint of the bilateral hips, the projection distance was 1 metre. The length of the lower limbs in Group C was controlled by the 'Y' line technique during the operation. The general data was shown in Table 1.

Table 1
General information of patients

	A group	B group	C group
The number of cases	134	166	50
Gender(M/F)	69/65	85/81	20/30
Age (years)	56.95±10.51	61.57±11.66	59.38±9.602
ONFH*	66	78	21
Osteoarthritis**	47	56	19
Femoral neck fracture	21	32	10
BMI (kg/m^2)	25.01±3.34	26.09±3.60	25.41±3.27
*: Osteonecrosis of femoral head; **: degree I DDH were included			

II Research Methods

During all of the operations, patients were placed in the lateral position, and the posterolateral approach was used. Three kinds of femoral stems which are almost in the same shape were used in this study, so

as to make this study more comparable between the groups. In Group A and Group C, a cementless prostheses BE femoral stem (Beijing Chunlizhengda Medical Instruments Co.)was used and the ‘Y’ line was drawn on its femoral rasp holder which located at the height of the femoral head centre. In Group B, two kinds of cementless prostheses were used, which were 60 CL femoral stems (AK Medical Holding Limited and 106 Corail femoral stems (Johnson& Johnson/ DePuy). There was no ‘Y’ line on the CL and Corail femoral rasp holder, but during the operations the surgeons also used the principle of the ‘Y’ line technique by visual inspection as well as other free hand methods to control LLD.

1.The method of controlling the leg length discrepancy by the ‘Y’ line technique

The basic principle of the ‘Y’ line technique is measuring the distance from the centre of the acetabulum to the line which connected between two teardrops (the height of the acetabulum) and the distance from the centre of the femoral head to the greater trochanter plane (the height of the femoral head) of the healthy hip on preoperative X-ray film. During the operation, after installed the prosthesis, try to make the height of the acetabular prosthesis centre and the height of the femoral head prosthesis centre be similar with that of the healthy hip, or correspondingly upward/downward move the two centres, so as to achieve the same length of bilateral lower limbs.

1.1 Preoperative measurement of the healthy hip on preoperative X-ray film

1.1.1 Measure The Height Of The Acetabulum A

First, drew the H-line –the line through the lowest point of the two teardrops (the lower edge of the bony acetabulum), and found out the rotation centre – spot O – of the femoral head (it was also the centre of the acetabulum). Then, the distance from O to the H-line was measured, which was the acetabulum height A.

1.1.2 Measure The Height Of The Femoral Head B

Drew the D-line, which was through the upper end of the great trochanter and vertical to the femoral longitudinal axis. Measured the distance from O to the D-line, which was defined as the height of the femoral head B (if point O was above the D-line, recorded it as positive value, if point O was under the D-line, recorded it as negative value) (Figure 1.a).

1.2 Intraoperative Measurement

1.2.1Measure the height of the acetabular cup A'

After implanted the acetabular cup and liner, a femoral head trial was placed into the liner, then, a Kirschner wire was placed perpendicularly to the operating table, and close to the inferior margin of the

bone acetabulum (that is the lower edge of the teardrop on X-ray film). The height of the acetabulum cup A'= the radius of the femoral head trial(r) + the distance from the femoral head trial to the Kirschner wire (E), if the Kirschner wire was further from the farthest point of the femoral head trial, record E as positive value (see Figure 1. c), otherwise it was negative value (see Figure 1, b).

1.2.2measure The Height Of The Femoral Head B'

The ‘Y’ line is one of a group of horizontal lines perpendicular to the longitudinal axis of the femoral stem rasp on the rasp holder, which was marked with ‘0’ and exactly located at the height of the femoral head centre when installing the standard length of the femoral head. After the optimal rasp were placed, the height of the femoral head B' could be obtained by measuring the distance from the top of the greater trochanter (paying attention to the soft tissue) to the ‘Y’ line by using a Kirschner wire to extend the line to the great trochanter, if the line was above the greater trochanter, recorded B’ as a positive value, otherwise B’ was negative value (see Figure 1.d,e).

1.2.3 Adjust the height of the femoral head during the operation

To make the two leg lengths equal after surgery, the formula A−A'=B−B' should be used. The formula states that the height of the acetabular cup moved upward or downward compared with that of the healthy hip, the femoral head height should move upward or downward the same distance accordingly. Since the A' value was fixed once the acetabular prosthesis was installed, it was necessary to adjust the height of the femoral head to the optimal B' value by using different size of stems and/or different length of femoral heads to meet A-A'=B-B'.

2. The method of controlling the leg length discrepancy in Group B

In Group B, all surgeons are familiar with the principle of the ‘Y’ line technology, but there is no ‘Y’ line on their rasp holders, thus they only visually used this principle during the operation as well as other free hand LLD controlling methods such as palpating the two knees, Shuck Test, palpating iliotibial tract tension and so on.

2.1 Postoperative Measurement

On the postoperative anteroposterior radiographs of bilateral hips, measured the distances from the tops of bilateral lesser trochanters to the H line; the difference of the two distances was regarded as the LLD value. The LLD was set to be positive when the affected limb was longer than the healthy limb and negative if not.

2 Statistical Methods

All the statistical analyses were performed with SPSS software for Windows (version 25.0 SPSS, New York, USA) and $p < 0.05$ was regarded as statistically significant. All sample data of the three groups were non-normal distribution. The Kruskal-Wallis test of measurement data, Chi-square test of ratios and the Chi-square test of grade data were used to compare the differences between postoperative LLD among the three groups.

Results

1. Average postoperative LLD was 4.74 mm (3.93) in Group A, 5.85 mm (4.60) in Group B and 2 mm (1.00) in Group C. Kruskal-Wallis test was used to compare the postoperative LLD of the three groups, and the difference was statistically significant ($Z=86.689$, $P < 0.001$). There were significant differences between Group A and Group B ($P < 0.002$), Group B and Group C ($P < 0.001$), Group A and Group C ($P< 0.001$, Figure 2).

2. The distribution of postoperative LLD in three groups was shown in Table 2. In Group C, the longest LLD was only 7 mm. Chi-square test was used to compare the postoperative LLD distribution among the three groups, and the difference was statistically significant($\chi^2=89.263$,$P < 0.001$).The LLD in Group C was significantly smaller than that of Group A($P< 0.001$) and Group B ($P< 0.001$), and the LLD in Group A was smaller than that in Group B ($P = 0.002$, Figure 3) .

3. The proportion of patients with postoperative LLD greater than 10 mm was 5.97% (8/134) in Group A, 14.3% (24/166) in group B and 0 in Group C. Chi-square test was used and the difference was statistically significant ($\chi^2=12.265$,$P=0.002$). There were significant differences between Group A and Group B ($P = 0.018$) and between Group B and Group C ($P = 0.004$), but there was no significant difference between Group A and Group C ($P = 0.078$, Figure 4).

Table 2 The distribution of postoperative LLD in Groups A, B and C

	The distribution of postoperative LLD					
Groups	≤2mm	2–4mm	4–6mm	6–8mm	8–10mm	>10mm
A (cases)	16	39	36	25	10	8
B (cases)	12	37	40	28	25	24
C (cases)	40	6	3	1	0	0

Discussion

The effect of unequal lower limb length after total hip arthroplasty

LLD can affect the daily life of patients in varying degrees and significantly reduce the patient's postoperative quality of life [2-5]. With the development of THA surgery technology, LLD has been

significantly decreased but not completely eliminated [6-8]. So far, there is no final conclusion on the range of LLD that patients can tolerate. Maloney [9] believed that there would be no symptom when LLD was less than 10 mm after total hip arthroplasty, however, some patients found it difficult to tolerate even a very small LLD [10]. In this study, the percentage of postoperative LLD > 10 mm and the distribution of LLD was statistically compared, the result showed that the complete use of the 'Y' line technique could control LLD better than use this technique visually combined with other free hand methods.

Advantages of 'Y' line technology

The most common used free hand methods to reduce LLD after THA are palpating the two knees, palpating iliotibial tract tension and the Shuck Test. However, such methods are inaccurate due to the influence of body position and types of anaesthesia [11]. An intraoperative device [12]navigation system [13, 14] and intraoperative fluoroscopy [15-18] could reduce LLD, but more surgical equipment or procedures were needed, which increased the cost and/or operation time and might increase the risk of infection. The control of LLD by solely relying on the preoperative measurement of the template was still unreliable [19], but if it was combined with the intraoperative measurement of the height of the femoral head prosthesis, LLD could be more effectively reduced [20]. However, the study did not consider the height of the acetabulum and some studies found that the height of the acetabulum changed in different degrees after THA compared with that before the operation [21].

The 'Y' line technique takes into account the preoperative measurement, the intraoperative changes in the height of the acetabulum and the height of the femoral head simultaneously, it should be more accurate theoretically.

In this study, the surgeons used the 'Y' line technical principle without the 'Y' line rasp holder in Group B did not obtain as good result as in Group A and Group C in which used the femoral rasp holder with the 'Y' line drawn on it. This further confirms the reliability of the complete use of 'Y' line technology in reducing LLD. In addition, by comparing the distribution of postoperative LLD between Group A and Group C, it was found that taking a standard preoperative anteroposterior X-ray of bilateral hips and using the 'Y' line technique were more effectively in reducing LLD.

The 'Y' line technology only uses the routine operative instruments, does not increase the surgical steps and additional measuring tools or equipment; therefore, it is easy to be used and there is no extra cost. Moreover, due to use the bony landmarks as a reference during the operation, it was little affected by the change of the patient position. If the preoperative anteroposterior X-ray of bilateral hips was taken according to the standard procedure, this method could achieve high accuracy without increased operation time and cost. The results of this study suggested that, not only the incidence of postoperative LLD > 10 mm decrease significantly, but also the average postoperative LLD decrease significantly in patients who used this method.

Factors affecting the use of 'Y' line technology

The quality of the preoperative anteroposterior X-ray of bilateral hips will affect the measured value [22] and has the greatest impact on the use of ‘Y’ line technology. The results of Group C showed that the standard anteroposterior X-ray of bilateral hips could greatly reduce LLD, and suggest that some X-rays provided by the imaging department may be substandard.

If the lower limbs are not sufficiently external rotated, the centre point of the femoral head and the apex of the greater trochanter are not on the same plane due to the anteversion angle of the femoral neck. When this happened combined with the projection point is too low, the measured height of the femoral head will be significantly higher than the actual value, leading to the postoperative extremity lengthening, as shown in Figure 5. Five cases among eight patients with postoperative LLD > 10 mm in Group A were related to this substandard preoperative X-ray as described above.

It shows that the hip external rotation as well as lower projection point will significantly affect the use of ‘Y’ line technology (Figure 5). To avoid this influencing factor, when the lesser trochanter was found too large and femoral calcar was not displayed clearly, or Shenton's line was discontinuous on the preoperative X-ray, it is necessary to take an X-ray again under the standard conditions, because these phenomena indicate that the internal rotation of the hip is insufficient and the projection point is dislocated.

Conclusion

In total hip arthroplasty, the use of femoral rasp holder with ‘Y’ line to apply a complete ‘Y’ line technique can control postoperative LLD more effectively than the visual ‘Y’ line technique combined with a comprehensive free hand method. Insufficient internal rotation of the hip and low projection position when taking a preoperative anteroposterior X-ray of bilateral hips are the important factors affecting the accuracy of the ‘Y’ line technique.

Declarations

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Ethics declarations

Conflict of interest: The authors declare no conflict of interest.

Ethics approval and consent to participate

Written informed consent was obtained from all participants.

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Figures

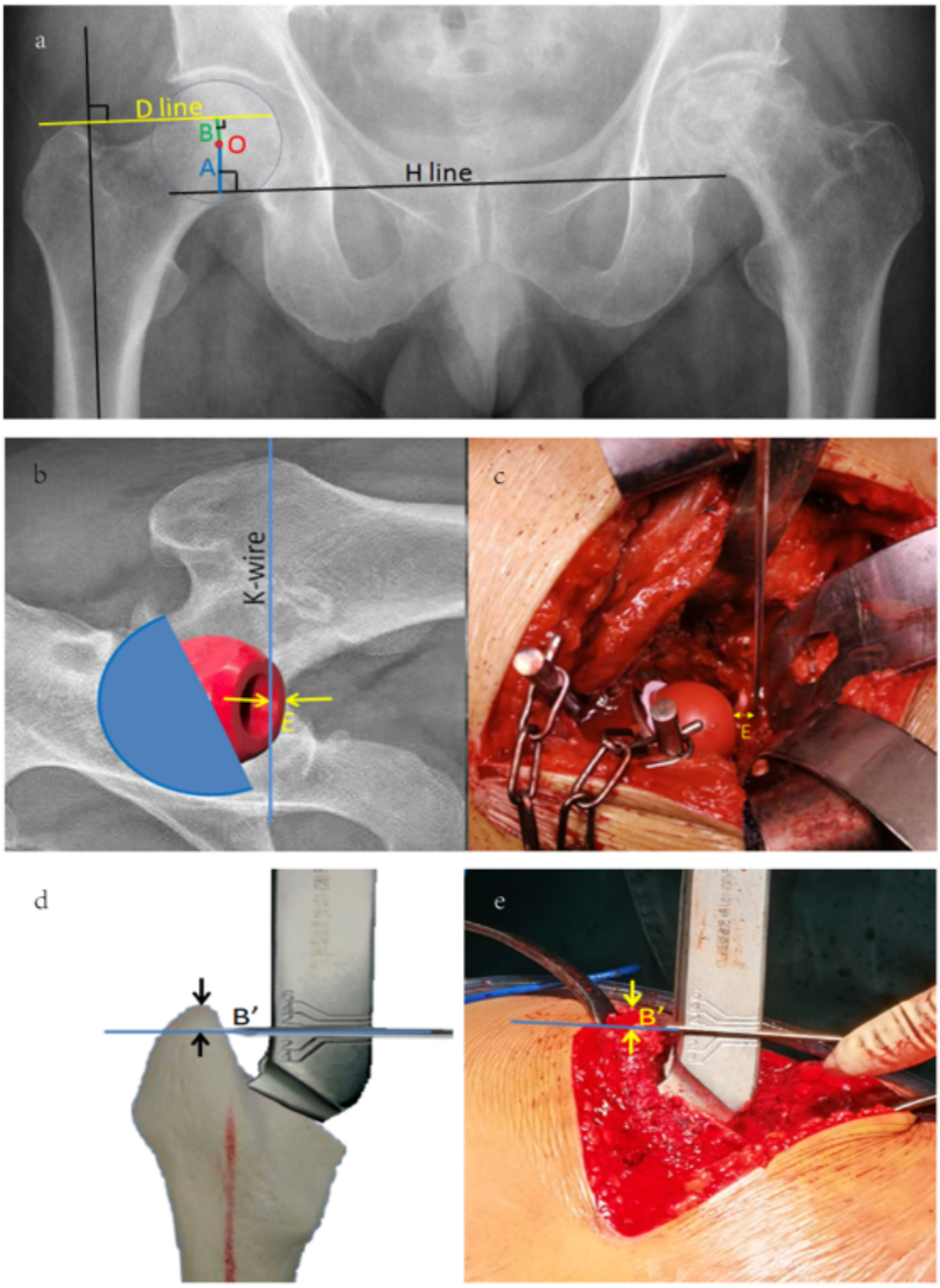

Figure 1

a Preoperative measurement of the healthy hip: A is the height of the acetabulum, B is the height of the femoral head. b, c: Intraoperative measurement of the height of acetabular cup: A': A'=r-E for the left picture(b), A' = r+ E for the right picture(c). d, e: Intraoperative measurement of the height of femoral head B'

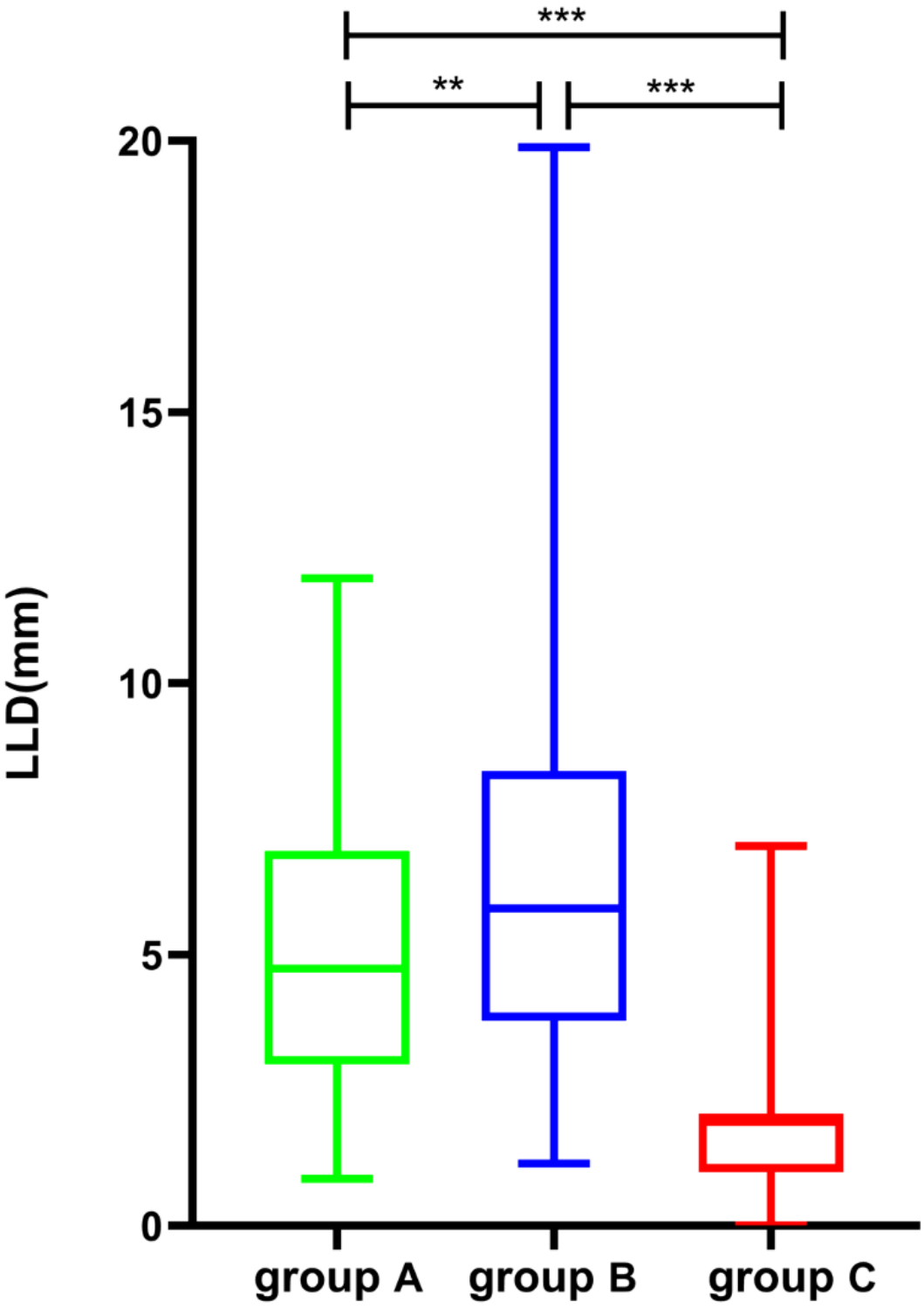

Figure 2

Comparison of postoperative LLD in Groups A, B and C. **P < 0.01, ***P < 0.001

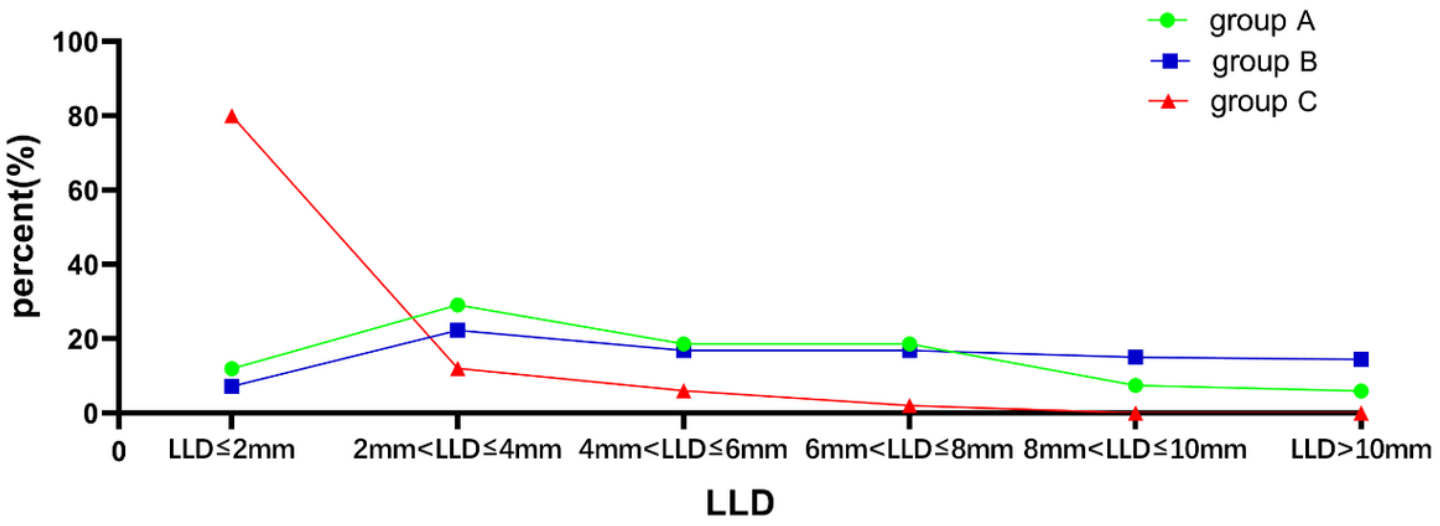

Figure 3

Comparison of the distribution of postoperative LLD in Groups A, B and C.

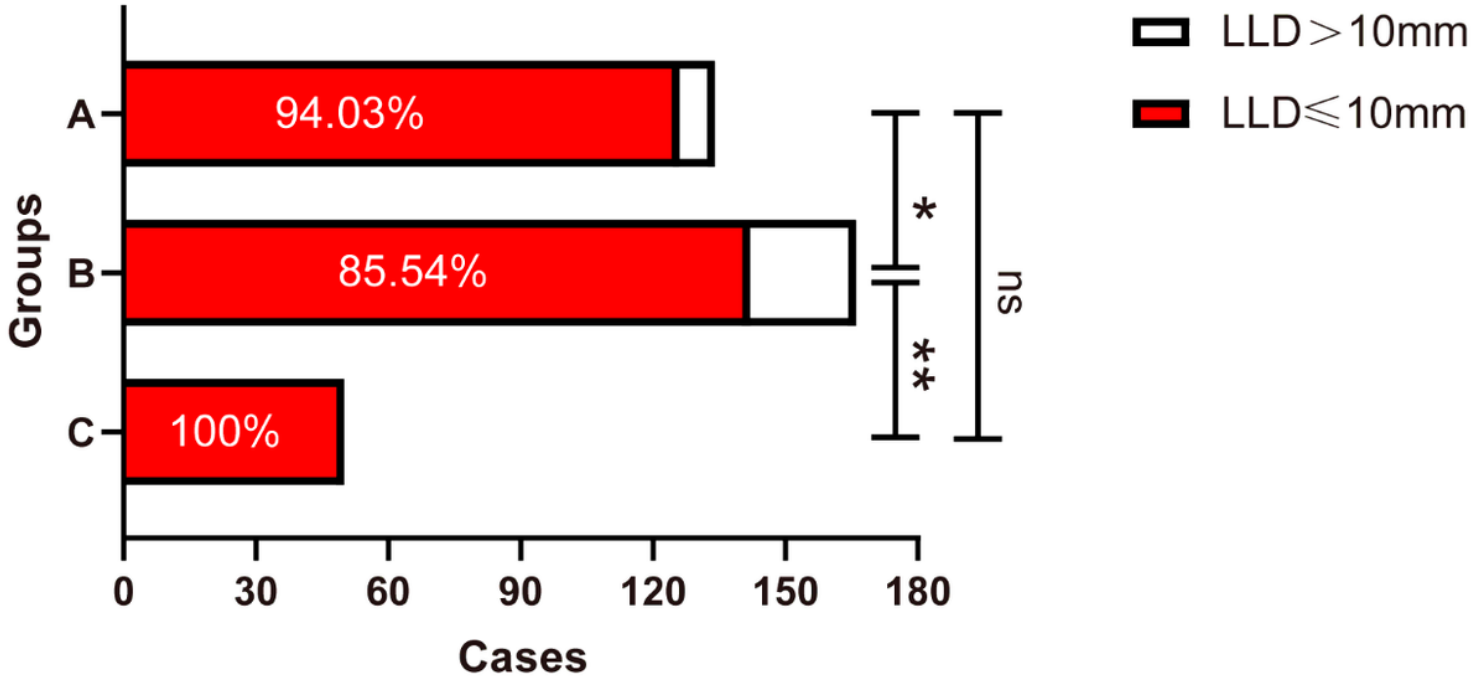

Figure 4

Comparison of the proportion of postoperative LLD>10mm in Groups A, B and C. *P < 0.05, **P < 0.01 or ns indicate no significance

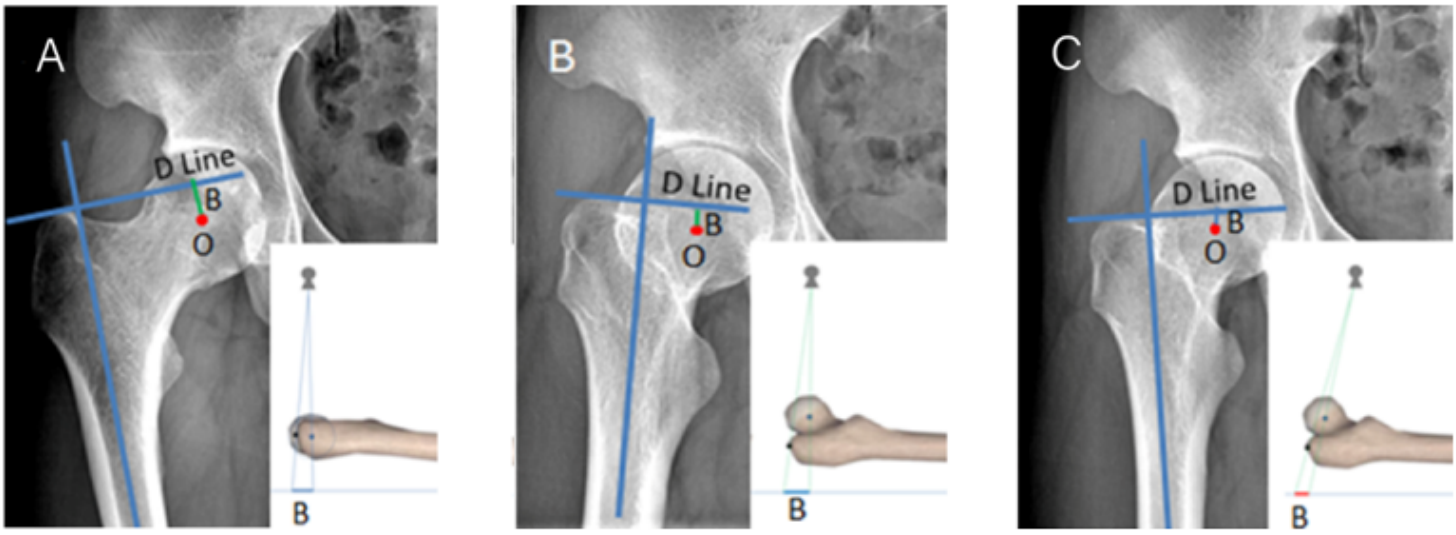

Figure 5

Bilateral hip X-ray of the same volunteer. A is the standard photographing as previously mentioned, B is the hip external rotated and the projection point is standard and C is the hip external rotated and the projection point is 10 cm below the midpoint of the bilateral hips, the femoral head centre is significantly higher than the actual value shows in picture A.