International Journal of Orthopaedics Sciences

E-ISSN: 2395-1958
P-ISSN: 2706-6630
IJOS 2022; 8(3): 223-227

www.orthopaper.com
Received: 05-05-2022
Accepted: 10-06-2022

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Preoperative planning of primary total hip arthroplasty using conventional radiographs

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DOI: https://doi.org/10.22271/ortho.2022.v8.i3d.3202

Abstract
Objective: The aim of this study was to present an analog method for preoperative planning of primary total hip arthroplasty procedures based on component measurements by overlaying the transparency of the prosthesis on preoperative radiographs and checking the accuracy, both for predicting the size of the acetabular and femoral components to be used and to restore offset and correct dysmetria if any.
Methodology: From May 2019 to June 2022, 18 primary total hip arthroplasties were performed and were analyzed in 18 patients at the Post graduate Department of Orthopaedics GMC Srinagar. Measurements on femoral and acetabular components obtained by planning were compared to those used in surgery. Displacements measured through preoperative planning was compared with planning measured on postoperative radiographs. Dysmetria was assessed before and after surgery.
Results: accuracy of 68.5% (p<0.001) in predicting the size of the acetabular component and 74.3% (p<0.001) in femoral nail prediction was observed. Displacements measured through preoperative planning was statistically similar to offsets measured postoperatively in radiographs. After surgery, we recorded absolute settlement in 42.5% of cases. In 81.8% the dysmetria was less than or equal to 1 cm and in 51.3% it was less than or equal to up to 0.5 cm.
Conclusions: Accuracy was 68.5% and 74.3% for acetabular and femoral components. Preoperatively planned offsets were statistically similar to as measured on postoperative radiographs. We found absolute alignment in 42.5% cases.

Keywords: Preoperative planning, primary total hip arthroplasty, conventional radiographs

Introduction

Preoperative planning of hip arthroplasty procedures was initially poorly understood and used because suggestions and prosthesis sizes were very limited [1, 2]. Today, variety of designs and number of sizes of components has increased considerably, and overall hip arthroplasty has turned into more complex procedure. Preoperative planning allows to appropriately choose component sizes, align limbs and reduce the duration of the operation [2]. Charnley [1] demonstrated the importance of preoperative time radiographic studies to select the correct size of components for work, and also emphasized the importance of offset reset. The latter is directly related to stability arthroplasty [1, 3-6]. Dysmetria is a common complication of total hip arthroplasty. It causes lumbalgia, gait disorders and sciatic nerve injury [7-11]. In this study, we used conventional radiographs to represent a method of preoperative planning for primary total hip arthroplasty based on component measurements through overlapping prosthesis foils on the preoperative radiograph. The study had the following objectives: to assess the accuracy of predictions for acetabular and femoral component sizes; to analyze offset recovery; and fix dysmetria.

Materials and Methods

Between May 2019 to June 2022, 18 primary total hip arthroplasties performed on 18 patients in the Post graduate Department of Orthopaedics, GMC Srinagar were analyzed. The average age was 65 years. A total of 12 patients (66.66%) were men and 6 (33.3%) were women. All patients were diagnosed with osteoarthritis.

The inclusion criterion was the presence of one-sidedness arthrosis of the hip joint.

Women with fracture following a road traffic accident and Exclusion criteria were bilateral osteoarthritis; moderate or severe acetabular protrusion according to Sotelo-Garza and Charnley classification; [12] acetabular dysplasia greater than Crowe type I; [13] femoral neck fracture; and changes in other joints that caused dysmetria. All arthroplasty procedures were performed using a posterior approach.

Radiographs of the pelvis were taken in the anteroposterior (AP) view, focused on the pubic symphysis, with the lower limbs internally rotated by 15◦ and a distance of 1m between apparatus flask and film; and in side view covering proximal one-third of the femur. The acetabular component was measured by overlap acetabular transparency on AP radiograph normal hips so that you can choose a number that matches the contour acetabulum best. The parameters used were upper lateral borders of the acetabulum, tears and Köhler's ilioschial line (Fig. 4 and 5). The size of the acetabular component was established so that it would not exceed the ilioschial line (Fig. 2).

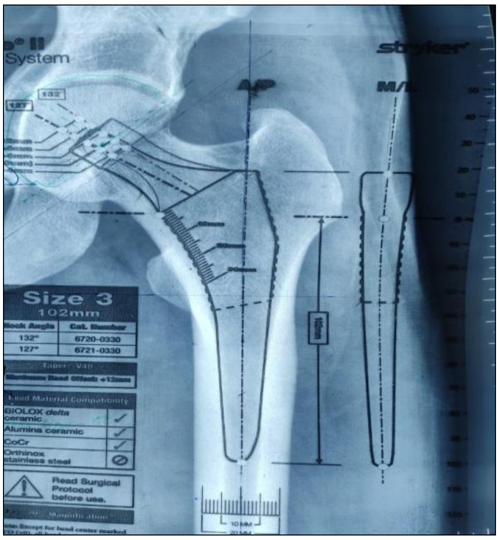

Fig 1: Measurement using the transparency

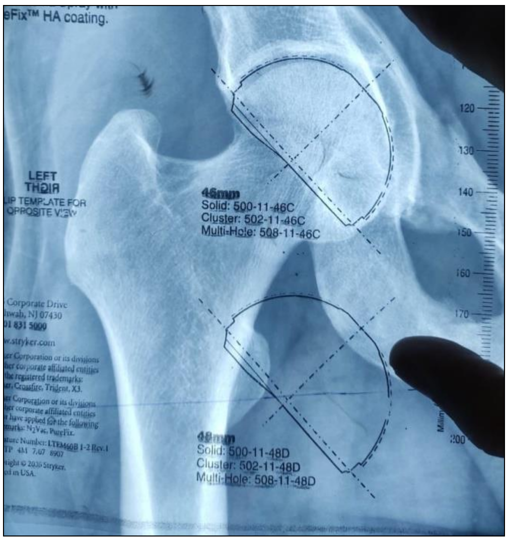

Fig 2: Measurement using the transparency.

After the center of rotation (CR) of the normal hip was marked on the radiograph (Fig. 4 and 5), it was transferred to the side to be operated. To transfer it, reference line was used as parameter:

One along the lower border of the tear (Fig. 4)

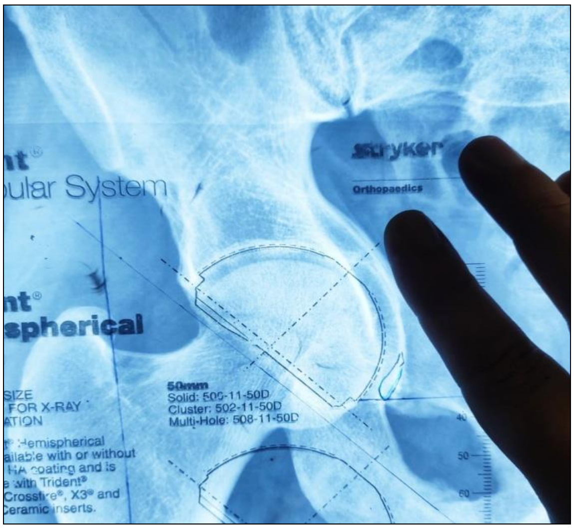

Fig 3: Measurement using the transparency.

Fig 4: Calculation of the dysmetria

Femoral offset was the distance along a line running perpendicular to the center of rotation of the femoral head to an intersection with a line passing through the center long axis of the femur [14]. The offset of the prosthesis was the distance from a line running perpendicular from the center of rotation of head of the prosthesis to the intersection with the passing line in the middle of the main longitudinal axis of the femoral nail (Fig. 5).

To select the size of the femoral component, its transparency was overlaid on the AP radiograph on the side to be operated (Fig. 4). The selected femoral component was determined to be the one with the offset closest to normal lateral. Dysmetria can be one of three types: at cost of femur, at the expense of the acetabulum, or at the expense of both femur and acetabulum (mixed or combined) [15]. Three lines on AP were used to identify dysmetria radiograph of the pelvis, centered on the pubic symphysis [15].

Line 1: determined by drawing a straight line through the outermost points of the sciatic tuberosities;

Line 2: determined by drawing a straight line along upper lateral border of the acetabulum;

Line 3: determined by drawing a straight line through centers of the lesser trochanters.

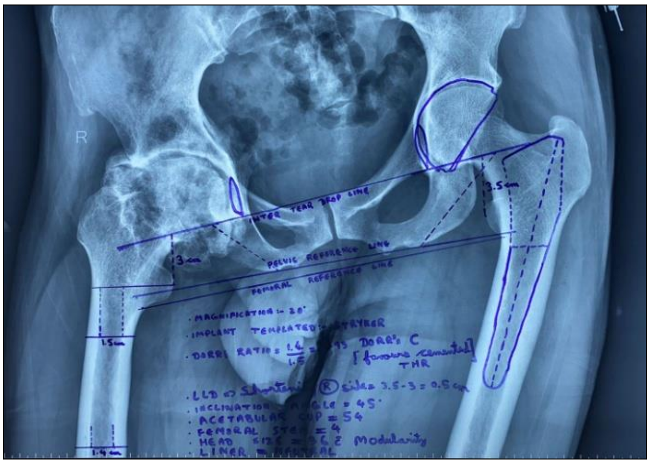

Fig 5: Preoperative planning

Fig 6: Preoperative planning

In normal hips, the three lines are parallel. Line parameters were used to measure dysmetri, along the lower border of the tears and line 3 (Fig. 6).
The pelvis with the acetabular component selected, the calculated CR, and the femur for surgery were drawn using tracing paper overlaid on the AP radiograph (Fig. 7). The drawing of the pelvis was then overlaid with the drawing of the femur, and both of these were placed on transparency femoral component (Fig. 6).
The level of the femoral neck osteotomy for limb alignment was defined by moving the drawings across femoral transparency. For this, lines 1, 2 and 3 had to be preserved parallel (Fig. 5).
A chi-square test was used to determine accuracy predictions for acetabular and femoral components.
The Mann-Whitney test was used to compare the planned offset measurements with those obtained on the postoperative radiograph. Postoperatively, dysmetria was analyzed.
Statistical Methods: The recorded data was compiled and entered in a spreadsheet (Microsoft Excel) and then exported to data editor of SPSS Version 20.0 (SPSS Inc., Chicago, Illinois, USA). A P-value of less than 0.05 was considered statistically significant.

Result

Accuracy 68.5% ($p<0.001$) in size prediction an acetabular component was observed (Table 1). Accuracy 74.3% ($p<0.001$) in femoral nail prediction was found Offsets measured in preoperative planning were statistically similar to offsets measured after surgery radiographs, with p = 0.410 (Table 3).
The mean preoperative dysmetria was 1.6 cm with range from 0.0 to 3.9 cm (Table 4). We observed after the operation that the limbs were straightened in 8 patients (44.4%), lengthened in 6 (33.3%) and shortened in 4(22.2%). Medium postoperative dysmetria was 0.4 cm, with a range from 0.0 to 2.1 cm (Table 5). We observed that postoperative dysmetria was less than or equal to 1.0 cm in 81.8% of patients and less than or equal to 0.5 cm in 51.3%. Regarding the femoral nail, it was observed to be neutrally positioned in 12 hips (66.6%), with valgus rotation in 4 (22.22%) and with varus rotation in 2 (11.11%).
Analysis of the mean inclination of the acetabular component in the frontal plane showed that it was 46◦, ranging from 33◦ to 57◦. Differences in offset on postoperative radiographs relative to what was planned, they were statistically similar (p = 0.214), with respect to neutral, varus and valgus positions femoral nail.
Correlation between variations in the postoperative period offset values relative to what was planned and slope acetabular component was not statistically significant (p = 0.657).

Discussion

During the 1970s, there were only a limited number of implants placed [2]. Today there are several different designs and large number of sizes available, which makes planning easier essential [2, 16]. However, few studies have evaluated the accuracy of component size predictions [2, 6, 13, 14, 15]. We initiated this investigation to evaluate method used in our institution. Today there are planning methods using digital radiographs. These enable high accuracy [6], as shown by Eggli *et al*., [6]. Who observed an accuracy of around 90% in the component predictions. The method described in our study was less accurate, but we can apply it to conventional radiographs at no additional cost for progress.
In our sample, we observed that the accuracy was 68.5% for acetabular components and 74.3% for femoral components. These values were similar to those reported by Paniego *et al*., [2] who found an accuracy of 83% for acetabular components and 76% for femoral components; and to those reported by González Della Valle *et al*., who observed accuracies of 83% and 78% for acetabular and femoral components. Both author groups used planning methods with conventional radiographs. It is difficult to predict the exact magnification on conventional radiographs. For this reason, to minimize possible deviations, we standardized the production of radiographs as described in the methodology.
Arthroplasty procedures aim to return the biome of the hip joint to normal conditions by selecting suitable the size of the prostheses in order to avoid intra-operative and post-operative complications and subsequent enlargement of the prosthesis longevity. The meaning of offset is related to functioning load-bearing uscles [1, 4, 5]: it can be restored by planning [1, 3-6]. Its restoration is related to stability arthroplasties [1, 3, 6]. Offsets measured in preoperative planning in our sample were statistically similar to those measured on postoperative radiographs. This is related with an accuracy of 74.3% in femur size prediction nails that had fixed offset values. So if the size the femoral component is correct, there is a higher probability achieving the planned offset.

Table 1: Frequency and percentage distribution of the acetabular components used at the two observation times

Acetabular component planned	Acetabular component used				Total
	44	48	50	52	
44	18 (32.10%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	18 (32.10%)
48	0 (0.00%)	20 (35.70%)	0 (0.00%)	0 (0.00%)	20 (35.70%)
50	0 (0.00%)	1(1.80%)	3 (5.40%)	0 (0.00%)	4 (7.10%)
52	0 (0.00%)	5 (8.90%)	1 (1.80%)	3 (5.40%)	9 (16.10%)
54	0 (0.00%)	0 (0.00%)	0 (0.00%)	3 (5.40%)	3 (5.40%)
56	0 (0.00%)	0 (0.00%)	1 (1.80%)	1 (1.80%)	2 (3.60%)
Total	18 (32.10%)	26 (46.40%)	5 (8.90%)	7 (12.50%)	56 (100.00%)

Table 2: Frequency and percentage distribution of the femoral nails used at the two observation times

Femoral component planned	Femoral component used						Total
	10.5	12	13.5	15	35.5	37.5	
10.5	8 (14.30%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	8 (14.30%)
12	3 (5.40%)	15 (26.80%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	18 (32.10%)
13.5	0 (0.00%)	0 (0.00%)	1 (1.80%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	1 (1.80%)
15	0 (0.00%)	1 (1.80%)	1 (1.80%)	1 (1.80%)	0 (0.00%)	0 (0.00%)	3 (5.40%)
16.5	0 (0.00%)	0 (0.00%)	0 (0.00%)	1 (1.80%)	0 (0.00%)	0 (0.00%)	1 (1.80%)
35.5	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	15 (26.80%)	1 (1.80%)	16 (28.60%)
37.5	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	2 (3.60%)	6 (10.70%)	8 (14.30%)
44	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	1 (1.80%)	1 (1.80%)
Total	11 (19.60%)	16 (28.60%)	2 (3.60%)	2 (3.60%)	17 (30.40%)	8 (14.30%)	56 (100.00%)

In situations where the acetabulum represents bone loss stocks or dysplasia, placement of the acetabular component, etc the center of ideal rotation is more difficult because in these cases of additional graft coverage from the femoral head may be needed. These cases were excluded from our study, as they may have biased the analysis of the center of rotation shift. Dysmetria is a common complication of the hip arthroplasty [7-9]. Its correction can be assumed by preoperative planning [1, 3, 6] and during surgery [8].
The operated side often stretches [7]. Dysmetria greater than 1 cm correlates with lumbalgia [9]. Our results were worse than those presented by Eggli *et al.*, [6] who observed dysmetria less than 5 mm in 94% of cases. In our sample, we recorded absolute settlement in 42.5% of cases. In 81.8%, dysmetria was less than or equal to 10 mm and in 51.3% it was less than or equal to 5 mm. However, he needs it it should be taken into account that the study by Eggli *et al.* [6] was performed using digital X-rays. Dolhain *et al.* [5] reported that varus or valgus positioning femoral and acetabular components affected offset in arthroplasty.

Table 3: Description of and comparison between the offsets planned and used

Pair of variables	*n*	Mean	Standard deviation	Minimum	Maximum	25th percentile	Median	75th percentile	Significance (*p*)
Offset planned (mm)	56	39.7	5.4	30.0	55.0	35.0	38.5	42.0	0.630
Offset used (mm)	56	40.3	6.4	30.0	57.0	35.0	39.0	45.0	

Source: Hospital Estadual Mário Covas.

In our sample, the relationship between the values of increased, decreased and equalized offset achieved after femoral insertion surgery component into a varus, valgus or neutral position were analyzed. It was observed that there were no statistically significant differences between the variable categories femoral nail position ($p = 0.123$). A femoral nail was placed neutral position in 66.66% of cases, valgus in 22.22% and in varus in 11.11%.

Table 4: Description of the affected lower limb before the operation

Length of affected lower limb before the operation (cm)	*n*	Mean	Standard deviation	Minimum	Maximum	25th percentile	Median	75th percentile
Shortened	53	1.7	0.9	0.4	3.9	1.0	1.5	2.3
Equalized	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	56	1.6	0.9	0.0	3.9	0.9	1.5	2.2

However, in the cases we observed valgus or varus positioning, these were minor faults that yes will not cause any significant deviations in the offset. Contrary to what was observed by Dolhain *et al.*, [5] from our sample, they found that there were no deviations in the offset related to changes in the inclination of the acetabular component. Dobzyniac *et al*. determined that ideal for femoral part was placing the nail in a neutral position in the front plane, with 20◦ to 30◦ anteversion and neutral position. For acetabular component, it should be 45◦ abduction and 20◦ to 30◦ anteversion. Lewinneck *et al.* [11] defined safety zone for the acetabular component containing the slope 30◦ to 50◦ in the frontal plane and anteversion 5◦ to 25◦. In our specimen, the acetabular component was placed using mean slope in frontal plane 46◦ with range from 33◦ to 57◦.

Table 5: Description of the affected lower limb after the operation

Length of affected lower limb before the operation (cm)	*n*	Mean	Standard deviation	Minimum	Maximum	25th percentile	Median	75th percentile
Shortened	11	0.9	0.7	0.3	2.1	0.4	0.8	1.7
Stretched	18	0.7	0.3	0.4	1.5	0.5	0.6	1.0
Equalized	27	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	56	0.4	0.5	0.0	2.1	0.0	0.3	0.6

To achieve greater accuracy in the positioning of prosthesis components, computer-supported navigation systems have been developed, which allows for less variation in acetabular location component. We did not use these systems because their the price is still high. In our study, the slope is moderate the acetabular component in the frontal plane was 46◦, with a range from 33◦ to 57◦. This variation was greater than what it has were presented using computer-aided navigation systems. Preoperative planning allowed for greater accuracy in selection of acetabular and femoral component sizes and facilitates the correction of dysmetria. This made it possible to predict intraoperative complications as needing femoral bone grafting for additional graft coverage in cases of acetabular dysplasia, necessity of in situ osteotomy femoral neck in cases of severe acetabular protrusion and the need for small components in small patients. It made it possible to choose a femoral component for reconstruction of offset and determine the ideal center of rotation at affected party.

Conclusions

- We found an accuracy of 68.5% and 74.3%, respectively, for acetabular and femoral components;
- Offsets measured during preoperative planning were statistically similar to those measured on postoperative radiographs;
- Absolute settlement occurred in 42.5% of cases. In 81.8% the dysmetria was less than or equal to 1 cm and in 51.3% it was less than or equal to up to 0.5 cm.

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