Restoration of femoral offset during hip replacement

A radiographic cadaver study

J. Urban Lindgren[1] and Joseph Rysavy[2]

Restoration of femoral offset is an important part of total hip arthroplasty. Since radiographs showing the femur at a sufficient degree of internal rotation to allow direct measurement of femoral offset are not usually available, templates of the prosthesis at 25 and 45 degrees of rotation were created. Radiographs of 20 cadaver femurs with a mean offset of 44 ± 5 mm (*r* 36–56) were then obtained at different degrees of rotation. Simple guidelines to indicate the correct template for each projection of the femur were found. The system could be used to select a prosthesis with correct offset using radiographs obtained at angles of rotation between 20 degrees internally and 40 degrees externally.

[1] Division of Orthopedics and [2]Department of Radiology, Creighton University School of Medicine, Omaha, NE, U.S.A.
Correspondence: Dr. Urban Lindgren, Karolinska Institute, Department of Orthopedics, Huddinge Hospital, S-141 86 Huddinge, Sweden. Tel +46–8 746 10 00. Fax +46–8 774 34 83
Submitted 91-10-29. Accepted 92-02-16

Commonly, hip prostheses have a relatively high neck-shaft angle and a tendency to reduce femoral offset. In order to maintain normal lever arms for the abductors and provide adequate stability, lateralization of the greater trochanter would, in most cases, be advisable (Charnley 1979). However, because of problems involved, trochanter osteotomy no longer appears to be the standard procedure. Instead, in order to achieve stability, a too long neck is often used which, by increasing leg length, can be a problem for the patient.

In the preoperative planning we often have to use radiographs which do not show a true anteroposterior projection of the femoral neck; with the femur in neutral or external rotation, the femoral neck appears shorter and more vertical. Although internal rotation is attempted during radiography, the hip disorder often prevents enough rotation to fully compensate for the anteversion of the femoral neck. In such cases, templates showing the projection of an anteverted prosthesis would be useful, especially if the femoral rotation could be estimated from the radiographs.

Material and methods

20 cadaver femurs were obtained from the Department of Anatomy at Creighton University School of Medicine. The mean length of the bones was 456 ± 35 mm. Using a uniform radiographic technique, the femurs were placed immediately above the film cassette and radiographs in different degrees of rotation around the diaphysis were made. The degree of rotation was determined using a pin applied to the posterior surfaces of both femoral condyles. 20 and 10 degrees of internal rotation, 0 degrees and 10, 20, 30, 40, and 50 degrees of external rotation were used. The perpendicular distance between the center of the femoral head and a line through the center of the femoral canal was measured on the different projections. In addition, the best landmarks to indicate the degree of rotation of the proximal femur were identified. Finally, the projection showing the best true AP of the femoral neck was selected (usually 20 degrees of internal rotation) and templated in order to define the ideal prosthesis for that femur. Then, templates of that prosthesis in different degrees of rotation (0, 25 or 45 degrees) were used in order to determine which template would accurately show the correct neck length on the different projections of the proximal femur. A good stem fit as well as correct placement of the center of rotation were required. For this study, in order to minimize variation, an oversized stem with exact fit was used and no space was left to show the cement layer. The femoral neck-shaft angle was 125 degrees.

Assessment of femoral rotation

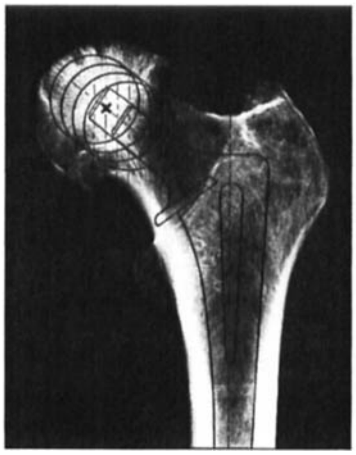
I. The proximal projection of the center of the femoral shaft coincides with the piriformis fossa. When the

Figure 1. 10 degrees of external rotation showing the two lines, a and b, projected above the piriformis fossa (c).

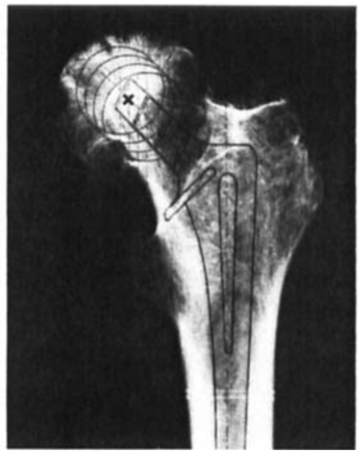
a. 20 degrees of internal rotation showing a true AP of the femoral neck. A standard template indicates that a long neck is necessary to restore femoral offset.

b. 0 degrees of rotation with the same template; this erroneously suggests that a medium neck should be used.

Figure 2. 40 degrees of external rotation showing the calcar femorale (d); for a, b, and c. See text to Figure 1.



c. The same degree of rotation as 3b but now with a template showing the prosthesis in 25 degrees of anteversion, again correctly indicating that a long neck is necessary.



d. 30 degrees of external rotation necessitating a 45 degree anteverted template to demonstrate the correct (long) neck length.

Figure 3. The proximal femur at different degrees of rotation. Note that an oversized stem was chosen to minimize variations between measurements. The center of rotation is indicated by X.

femur was rotated it could be seen that the medial wall of the greater trochanter which forms the fossa gave rise to two vertical lines on the radiograph (Figures 1 and 2). These could be used to determine the degree of rotation. The distance between the lines was measured at 1 cm above the middle of the piriformis fossa.

II. The line created by the posterior margin of the greater trochanter with increasing degrees of external rotation projected further medially on the femoral neck and finally projected over the femoral head (Figures 1 and 2).

III. At both extremes of rotation used here the following was noted: on internal rotation the lesser trochanter projected over the medial cortex so that it caused a *uniform* increase in the density of the medial cortex (Figure 3 a); on extreme external rotation the calcar femorale was projected as a separate structure (Figure 2).

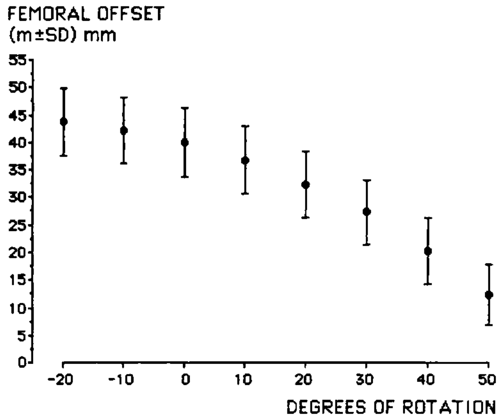


Figure 4. Projected femoral offset as a function of rotation of the femur around its longitudinal axis.

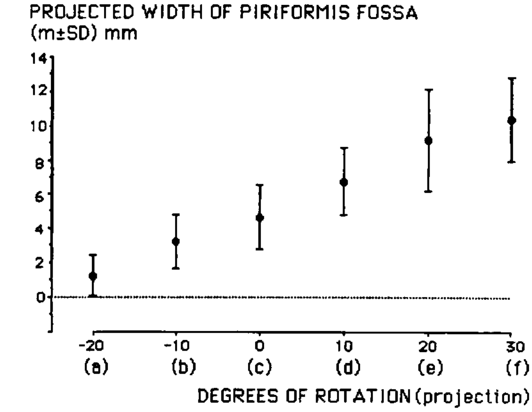


Figure 5. The projected width of the piriformis fossa (the distance between a and b in Figures 2 and 3) measured at different degrees of rotation (projections a, b, c, d, e, and f in Table 1).

Table 1. Projections where the template was consistent with the selected prosthesis

Case	Template rotation 0°	25°	45°
1	ab	cd	e
2	abc	d	ef
3	ab	cd	f
4	abc	de	f
5	ab	cd	ef
6	abc	de	f
7	abc	de	fg
8	–	–	–
9	ab	cd	ef
10	abc	de	f
11	a	bcd	ef
12	ab	cd	ef
13	abc	d	ef
14	ab	cd	ef
15	ab	c	def
16	abc	cd	ef
17	ab	cdef	g
18	abcd	e	f
19	abc	def	g
20	a	bc	def

Internal rotation: a 20°, b 10°, c 0°
External rotation: d 10°, e 20°, f 30°, g >30°

Table 2. Recommended template

Projected distances between the anterior and posterior wall of piriformis fossa:	Recommended template:
~ 5 mm	25° rotation
~ 10 mm	45° rotation
or	
When lesser trochanter causes uniformly increased radiodensity of medial cortex	Standard
When tip of trochanter projects over lateral margin of femoral head	25° rotation
When calcar femorale is projected as independent structure	45° rotation

Results

The mean femoral offset was 44 (36–56) mm with one case excluded because of a healed femoral neck fracture and an offset of 31 mm. Offset was less than 48 mm in 15 femurs and less than 53 mm in 18. The projection which gave the highest value for offset was usually the one at 20 degrees of internal rotation (19 cases) although, as a rule, there was only a small difference between 20 and 10 degrees of internal rotation (Figure 4). Commonly, each template of the selected prosthesis gave a good fit on two or three consecutive projections (Table 1).

In order to be able to select a template with a correct degree of rotation the different criteria were correlated with the templates used (Figure 3). The best criterion was the projected distance between the medial walls of the trochanter at the piriformis fossa. With the data converted to the 15–20 percent magnification of a standard radiograph (Figure 5), a 5 millimeter distance or more suggested that at least the 25 degree rotated template should be used (Table 2). Where the distance was

5 millimeters we found that the 25 degree rotated template should have been used at a projection with *less* rotation than the actual one and there was no false positive finding. With a distance between the lines of 10 mm or more, a 45 degree rotated template was considered necessary. In 4 cases the 45 degree template became necessary when the distance was 8 or 9 mm and in 7 cases it only became necessary when the distance was 11 to 13 mm showing that this criterion was less accurate than that for the 25 degree template. Regarding the other criteria for rotation it was found that in the internal rotation position where the lesser trochanter uniformly increased the radiodensity of the medial cortex, a standard template with 0 degrees of rotation should be used. When the line indicating the posterior border of the trochanter at the piriformis fossa projected at the lateral part of the femoral head or over it, a template that was rotated 25 degrees or more was necessary, and when the calcar was projected free, a 45 degree or more rotated template was always necessary. However, these criteria were less sensitive than the criteria using the vertical lines above the piriformis fossa.

Discussion

Shortening the lever arm for the abductors by reducing the femoral offset causes Trendelenburg's limp and/or lateral hip pain. In addition, a short lever arm increases the vertical loads on the acetabulum. Reduced femoral offset may also cause impingement, with dislocation or pain. If the femur is made too long, the patients usually feel considerable discomfort during the first year after the operation and many will need a heel lift on the contralateral side for life. A shortened femur is usually better tolerated. Finally, if femoral offset is restored to normal, the anteversion of the prosthesis should also be made to conform with the anatomy. For preoperative planning, most commonly the 0 or 25 degree template should be used, and rarely the 45 degree template. In cases where the contralateral hip is less involved, the 0 degree template may be used on a radiograph of that hip. This can be useful when there is severe deformation after fractures.

Charnley's original femoral component had a 45 mm offset. Because of the high number of stem fatigue fractures with the alloy used at that time, the offset for the standard component was reduced to 40 mm. Most manufacturers of hip prostheses have preferred to use the shorter offset for their prostheses. A small femoral offset reduces the bending and the torsional moment on the femoral prosthesis which could reduce the risk for stem loosening. Soon after surgery uncemented femoral prostheses are at increased risk and should not, as a rule, be allowed full weightbearing immediately if a long offset has been used (O'Connor et al. 1989, Robinson et al. 1989). However, an increase in the femoral offset even to 53 mm has not been shown to cause micromotion in simulated one-legged stance or stair climbing when cemented prostheses were studied (O'Connor et al. 1989). Furthermore, with modern surgical technique mechanical loosening of cemented femoral prostheses has become rarer. For example, in an over 10-year follow-up of 103 cemented HD2 total hip replacements (Howmedica Inc.) Mulroy and Harris (1990) reported only three definitely loose femoral components but a 42 percent incidence of acetabular loosening. If a cane or a limp is to be avoided, the smaller offset must be compensated with greater muscle forces which will cause excessive acetabular loads. The accurate restoration of femoral offset is mechanically advantageous; it is necessary for normal kinematics and obviates the need for lengthening the extremity at the operation.

References

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