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Posterior reference guides do not always maintain the size of posterior femoral condyles in TKA

Yukihide Minoda[1] · Shigekazu Mizokawa[1] · Yoichi Ohta[1] · Mitsuhiko Ikebuchi[1] · Maki Itokazu[1] · Kazumasa Yamamura[1] · Suguru Nakamura[1] · Hiroaki Nakamura[1]

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Abstract
Purpose Posterior reference guides are provided by many manufacturers. However, the true posterior femoral condyle bone resection thicknesses using posterior reference guides are not stated by the manufacturers. The purpose of this study was to analyse the influence of the posterior reference guide designs on the posterior femoral condyle bone resection thickness.
Methods Thickness of posterior femoral condyle bone resection and thickness of prostheses were investigated in 8 types of total knee prostheses using the production drawings provided by the manufacturers.
Results Posterior femoral condyle bone resection thickness differed between prostheses. Change in size of the medial posterior condyle ranged from −0.5 to 1.4 mm at 0° external rotation, from −2.9 to 1.4 mm at 3° external rotation, and from −5.3 to 1.4 mm at 6° external rotation. Change in size of lateral posterior condyle ranged from −0.5 to 1.4 mm at 0° external rotation, from −0.4 to 3.4 mm at 3° external rotation, and from −0.4 to 5.3 mm at 6° external rotation.
Conclusions This study showed that posterior femoral condyle bone resection thickness was different for each posterior reference guide. The rotation centre of posterior reference guides influenced the bone resection thickness in the posterior femoral condyle. The size of the posterior femoral condyles increased in some guides but decreased in other guides. The maximum differences in size changes of the posterior femoral condyles between the guides were 1.9 mm at 0° external rotation, 4.1 mm at 3° external rotation, and 6.3 mm at 6° external rotation. To control the size of posterior femoral condyles, the posterior reference guide design should be checked before use.

Keywords Total knee arthroplasty · Posterior reference guide · Posterior femoral condyle · Rotation of femoral component

Introduction

Preparing appropriate extension and flexion joint gaps is important for functional restoration of the knee joint after total knee arthroplasty (TKA) [8, 9, 14, 19, 20]. The posterior femoral condyle bone resection thickness and the rotation of the femoral component affect the flexion joint gap [3, 5, 13].

There are two surgical instruments to position the femoral component: (1) the anterior reference guide and (2) the posterior reference guide. The former guide provides a constant resection thickness at the anterior femoral condyle, and the resection of the posterior femoral condyle will be in accordance with the size of the implant. However, the latter guide provides a constant resection thickness at the posterior femoral condyle, and the anterior cut is performed according to the size of the femoral component [6, 22]. In posterior reference guides, therefore, the posterior femoral condyle bone resection thickness depends on the design of the guides.

The posterior reference guide design affects posterior femoral condyle bone resection thickness, which may change the posterior condylar offset [1, 7, 23] and the size of flexion joint gap [3, 5, 13]. However, the relationship

✉ Yukihide Minoda
yminoda@msic.med.osaka-cu.ac.jp

[1] Department of Orthopaedic Surgery, Osaka City University Graduate School of Medicine, 1-4-3 Asahi-machi, Abeno-ku, Osaka 545-8585, Japan

between the bone resection thicknesses of the medial and lateral posterior femoral condyles using posterior reference guides and the thickness of the femoral component is not stated by the manufacturers in their product information. There have been no reports on the difference of the setting between various posterior reference guides.

The hypothesis of this study was that the posterior femoral condyle bone resection thickness was different for each posterior reference guide. The purpose of this study was to investigate the design of posterior reference guides, femoral cutting blocks, and femoral components using production drawings provided by the manufacturers and to analyse the influence of the rotation centre of the posterior reference guides on the medial and lateral posterior femoral condyle bone resection thickness.

Materials and methods

Eight types of total knee prostheses, for which production drawings of posterior reference guides, femoral cutting blocks, and femoral components were provided by the manufacturers, were investigated (Table 1). Posterior reference guides were classified into 3 types according to the rotation centre for femoral component rotation: medial rotation, central rotation, and lateral rotation (Fig. 1).

The distance from the centre of the fixation pinholes of the posterior reference guides to the feet for the medial and lateral posterior femoral condyles was described in the production drawings provided by the manufacturers (D1med on the medial side and D1lat on the lateral side) (Fig. 2). The distance from the centre of the fixation pinholes to the lower edge of the cutting slot for the posterior femoral condyle was described in the production drawings of the femoral cutting blocks provided by the manufacturers (D2) (Fig. 3). To take into account the thickness of the cutting slot of the femoral cutting blocks and the thickness of the bone saw, the anterior edge of the cutting slot was used for D2 measurement. The value of D1–D2 represents the posterior femoral condyle bone resection thickness. The thickness of the metal posterior condyle in the femoral components (D3) was described in the production drawings provided by the manufacturers (Fig. 4). The values of D1, D2, and D3 were also described in various degrees of external rotation. The values of D1, D2, and D3 were described to one decimal place in all the production drawings.

The size change of the medial and lateral posterior femoral condyles using posterior reference guides was calculated as follows:

Table 1 Type of posterior reference guide

Manufacturer	Product	Type of posterior reference guide
Microport (Memphis, TN, USA)	Evolution (size 1–4)	Medial rotation
	Evolution (size 5–8)	Medial rotation
Biomet Japan (Tokyo, Japan)	Vanguard custom	Medial rotation
Biomet (Warsaw, IN, USA)	Vanguard	Central rotation
Stryker (Mahwah, NJ, USA)	Triathlon	Central rotation
	Scorpio NRG PS	Central rotation
	Scorpio NRG CR	Central rotation
Smith & Nephew (Memphis, TN, USA)	Legion	Lateral rotation

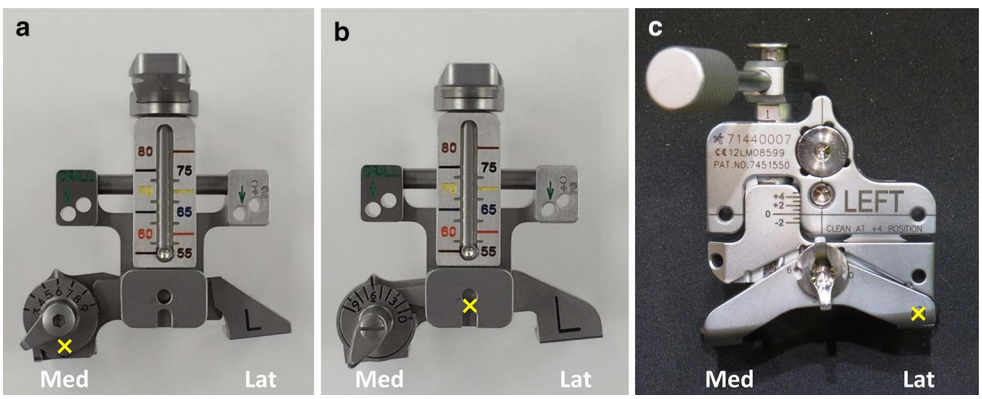

Fig. 1 Three types of posterior reference guides are shown: **a** medial rotation type (Vanguard custom), **b** central rotation type (Vanguard), and **c** lateral rotation type (Legion). *Yellow crosses* indicate the centre of rotation in each posterior reference guide

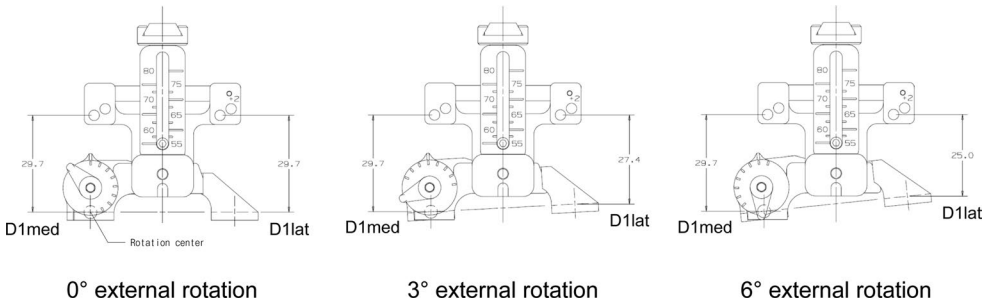

Fig. 2 The production drawings of Vanguard (Biomet Japan, Tokyo, Japan) custom posterior reference guide are shown. The distance from the centre of the posterior reference guide fixation pinholes to the feet for the medial posterior femoral condyle (D1med) and lateral posterior femoral condyle (D1lat) was checked at various degrees of external rotation. This was a medial rotation type guide. Thus, the D1med value is constant (29.7 mm) regardless of the degree of external rotation

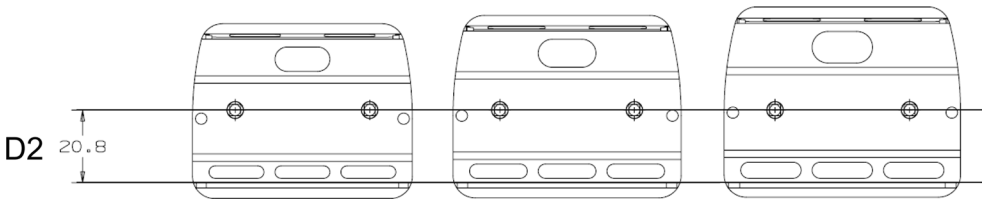

Fig. 3 The production drawings of Vanguard femoral *cutting block* are shown. The distance from the centre of the fixation pinholes to the anterior edge of the cutting slot for the posterior femoral condyle (D2) is 20.8 mm for any cutting block size

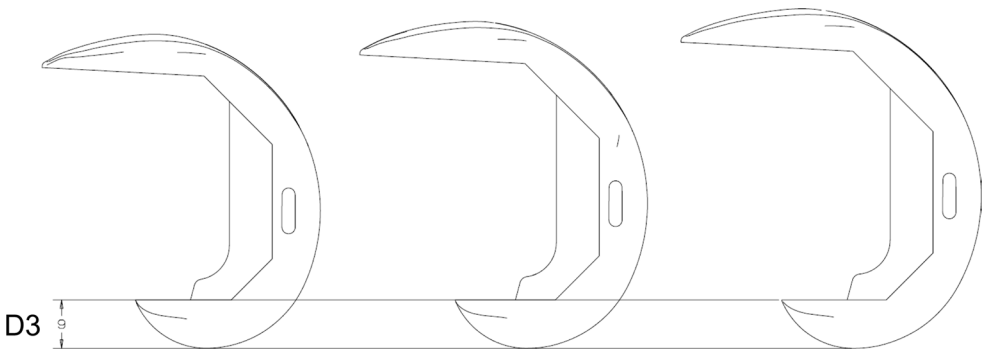

Fig. 4 The production drawings of Vanguard femoral component are shown. The thickness of femoral components (D3) is 9 mm for any femoral component size

- Change in size of the medial posterior femoral condyle = D3 − (D1med − D2)
- Change in size of the lateral posterior femoral condyle = D3 − (D1lat − D2)

If the size of the posterior femoral condyle increased, the value was expressed in positive values. If the size of the posterior femoral condyle decreased, the value was expressed in negative values.

Results

Three guides were classified as medial rotation type, 4 guides as central rotation type, and 1 guide as lateral rotation type (Table 1). When the rotation was set at 0° external rotation, the medial posterior condyle bone resection thickness was basically equal to that of the lateral posterior condyle (Table 2). However, the femoral condyle bone resection thickness at 0° external rotation (D1–D2) was not always equal to the thickness of the prosthesis (D3). Therefore, the change in size of the posterior femoral condyles differed between prostheses even at 0° external rotation.

The changes in size of the medial posterior femoral condyles using posterior reference guides are shown in Fig. 5. The more the femoral component was externally rotated, the more the difference between prostheses increased. In the medial rotation type, the medial posterior femoral condyle size did not change, regardless of external rotation

Table 2 D1, D2, D3, and the change of size in the femoral condyles at 0° external rotation

Product	D1med and D1lat (mm)[a]	D2 (mm)[b]	Thickness of bone resection in posterior femoral condyles (D1–D2) (mm)	D3 (mm)[c]	The change of the size in the femoral condyles [D3 − (D1 − D2)] (mm)
Evolution (size 1–4)	28.9	19.3	9.6	10	0.4
Evolution (size 5–8)	28.9	19.3	9.6	11	1.4
Vanguard custom	29.7	20.9	8.8	9	0.2
Vanguard	29.7	20.9	8.8	9	0.2
Triathlon	26	18	8	8.2	0.2
Scorpio NRG PS	28	20	8	8.2	0.2
Scorpio NRG CR	28	20	8	7.5	−0.5
Legion	26.3	16.4	9.9	9.5	−0.4

[a] D1med and D1lat represent the distance from the centre of fixation pinholes of the posterior reference guides to the feet for medial and lateral posterior femoral condyles. The values of D1med and D1lat were same at 0° external rotation

[b] D2 represents the distance from the centre of fixation pinholes to the anterior edge of the cutting slot for posterior femoral condyles

[c] D3 represents the thickness of the metal posterior condyles in femoral components

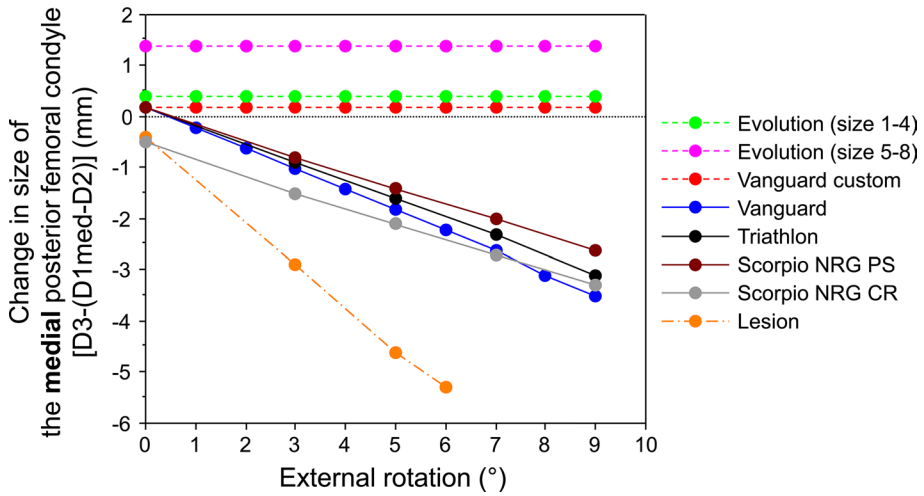

Fig. 5 The relationship between the change in size of the medial posterior femoral condyle [D3 − (D1med − D2)] and the degree of external rotation is shown. The *dotted line* represents the medial rotation type. The *solid line* represents the central rotation type. The *long dashed/short dashed line* represents the lateral rotation type

(dotted lines in Fig. 5). In the central rotation type, the size of the medial posterior femoral condyle gradually decreased as the femoral component was rotated externally (solid lines in Fig. 5). In the lateral rotation type, the size of the medial posterior femoral condyle rapidly decreased as the femoral component was rotated externally (long dashed/short dashed line in Fig. 5).

The changes in size of the lateral posterior femoral condyles using posterior reference guides are shown in Fig. 6. The more the femoral component was externally rotated, the more the difference between the prostheses increased. In the medial rotation type, the size of the lateral posterior femoral condyle rapidly increased as the femoral component was rotated externally (dotted lines in Fig. 6). In the central rotation type, the size of the lateral posterior femoral condyle gradually increased as the femoral component was rotated externally (solid lines in Fig. 6). In the lateral rotation type, the size of lateral posterior femoral condyle did not change regardless of external rotation (long dashed/short dashed line in Fig. 6).

The changes of the average size of the medial and lateral posterior femoral condyles using posterior reference guides are shown in Fig. 7. The more the femoral component was externally rotated, the more the difference between the prostheses increased. In the medial rotation type, the average size of the medial and lateral posterior femoral condyles gradually increased as the femoral component was rotated externally (dotted lines in Fig. 7). In the central rotation type, the average size of the medial and lateral posterior femoral condyles was almost constant regardless of external rotation (solid lines in Fig. 7). In the lateral rotation type, the average size of the medial and lateral

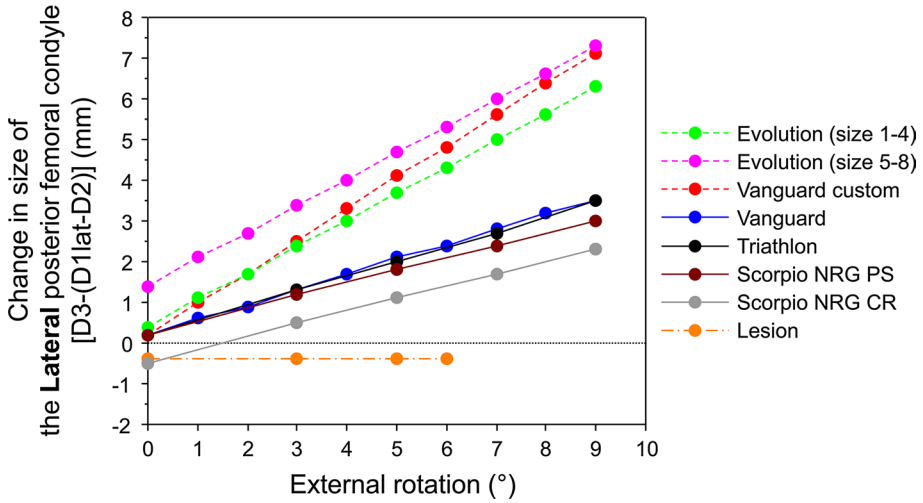

Fig. 6 The relationship between the change in size of the medial posterior femoral condyle [D3 − (D1lat − D2)] and the degree of external rotation is shown. The *dotted line* represents the medial rotation type. The *solid line* represents the central rotation type. The *long dashed/short dashed line* represents the lateral rotation type

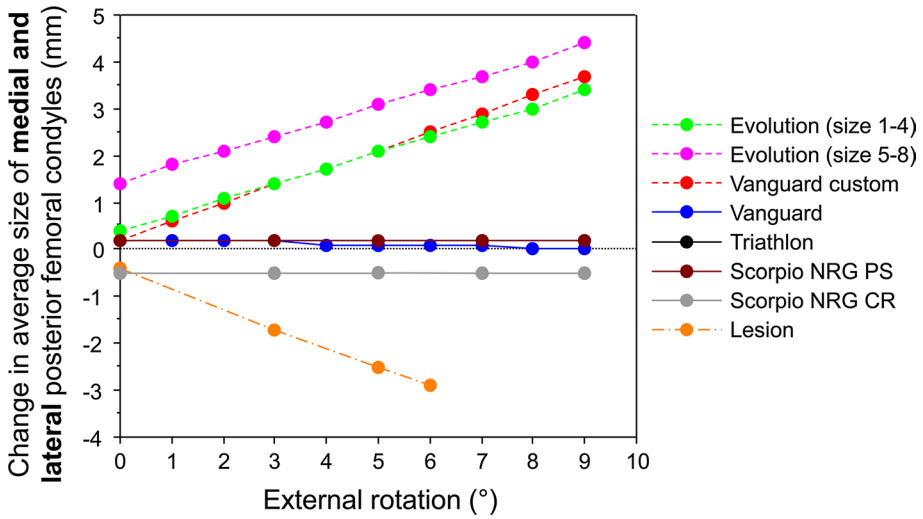

Fig. 7 The relationship between the change in average size of the medial and lateral posterior femoral condyles and the degree of the external rotation is shown. The *dotted line* represents the medial rotation type. The *solid line* represents the central rotation type. The *long dashed/short dashed lines* represent the lateral rotation type

posterior femoral condyles gradually decreased as the femoral component was rotated externally (long dashed/short dashed line in Fig. 7).

Discussion

The most important finding of the present study was that the rotation centre of the posterior reference guide affects the size of the femoral condyle. Even if the rotation was set at 0° external rotation, the bone resection thickness was not always equal to the thickness of the femoral component (Table 2). Some posterior reference guides were designed to make a thicker bone resection than the femoral component, and others were designed to make a thinner bone resection than the femoral component at 0° external rotation. It was because that each posterior reference guide was designed based on different concepts. Therefore, the size of the posterior femoral condyles increased in some prostheses but decreased in other prostheses. The difference in size changes between the prostheses was up to about 2 mm.

The types of posterior reference guides used influenced the posterior femoral condyle bone resection thickness. When the medial rotation type was used, the bone resection thickness in the posterior femoral condyle was constant on the medial side but decreased on the lateral side, as the femoral component was rotated externally. Thus, the medial rotation type posterior reference guide increased the average size of the medial and lateral posterior condyles, as the femoral component was rotated externally. When the central rotation type was used, the bone resection thickness in the posterior femoral condyle increased on the medial side but decreased on the lateral side, as the femoral component was rotated externally. When the lateral rotation type was used, the posterior femoral condyle bone resection thickness was constant on the lateral side but increased on the medial side, as the femoral component was rotated

externally. Thus, the lateral rotation type posterior reference guide decreased the average size of the medial and lateral posterior condyles, as the femoral component was rotated externally. The value of external rotation also influenced the bone resection thickness in the posterior femoral condyle. The more the femoral component was externally rotated, the more the difference in size changes of the medial and lateral posterior femoral condyles increased between prostheses (Figs. 5, 6, 7).

The advantage of this study is that we used the production drawings directly provided by the manufacturers. Therefore, theoretically, neither measurement errors nor surgical errors were present, and the measurements in this study were accurate and reliable.

Posterior femoral condyle bone resection thickness affects not only the size change of the posterior femoral condyle but also the size of the flexion joint gap. An increase in the anteroposterior dimension of the femoral condyle may cause an increase in femoral component size [12]. An increase in the femoral component size may result in mediolateral dimension overhang [2, 4, 15] and patellofemoral joint pressure [11]. Thicker bone resection of the posterior femoral condyle results in a larger flexion joint gap. Thinner bone resection of the posterior femoral condyle results in a smaller flexion joint gap. When the femoral component was set at 3° external rotation, Evolution (medial rotation type) increased the average size of the medial and lateral posterior femoral condyles by 2.4 mm, and Legion (lateral rotation type) decreased by 1.7 mm. Thus, the difference in the flexion joint gap between Evolution and Legion would be 4.1 mm, even in the same patients. When the femoral component was set at 6° external rotation, the difference of the flexion joint gap between the two prostheses was more distinct (6.3 mm) because the two prostheses had different types of posterior reference guides. The Evolution posterior reference guide is a medial rotation type and increased the average size of the medial and posterior femoral condyles as the femoral component was external rotated. However, the Legion posterior reference guide is a lateral rotation type and decreased the average size of the medial and posterior femoral condyles as the femoral component was external rotated. Therefore, to control the flexion joint gap, a different operative strategy should be adopted for each type of posterior reference guide. Resection of posterior cruciate ligament (PCL) increases the joint gap more in flexion than in extension by 3–4 mm [10, 16, 17]. Thus, in PCL substitute (PS) prosthesis, flexion joint gap tends to be larger than extension joint gap [10, 21]. For PS prosthesis, the medial rotation type posterior reference guide may be suitable, because it increases the size of femoral condyles and decreases the flexion joint gap. In PCL retaining (CR) prosthesis, flexion joint gap tends to be smaller than extension joint gap and PCL release is often necessary [17, 18, 21]. For CR prosthesis, the central or lateral rotation type guide is suitable, because it maintains or decreases the size of femoral condyles and maintains or increases the flexion joint gap.

The limitation of this study is that the instruments and components were not directly measured. Instruments and components, which surgeons use during operation, have some errors during the manufacturing process. This study did not consider such error.

Conclusions

The current study showed that posterior femoral condyle bone resection thickness is different for each posterior reference guide. The rotation centre of the posterior reference guides influenced the posterior femoral condyle bone resection thickness. The posterior reference guide design should be checked before use.

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