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Original Article

The Extramedullary Guide of the Proximal Tibia Resection Should be seen Straight in Front during Total Knee Arthroplasty

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Abstract If surgeons see the shaft of the extramedullary guide from lateral to the guide during preparation of the proximal tibia resection during total knee arthroplasty, the tibial component may be implanted in varus position in the frontal plane. In order to clarify the effect of the angle of the surgeons' sight relative to the sagittal plane and the posterior slope angle of the resected surface on varus position of the tibial component in the frontal plane, mathematical analysis was performed. Three-dimensional coordinate system was utilized so that the central axis of the tibial shaft on the Z-axis and the shaft of the guide were skew. The relationship between two lines was analyzed solving equations on three dimensional planes. When the posterior slope angle is 10°, and if surgeons see the shaft of the guide 10°, 20° and 30° lateral to the sagittal plane, and the shaft and the central axis of the tibial shaft would seem to be parallel, the true varus tilt angle of the shaft on the frontal plane is 1.8°, 3.7° and 5.8°, respectively. The extramedullary guide should be seen straight in front of the guide.

Key words: total knee arthroplasty, tibial component, posterior slope, guide

Introduction

The mean tibial posterior slope angle in the medial plateau has been reported to be between 10° and 14°[1)2)]. The tibial posterior slope varies among each individual, and the cutting angle should be determined in each case to avoid any mismatch of the patient's posterior slope of the tibia after implantation during total knee arthroplasty (TKA). In order to cut the proximal tibia with a posterior slope, the extramedullary guide which has a bone saw slot perpendicular to the shaft, should be tilt posteriorly in the sagittal plane. In the frontal plane, the tibial component should be inserted in the neutral alignment because varus tibial component alignment has increased odds of failure[3)~9)]. However, technical factors of varus tibial component have been still obscure. Our hypothesis was that one factor may be the pitfall of the alignment of the guide. Even though a shaft of the guide is thought to be set completely parallel to the central axis of the tibial shaft in the frontal plane, there is a possibility that tibial component is inserted in some degrees of varus or valgus malposition. Figure 1 demonstrates the relationship between the central

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axis of the tibial shaft (a rod that is placed perpendicular to the floor) and the shaft of an extramedullary guide that tilts posteriorly. When surgeons see the guide lateral to the sagittal plane, the rod and the shaft of the guide seem to be parallel (Fig. 1a). However, the shaft of the guide is tilted in varus position in the true frontal plane (Fig. 1b). Skew lines can be seen parallel in some conditions. The angles which surgeons see the extramedullary guide influence the varus / valgus position of the tibial component. In this study, mathematical analysis was performed in order to clarify the effect of the angle of the surgeons' sight relative to the sagittal plane and posterior slope angle of the resected surface of the proximal tibia on varus/valgus position of the tibial component in the frontal plane.

Methods

Three-dimensional coordinate system was utilized so that the rod (central axis of the tibial shaft) was on the Z-axis and

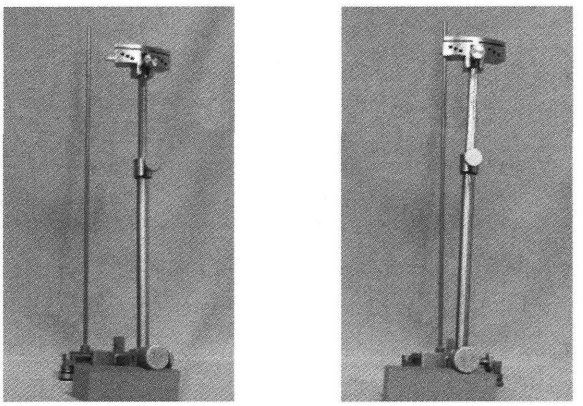

Fig. 1 View 30° lateral to the front of the extramedullary guide and the rod which demonstrates the central axis of the tibial shaft. In this angle, the rod and the shaft of the guide can be seen to be parallel (1a). In the true frontal plane, however, the shaft of the guide is tilt in varus position relative to the rod (1b).

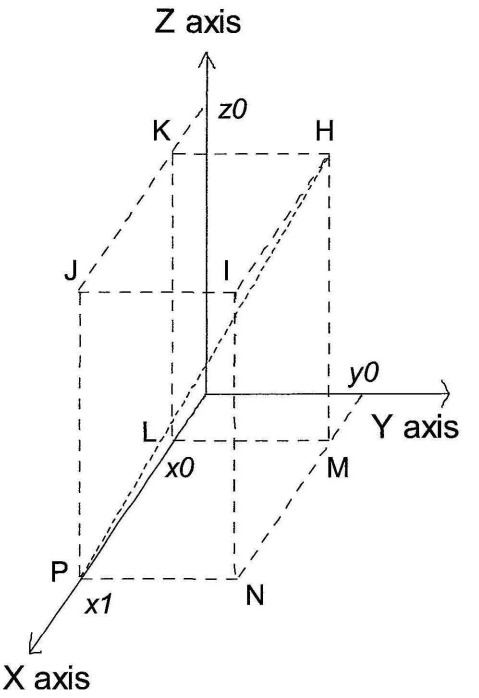

Fig. 2 In order to clarify the phenomenon in which two skew lines can be seen parallel, three coordinate system is utilized. The rod that demonstrates the central axis of the tibial shaft, is on the Z -axis. Line PH represents the shaft of the extramedullary guide. Z- axis and Line PH are skew. In some conditions, however, Z-axis and Line PH can be seen parallel.

posterior tilt of the shaft of the extramedullary guide without varus or valgus tilt was in the X-Z plane (sagittal plane) (Fig. 2). The Y-Z plane represents the frontal plane. The X-Y plane represents the axial plane. In the Fig. 2, Line PH represents the shaft of the extramedullary guide. Line PH (the shaft) and Z-axis (the rod) are skew. Angle of the posterior tilt of the shaft relative to the Z-axis in the X-Z plane is defined as a° (Fig. 3). This angle also represents the posterior slope angle of the resected surface. Angle of Line PH relative to the X-axis on

the X-Y plane is defined as b° (Fig. 3). This angle represents the angle of the surgeons' sight relative to the X-Z plane (sagittal plane). Tilt angle of the shaft relative to the Z-axis in the Y-Z plane is defined as q° (Fig. 3). This angle represents the varus angle of the shaft of the guide relative to the X-Z plane. In these conditions,

On the X-Z plane (Fig. 3),

$$\tan a^\circ = (x1-x0)/z0$$

$$z0 \times \tan a^\circ = (x1-x0) \qquad (1)$$

On the Y-Z plane (Fig. 3),

$$\tan q^\circ = y0/z0$$

$$y0 = z0 \times \tan q^\circ \qquad (2)$$

On the X-Y plane (Fig. 3), according to(1) and (2),

$$\tan b^\circ = y0/(x1- x0)$$

$$= (z0 \times \tan q^\circ)/ (z0 \times \tan a^\circ)$$

Therefore,

$$\tan q^\circ = \tan a^\circ \times \tan b^\circ$$

$$q^\circ = \tan\text{-}1 \ \{\tan a^\circ \times \tan b^\circ\}$$

Through solving the equation, relationship among three angles can be assessed. On the X-Y plane, if the angle of the surgeons' sight relative to the X axis is b°, the Z-axis (the rod) and the Line PH (the shaft) are seen to be parallel. However, the tibial component will tilt in q° in the frontal plane.

Results

When the posterior slope angle is 5°, if surgeons see the shaft of the guide in 10°, 20° and 30° lateral to the X-Z plane, and the rod and the shaft seem to be parallel, the true varus tilt angle of the shaft relative to the rod on the Y-Z plane (frontal plane) is 0.9°, 1.8° and 2.9°, respectively. When the posterior slope angle is 10°, the varus tilt angle of the shaft relative to the rod on the Y-Z plane was 1.8°, 3.7° and 5.8°, respectively.

Discussion

Posterior tilt of the tibial component is an important issue in order to obtain larger flexion angle, to obtain proper ligament balancing in flexion, and to achieve stable fixation of the tibial component in the cruciate retaining TKA[2)10)]. If the proximal tibia is cut without posterior slope in knees with 10° tibial posterior slope, the femorotibial joint will be too tight in flexion in the cruciate retaining TKA. The cutting angle of the proximal tibia should be decided based on the posterior slope angle of the each case.

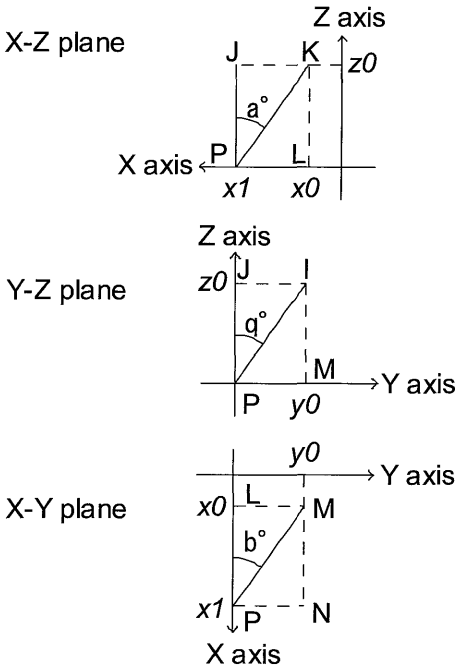

Fig. 3 In the X-Z plane, Line PK represents posteriorly tilt shaft of the extramedullary guide. The shaft is tilted at a°.
In the Y-Z plane, Line PI represents the shaft of the extramedullary guide. The shaft is tilted in q° varus position.
In the X-Y plane, Line PM represents the shaft of the extramedullary guide. b° is the angle of the lateral deviation of the surgeon's sight relative to the X-Z plane.

There is another method to cut the proximal tibia with some degree of posterior slope. An extramedullary guide which has a tilt slot can be used. The guide is set parallel to the anterior cortex of the tibial shaft. However, many kinds of guides with different tilt angle are necessary in this method. Therefore, it is easier for surgeons to tilt the extramedullary guide with the slot perpendicular to the tibial shaft posteriorly.

Varus tibial component position shifts the loading axis of the lower extremity medially, which may induce over-load in the medial compartment[3)~6)]. Varus tibial component position subsequently induce wear of ultra-high-molecular-weight polyethylene of the tibial insert[7)~9)]. Tibial component should be implanted, so it is not set in varus position.

Because the surgeon stands lateral to the patient during TKA, the surgeon can easily see the extramedullary guide from lateral to the front of the extramedullary guide (Fig. 4). If the proximal tibia is resected perpendicular to the long axis of the tibial shaft in the sagittal plane, the resected surface of the proximal tibia is perpendicular to the long axis of the tibial shaft in the frontal and sagittal planes, even though the surgeon sees the rod at any different angle on the axial plane. However, if the proximal tibia is resected with some degree of posterior slope, lateral deviation of the surgeon's sight from the front of the extramedullary guide may induce varus tilt of the resected surface of the proximal tibia. The larger the posterior slope is, the larger the effect of the lateral deviation of the surgeon's sight is. The results showed that when the posterior slope angle is set 10°, if surgeons see the shaft of the guide in 10°, 20° and 30° lateral to the sagittal plane, and the shaft of the guide is seen parallel to the tibial shaft, the tibial component may be in 2°, 4° and 6° varus position, respectively in the true frontal plane. During TKA, rotationally neutral position of the tibial component is decided based on the line from the attachment of the posterior cruciate ligament to the medial one-third of the tibial tuberosity[11)]. The extramedullary guide should be set perpendicular to this line in the axial plane, and the guide should be seen straight in the front.

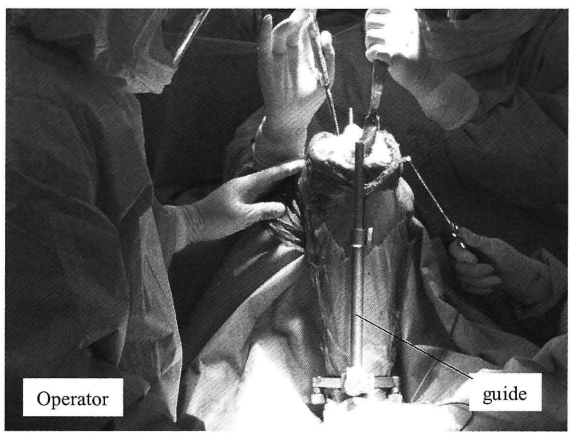

Fig. 4 The position of the operator during total knee arthroplasty is shown. The operator stands lateral to the extramedullary guide of the tibia resection. The surgeon can easily see the extramedullary guide from lateral to the front of the guide.

In addition to the posterior slope of tibial plateau, the center of the tibial articular surface may locate medial to the central line of the tibial shaft and / or the tibia may have medial torsion in Japanese patients with medial osteoarthritic knees[11)12)]. Especially, torsion of the tibia has a possibility to influence the surgeon's sight. If the second toe is used for the rotationally neutral position of the tibial component in case with tibial torsion, the cutting guide may not be set in the proper position because the proximal tibia faces another direction. The range between the direction of the ankle

and the one-third of the tibial tuberosity has been reported more than 50°[11]. These three anatomic variations of the tibia in each case should be taken into account in order to insert the tibial component in the proper position. Before TKA, the authors routinely take an anteroposterior view radiograph of the tibia with a K wire on the skin so that the K wire shows the central axis of the tibial shaft (Fig. 5a) and an anteroposterior view radiograph of the knee (Fig. 5b). A line is drawn on the skin along the K wire (Fig. 5c). If the fibular head in the anteroposterior view radiograph of the tibia shifts medial compared to that in the anteroposterior view of the knee, the tibia may have medial torsion (Figs. 5a and 5b)[11]. The line on the skin is also useful to set the shaft of the extramedullary guide parallel to the central axis of the tibial shaft (Fig. 5c).

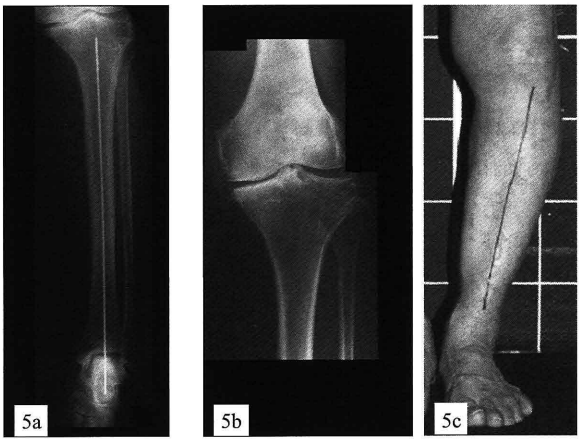

Fig. 5 Preoperative anteroposterior view radiographs of the tibia with a K wire that shows the central axis of the tibial shaft (5a) and of the knee (5b), and the line on the skin drawn along the K wire (5c) are shown. The fibular head shifts medial on the radiograph of the tibia compared to that on the radiograph of the knee. The tibial has medial torsion. The line on the skin is used to set the extramedullary guide parallel to the central axis of the tibial shaft.

In conclusion, the extramedullary guide with a bone saw slot perpendicular to the shaft should be seen straight in the front when the proximal tibia is cut with some degree of posterior tilt during total knee arthroplasty.

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(和文抄録)

人工膝関節置換術において，脛骨コンポーネント用髄外骨切りガイドは正面からみるべきである

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【目的】後十字靱帯温存型人工膝関節置換術では，各症例の脛骨関節面の後方傾斜にしたがって脛骨中枢の骨切りの後方傾斜角度を決定する．シャフトに垂直な骨切りスロットを持つ髄外ガイドを使用した場合，後方傾斜をつけるためにガイドを後方へ傾斜して設置するが，ガイドを外側から見た場合，ガイドが脛骨長軸に平行に設置されたと見えた場合でも実際は内反位に設置されている可能性がある．本研究では，術者がガイドを見る角度とガイドの後方傾斜角がガイドの内反傾斜角に与える影響を数学的に検討した．

【方法】3次元の座標を設定し，X軸は前方方向，Y軸は横方向，Z軸は縦方向とした．脛骨長軸をZ軸とし，髄外ガイドを示す線をZ軸とねじれの位置に引いた．ねじれの位置にある線をそれぞれ，X－Z面，Y－Z面，X－Y面上に投影した線を使用し，その線が各軸になす角を用いて，後方傾斜角（X－Z面上のZ軸に対する角），術者のX軸より外側へずれた視線の角度（X－Y面上のX軸に対する角）および正面から見た場合の髄外ロッドの内反角（Y－Z面上のZ軸に対する角）の3つの角の関係を方程式にて表現し，後方傾斜を設置し，術者の視線が10度，20度，30度外側へずれた際にねじれの位置にある線がZ軸と平行になる場合のガイドのZ軸からの内反角を算出した．

【結果】後方傾斜を10度つけた場合ガイドの正面から外側へ10度，20度，30度ずれてガイドを見てガイドが脛骨長軸と平行に見えた場合，実際にはガイドは内反し，その角度はそれぞれ1.8度，3.7度，5.8度であった．

【結論】シャフトに垂直な骨切りスロットを持つ髄外ガイドを後方傾斜をつけて設置する場合，術者は膝とガイドを正面から見るべきである．