Distance of the Femorotibial Joint Gap can be Controlled in the Modified Ligament Dependent Cut Procedure during Total Knee Arthroplasty

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Abstract During total knee arthroplasty in fifty consecutive cases, the distal femur and proximal tibia were initially cut. After posterior cruciate ligament excision, the femorotibial joint was expanded by a Tensor / balancer device with 30 inch-pounds of torque (in.lbs) both in extension and flexion, and ligament balancing was obtained in full extension. Then the knee was flexed at 90°, and the femoral rotational axis was decided so that the axis was parallel to the tibial cut surface and the joint gap was the same between extension and flexion. The relationship between the distance of the joint gap expanded by a Tensor / balancer device with 30 in.lbs and the size of the bearing insert was assessed. The results showed that a 24 or 25-mm joint gap expanded by a Tensor / balancer device in full extension was optimal for a 10-mm bearing insert. Therefore, if the resection level of the tibia is set 24 or 25 mm from the femoral cut surface, a 10-mm bearing insert can be used. In 49 cases, the size of the femoral component was one size (4 mm) larger than that predicted based on the bony structure shown in the radiographs of the knee. With this procedure, ligament balancing and optimal joint gap both in extension and flexion can be obtained based on the predicted bearing insert in the knee.

Key words : total knee arthroplasty, operative technique, ligament dependent cut

Introduction

Current operative techniques and designs of femoral and tibial components during total knee arthroplasty (TKA) have been established mainly based on the anatomic configurations of normal lower extremities in the United States and Europe. Current, the so-called independent cut procedure, which uses fixed bony landmarks for bone resection, is in wide use. However, anatomic configurations differ between osteoarthritic and normal knees, and fixed bony landmarks may not be reliable in osteoarthritic knees. Therefore, the advantages of the so-called ligament-dependent cut procedure may be re-evaluated during TKA. On the other hand, the distance of the femorotibial joint gap is consequently decided according to the resection levels of the femur and the tibia, with the extent of the ligament release. In this study, the distance of the joint gap expanded by a Tensor / balancer device was assessed, so that a predicted bearing insert could...
be used. Modification of the dependent cut procedure was then discussed.

**Materials and methods**

Fifty consecutive cases were assessed. Subjects included 32 females and 18 males. Thirty-eight patients had osteoarthritis and 12 patients had rheumatoid arthritis. The mean age was 72.5 years, mean height was 152.5 cm, and mean body weight was 53 kg. The mean extension angle and flexion angle were 13.5° and 108.8°, respectively. The posterior slope angle of the cut tibial surface was set at 7° for all cases. The modified ligament-dependent cut procedure was performed using the Zimmer LPS Flex Fixed system (Zimmer, Warsaw, IN, USA) in all cases. This system has a posterior stabilized mechanism. The operative technique is described. A Tensor/balancer device (Stryker Howmedica Osteonics, Allendale, NJ, USA) was used during TKA. In our preliminary study, optimal tension in pounds for the Tensor/balancer device was assessed. The collateral ligaments were not tensed with 20 inch-pounds of torque (in. lbs). The joint gap was about 2 mm wider with 40 in.lbs compared with that with 30 in. lbs. However, bone collapse was observed in some cases, when 40 in.lbs was applied, therefore, 30 in.lbs was applied in this study.

In each case, the distal femoral and proximal tibial cuts were performed perpendicular to the mechanical axis initially'. After the posterior cruciate ligament (PCL) excision, the tibial tray trial was set on the tibial cut surface. Osteophytes and the medial edge of the tibial condyle which was not covered with the tray were removed. The angular asymmetry was checked using the Tensor/balancer device with 30 in.lbs (Fig. 1a) both in extension and at 90° flexion. The medial ligament release was performed and the ligament balancing was obtained in full extension. The order is deep medial collateral ligament (MCL), superficial MCL (anterior and posterior fibers), pes anserinus, semimembranosus and medial head of the gastrocnemius. The angular asymmetry between the medial and lateral femorotibial joints was less than 2° in 39 cases and was 2° in 11 cases. Next, the distance of the femorotibial joint gap, which had been expanded using the Tensor/balancer device with 30 in.lbs (Distance G), was measured in millimeters (mm) (Fig. 1a).
Next, the femorotibial joint was expanded using the Tensor/balancer device with 30 in.lbs at 90° flexion (Fig. 1b). A line (Line P) was drawn on the cut surface of the femur so that Line P and the tibial cut surface were parallel and the distance between them was 2 mm longer than Distance G. Because the posterior flange of the femoral component in the Zimmer LPS flex fixed system is 1.5 mm thicker than the distal part, the flexion gap should be set 2 mm wider than the extension gap in order to obtain the same joint gap at extension and flexion. Line P was used to set the resection line of the posterior condyles. The anteroposterior (AP) size of the femoral component was determined based on the distance from the anterior cortex to Line P. The AP cut was then performed with the anterior reference technique.

The tibial bearing insert trial was inserted, and the optimal thickness of the tibial bearing insert was decided so that the knee could be fully extended and the manual varus and valgus stress expanded joint gap less than 2 mm or 2 mm. The relationship between Distance G and the thickness of the bearing insert used during the TKA was assessed. The size of the femoral component with this modified ligament-dependent cut procedure was compared with that based on the bony structure shown on AP and lateral radiographs of the knee. Two days after the TKA, the extension angle of the knee was re-evaluated. If the knee had extension disturbance more than 4°, the optimal articular surface was thought to be one size smaller.

Results

The angular asymmetry in flexion was more than 2° in six cases and these cases were excluded from this study. In other 44 cases, ligament balancing was obtained in flexion and the angular asymmetry was less than 2° or 2°. A 10-mm thick bearing insert was used in 30 cases, and Distance G was 24 or 25 mm in 26 cases. In one case, Distance G was 28 mm. This case was the only one in which the AP size of the femoral component was two sizes larger than the size predicted based on the bony structure shown on the radiographs of the knee. In this case, an additional tibial cut and posterior capsule release were performed, because the extension was disturbed. The popliteus tendon was also released. In other three cases, Distance G was 22 or 23 mm. Those three cases had flexion contracture more than 20° before the TKA, and the posterior capsule release and the excision of posterior osteophytes were necessary in order to get the full extension. Distance G after the posterior capsule release was 25 or 26 mm in these three cases.

A 12-mm thick bearing insert was used in 11 cases. However, three cases had 5° to 7° extension disturbance after TKA, and the thickness of the bearing insert was defined as 10 mm. Distance G was 25 mm in those cases. Distance G was 26 or 27 mm in the other eight cases. A 14-mm thick bearing insert was used in three cases in which Distance G was 29 – 31 mm.

In 49 cases, the AP size of the femoral component was one size larger than that based on the bony structure shown on the radiographs.

Discussion

The results showed that 24 or 25 mm of Distance G using a Tensor/balancer device with 30 in.lbs seemed optimal for a 10-mm bearing insert with the Zimmer LPS Flex Fixed system. This means that a 10-mm bearing insert will be used when the femor-
modified ligament dependent cut

otibial joint gap expanded by a Tensor / balancer device with 30 in.lbs is set at 24 or 25 mm. Based on this concept, the distance of the joint gap can be controlled both in extension and flexion during the modified ligament-dependent cut procedure. This method is called the “joint gap control procedure”. Operative techniques of this procedure for varus knee are described. A 10-mm thick bearing insert is usually used. Before TKA, a varus stressed AP radiograph is taken. On the radiograph, the predicted resection levels of the distal femur and the proximal tibia are marked, so that the distance between the two resection levels in the lateral femorotibial joint is about 27 mm (110% enlarged) (Figs. 2a and 2b). Because of loose lateral ligament, medial release is necessary in order to obtain the ligament balancing. Therefore, the thickness of the resected bone from the proximal tibia is not the same as the thickness of the tibial component.

During TKA, the modified ligament dependent cut procedure is performed. The resection level is determined according to the preoperative planning. If the resection level is decided according to the distal end of the destroyed medial femoral condyle, the resection level may be too proximal. After the proximal tibia is cut, angular asymmetry of the femorotibial joint is checked using a Tensor / balancer device with 30 in.lbs both in full extension and at 90° flexion. The medial ligament release is performed. The ligament balance in extension is obtained so that the angular asymmetry is less than 2° or 2°. The distance of the femorotibial joint gap is also measured, and the thickness of the bearing insert is predicted. If the joint gap is less than 24 mm, the additional cut of the distal femur or the proximal tibia may be necessary. Next, the femorotibial joint is tensed in 90° flexion, and the angular asymmetry is measured. The asymmetric angle is to be the external rotation angle of the femoral component relative to the posterior condylar line (Fig. 1b). Line P is drawn on the femoral cut surface so that the distance between Line P and the tibial cut surface is the same with the joint gap in extension. The most important advantage of this procedure is that the alignment and location of Line P can be assessed before the AP cut, referring the posterior condylar line, the epicondylar axis, and the AP axis. If Line P is located posterior to the femoral cut surface, the AP size of the femoral component will be too large. The distal femur is re-cut, and the smaller femoral component can be used. The joint gap in flexion can be controlled by using this method. This joint gap control procedure is totally different from classical ligament-dependent cut procedures12). In this procedure, the coronal alignment is decided according to the mechanical axis, and the axial alignment is decided according to both the ligament balancing and the anatomic landmarks. Current, commercially available Tensor / balancers are used only when the patella is everted. Further investigation of clinical results of TKA with the modified ligament dependent cut procedure is necessary.

The results of this study showed that the size of the femoral component is generally one size (4 mm) larger than the size based on the bony structure shown on the radiographs. Kadoya et al. reported that the flexion gap significantly increased in the medial and the lateral sides (4.8 mm and 4.5 mm, respectively) after the resection of the PCL13). The resection of the PCL induces wider joint gap in flexion. In the independent cut procedure, the size of the femoral
component may be too small for the posterior stabilized system, which has a risk of dislocation of the spine-cam mechanism. With the joint gap control procedure, the femorotibial joint at 90° flexion can be stably set.

If the AP size is too large, the larger femoral component may disturb full extension, because the posterior flange can impinge against the posterior structure of the joint. Therefore, if Line P is too posterior, then the distal femur should be re-cut, and a thicker bearing insert should be used. The resection level of the posterior condyles moves anteriorly, and the optimal size of the femoral component can be used.

So called posterior clearance which consists of excision of the PCL, posterior capsular release, removal of posterior osteophytes and removal of the posterior condyles that are not covered with posterior flange of the femoral component is still a controversial issue. If the knee had extension disturbance, the posterior clearance is necessary. After the posterior clearance, the distance of the femorotibial joint gap may be longer. Therefore, the posterior clearance should be performed carefully, and the joint gap should be re-checked using the Tensor / balancer device after the posterior clearance.

The femoral rotational axis should not be internally rotated relative to the posterior condylar line, because internal rotation of the femoral component can induce patellofemoral disorder. There are two factors that may induce internal rotation of the femoral rotational axis. The first is medial ligament release, which will rotate the femur around the central axis of the femur relative to the tibial cut surface when the knee is tensed (Fig. 3). The femoral rotational axis parallel to the tibial cut surface may internally rotate relative to the posterior condylar line in the ligament-dependent cut procedure. The second factor is the valgus position of the distal femoral cut. On the preoperative radiograph of the lower extremities, the angle between the line perpendicular to the mechanical axis and the tangent to the distal femoral condyles is defined as the femur resection angle (FRA). FRA is positive when the line perpendicular to the mechanical axis is internally rotated relative to the tangent. FRA is not only the resection angle of the distal femoral condyles but it is also the external rotation angle of the AP cut relative to the posterior condylar line if the ligament balancing is normal (Fig. 4). Therefore,
Fig. 3 Before (3a) and after (3b) medial release. In each scheme, the joint is tensed. In varus knee, after the medial ligament release, the tibia will rotate in the valgus position in the frontal plane in full extension. At 90° flexion, the femur will rotate externally around the central axis of the femur after the medial ligament release. As shown in Fig. 1, the angle between the tibial cut surface and the posterior condyle line is to be the external rotation angle of the femoral rotational axis relative to the posterior condylar line.

FRA should be positive so as not to internally rotate the femoral rotational axis (Fig. 5). In cases with lateral bowing of the femoral shaft, the distal femoral cut may not be set to be perpendicular to the mechanical axis, but, rather so that the femoral rotational axis is externally rotated relative to the posterior condylar line. With the joint gap control procedure, if Line P is still internally rotated relative to the posterior condylar line after the preparation of the distal femur, the distal femur can be re-cut in a more varus position.

In this study, patients who were relatively lightweight and small in size were assessed. In larger or heavier patients, the distance of the femorotibial joint expanded by the Tensor / balancer device may differ. Likewise, with a different TKA system, the distance may differ. The flexion contracture also influences the femorotibial joint gap.

However, Winemaker described an operative technique based on the same concept, in which both a posterior-stabilized or a posterior cruciate-retaining design is used16). The concept of the joint gap control procedure may be applied to any case.

**Conclusion**

The distance of the femorotibial joint expanded by a Tensor / balancer device can be determined so that a predicted bearing insert is used during total knee arthroplasty. Based on this concept, a modified ligament-dependent cut procedure was established. Ligament balancing and optimal joint gap at both extension and flexion can be obtained in any knee with this procedure.

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If FRA (femur resection angle) is negative, the resection line (broken line) is in too valgus position. The AP cut will rotate internally relative to the posterior condylar line in the ligament-dependent cut procedure in order to get the ligament balancing in flexion.

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References


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人工膝関節置換術において、改良型 ligament dependent cut 法により
関節裂隙の距離はコントロール可能である

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現在の人工膝関節置換術（以下，TKA）では
ligament independent cut 法が主流であるが，観
帯バランスが獲得できない症例もある。本研究で
は，観帯バランスを用いて開大した関節裂隙の
距離と使用した脛骨インサートの厚みの関係を調
査した。さらにその結果をもとに ligament
dependent cut 法の改良型に関して検討を加えた。
Zimmer 社 LPS PS システムを使用した 50 症例
において，術中，まず，大腿骨遠位および脛骨近
位を機能軸に垂直に切骨した。観帯バランスを
使用して，膝伸展位で観帯バランスを獲得し，裂
隙間の距離を計測，その距離を距離 G とした。次
に膝屈曲 90 度で裂隙を開大し，伸展位と同様の裂
隙を作成するように AP カットを行った。その後，
使用した脛骨インサートの厚みと距離 G の関
係を検討した。さらにレントゲン上から予想され
る大腿骨コンポーネントと実際に使用したサイズ
の関係に関しても検討を行った。

その結果，観帯バランスを用いて 30 インチポ
ンドにて開大した伸展位での裂隙の距離は，10
mm の厚みのインサートを用いる場合は 24～25
mm が最適であると判明した。本結果は逆に裂隙
を 24～25 mm に設定すると 10 mm のインサート
が使用可能となることを意味している。本コンセ
プトを用いると ligament dependent cut 法を改
良することが可能となる。

内側型変形性膝関節症に対する改良 ligament
dependent cut 法の手術手技を以下に示す。まず，
大腿骨遠位および脛骨近位を基本に機能軸に垂直
に切骨する。脛骨の切骨レベレは 24～25 mm に
なるように決定する。通常，外側の観帯が緩んで
いるため，内側の観帯剝離が必要になり，脛骨切
骨量は通常の手技で行われているコンポーネント
の厚み分より小さくなる。骨棘を切除後，脛骨切
骨面に脛骨トレイをのせてサイズを決定，トレイ
に覆われていない内側関頭も切除する。この時点で
観帯バランスを用いて 30 インチボンドで裂隙
を開大し，膝伸展位および屈曲 90 度での angular
asymmetry を計測する。この結果にて内側観帯剝
離の順序を決定するが，膝伸展位にて観帯バラン
スを獲得した後に伸展位での観帯間距離を計測す
る。次に膝屈曲にて angular asymmetry を計
測するが，この角度が AP カットの外旋度とな
る。さらに伸展位裂隙間距離を参考にしてコン
ポーネントのサイズを決定する。本手技の最も重
要な長所は AP カットの前に後方観切骨線の角
度と部位を評価できることである。本手技では前
額面アライメントは機能軸を基準に，回旋アライ
メントは観帯バランスと解剖学的ラシドマークを
参考に決定する。