ACTA
ORTHOPAEDICA
et
TRAUMATOLOGICA
TURCICA

Author's translation

Acta Orthop Traumatol Turc 2005;39(5):404-410

# The effect of open wedge osteotomy on the posterior tibial slope

## *Açık kama osteotomisinin posterior tibial eğim üzerine etkisi*

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**Amaç:** Proksimal tibial osteotomi alt ekstremitenin koronal plandaki dizilimini ve yük dağılımını değiştirerek etkili olan bir yöntemdir. Bununla birlikte, tibia üst uç osteotomisi sagital planda da değişikliklere neden olabilir. Bu çalışmada açık kama osteotomisinin sagital plandaki etkileri araştırıldı.

**Çalışma planı:** Osteoartrit nedeniyle proksimal tibial osteotomi uygulanan 20 kadın hastanın (ort. yaş 54.1; dağılım 43-64) 22 dizi çalışmaya alındı. Hastalara Puddu plağı kullanılarak açık kama osteotomisi uygulandı. Ameliyat öncesi ve sonrasında yan diz grafilerinde posterior tibial eğim açıları ölçülerek karşılaştırıldı. Ortalama izlem süresi 12.8 ay (dağılım 4-33 ay) idi.

**Sonuçlar:** Bütün hastalarda osteotomi hattı ortalama 10.8 haftada (dağılım 8- 14 hafta) kaynadı. On beş dizde ameliyat öncesindeki tibiofemoral eklem hareket açıklığı korundu; yedi dizde 5-10 derece arasında değişen hareket kaybı meydana geldi. Ameliyattan sonra üç hastada patellofemoral eklemde ağrı veya hareket kısıtlılığı şikayetleri görüldü. Düzeltme kaybı ve derin enfeksiyona rastlanmadı. Ameliyat öncesinde ortalama 7.2±4.1 derece olan posterior tibial eğim açısı, ameliyat sonrasında 3.5 derece artış göstererek 10.8±4.1 derece bulundu ($p<0.005$). Eğim açısında en çok artış, destek plağının osteotomi hattının daha ön kısmına yerleştirilmiş olduğu olgularda görüldü.

**Çıkarımlar:** Bulgularımız, açık kama osteotomisinin posterior tibial eğim açısını anlamlı derecede artırdığını gösterdi. Bu artışta, tibia üst ucunun üçgen şeklinde olmasının yanı sıra plağın şekli ve uygulama yerinin de etkisi olabilir. Plağın, osteotomi hattını arkadan öne doğru azalan yükseklikte tutacak şekilde düzenlenmesi, posterior tibial eğim açısındaki değişiklikleri azaltabilir.

**Anahtar sözcükler:** Kemik plağı; eklem instabilitesi/etyoloji; diz eklemi/radyografi; osteoartrit, diz/cerrahi/radyografi; osteotomi/yöntem; patella; tibia/cerrahi/radyografi.

**Objectives:** Proximal tibial osteotomy improves the alignment and weight distribution of the lower extremity on the coronary plane. However, upper end osteotomy of the tibia may cause changes in the sagittal plane. In this study, we evaluated open wedge osteotomy operations with regard to its effect on the sagittal plane.

**Methods:** The study included 22 knees of 20 female patients (mean age 54.1 years; range 43 to 64 years) who underwent proximal tibial osteotomy for osteoarthritis. Open wedge osteotomy was performed in all the patients with the use of a Puddu plate. Pre- and postoperative posterior tibial slope angles were measured on lateral radiographs. The mean follow-up period was 12.8 months (range 4 to 33 months).

**Results:** Union of the osteotomy line was obtained in all the patients in a mean of 10.8 weeks (range 8 to 14 weeks). While the tibiofemoral range of motion did not change in 15 knees, it decreased by 5 to 10 degrees in seven knees postoperatively. Complaints of pain or limitation of the patellofemoral joint were observed in three patients. No correction loss or deep infection developed. The mean posterior tibial slope angle showed a significant increase by 3.5 degrees, from preoperative 7.2±4.1 degrees to postoperative 10.8±4.1 degrees ($p<0.005$). The more anteriorly the plate was placed in the osteotomy line, the higher increase in the posterior tibial slope angle was noted.

**Conclusion:** These findings suggest that open wedge osteotomy results in a significant increase in the posterior tibial slope angle, which may be associated with the triangular shape of the upper end of the tibia, the design of the plate, and the site of plate application. The use of a plate with a decreasing height from posterior to anterior may decrease these changes in the posterior tibial slope angle.

**Key words:** Bone plates; joint instability/etiology; knee joint/radiography; osteoarthritis, knee/surgery/radiography; osteotomy/methods; patella/radiography; tibia/surgery/radiography.

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**Received:** 11.04.2005 **Accepted:** 04.08.2005

Osteoarthritis may be caused by knee ligament injuries (menisectomy, injury of the anterior cruciate ligament etc.) due to sports activities in the early ages, as well as being caused by degenerative factors in the elder ages. In the current practice, proximal tibial osteotomy is one of the most common methods used in osteoarthritis of the knee joint affecting only one compartment.[1-7] Although there are several different techniques, open and closed wedge osteotomies are more often used.[2,5,8-11] These osteotomies, essentially aim to transfer the weights on the knee joint to the less affected regions, by changing the alignement of the lower extremity on the coronary plane. Studies on this subject are mostly about sufficiency of these corrections.[3,4,9,10,12-15] However, depending on the technique used, some changes may also occur in the weight distribution on the saggital plane. These changes may cause some positive or negative effects, especially in patients having anterior or posterior cruciate ligament insufficiencies; and may result in stress condensation on the intact ligaments and new ligament lesions over the long term.[16,17] Furthermore; this increase of tibial slope should be taken consideration in the knee arthroplasty which is inevitable in some of these patients, in todays' tendency of minimal invasive surgery.[2,18,19] It has been reported that; in unicompartmental knee arthroplasty, a posterior tibial slope more than 7 degrees will expectedly cause some negative affects especially in the knees having anterior cruciate ligament (ACL) injury. [18]

Studies showed that high tibial osteotomies may result in a change in the tibial slope angle.[4] Changes in the posterior tibial slope angle (PTSA) also affect the relationship between patella and patellar tendon.[20] Triangular shape of the upper end of the tibia makes easier to occur the changes of PTSA on the undesirable plane. How much different techniques used in proximal osteotomy affect the proximal tibial slope angle is still a subject needing to be researched. According to our knowledge; number of the clinical and laboratory studies on changes in the tibial slope after the proximal tibial osteotomy is extremely limited.[16,17,21] We have encountered only one clinical study analysing affects of dome osteotomy. [21]

In this study we aimed to analyze the changes of PTSA in patients who have undergone open wedge osteotomy which is a common method of current practice.

## Patients and methods

Twenty-two knees of the 20 women (mean age 54.1; range 43 to 64 years) who were undertaken open wedge osteotomy between 2002 and 2004, because of osteoarthritis on the medial joint distance and had union on the osteotomy line with at least 4 months of follow-up period, were included in this


**Figure 1. (a**) Pre-operative and **(b)** post-operative lateral radiographs of 51 years old female patient who underwent proximal tibial osteotomy by open wedge osteotomy. Increase of PTSA is seen.

study. The cases who had undergone other osteotomies (closed wedge, dome osteotomy etc.), who had undergone a second operation for greft placement due to non-union, who had undergone another surgery because of a deep infection or cases having correction loss were kept out of the study. In four of the patients right knee was affected while in 14 of them left one was, in two of them both knees had the osteoarthritis.

Osteotomy was performed to the patients having osteoarthritis in the medial compartment accompanying varus deformity, not having flexion contracture, having at least 90 degrees range of motion. Medial tibia-femoral osteoarthritis was evaluated according to Ahlback radiographic classification system and all knees were classified as grade I and II. [22] Severe bone loss in femoral condyle or in tibial plateau and romatoid arthritis were accepted as contraindications for applying proximal tibial osteotomy.

**Figure 2.** Measuring of PTSA (α) on the lateral knee radiograph. PTSA was measured as an angle between the line of drawn perpendicular to the tangential line of posterior tibial cortex and the posterior tibial plateau angle.

AP standing radiographs of the both knees and lateral radiography at 30 degrees flexion of each knee were taken in all patients pre-operative period. In the orthorontgenography taken standing position, the line drawn from center of the femoral head has been extended to the 2/3 medial and 1/3 lateral intersection point on the plateau. A second line from the center of the ankle to the same point on upper end of tibia has been drawn and the angle between two lines has been measured and this value has been planned as the correction angle. An interval of 1 mm has been aimed for each correction of 1 degree. By this way; passing of the mechanical axis through approximately 1/3 lateral and 1/3 median intersection point of the tibial plateau has been provided after the correction.

**Surgical technique**

Antibitic proflaxy with first generation sephalosphorin which was initiated pre-operatively was carried out for 48 hours. Low molecule weight heparin was applied for tromboemboly proflaxy from the preoperative period till the tenth day of the postoperative period. Open wedge osteotomy was started with anteromedial longitudinal incision. Puddu plate (Arthrex, Munich, Germany) was applied with two cancellous and two cortical screws with help of C arm facility using Puddu surgical technique. Opening distance (Minimum 9, maximum 12.5 mm) was calculated pre-operative period. The space was filled with cancellous graft obtained from the iliac wing at the same side (Figure 1). While plaster splint has been used for 4 weeks in a patient having a nondisplaced fracture during operation on the lateral tibial plateau, elastic bandage and the mean pressured socks was used in other patients during the postoperative period. Passsive ROM exercises were begun as much as patient can tolerate with ice application and leg elevation at intervals. After 4 weeks' period, partial loading has been started. Once the consolidation occured, complete loading has been allowed.

Posterior tibial slope angle was determined as the angle between the line going perpendicular to the line passing tangent to the posterior tibial cortex and

the posterior slope of tibial plateau (Figure 2). These angles were measured in lateral knee graphies taken in the preoperative period and at last postoperative control after the union have completed. Values measured in the preoperative and postoperative periods were compared with the paired t-test. P<0,05 values were accepted as significant. Patients were examined for articular range of motion and patellofemoral pain in the last control and their satisfaction of the surgery were evaluated. Pain evaluation was performed by visual analogue scale (VAS). The mean follow-up period was 12.8 (range, 4 to 33) months.

## Results

Union of the osteotomy line was obtained in a mean of 10.8 weeks (range, 8 to 14 weeks). The mean posterior tibial slope angle was measured as 7.2±4.1 degrees in pre-operative radiographs and 10.8±4.1 degrees in post-operative radiographs. Post operative 3.5 degrees increase of tibial slope angle was statistically significant (p<0.005). The more anteriorly the plate was placed in the osteotomy line, the higher increase in the posterior tibial slope angle was noted.

Nondisplaced lateral plateau fracture occurred in one patient and superficial infection developed in another patient as complication. Infection was treated with sensitive parenteral antibiotic treatment without the need of surgical operation. Nondisplaced lateral plateau fracture which occurred during osteotomy procedure was fixed with long metaphyseal screws and extremity was kept in plaster cast for four weeks. Union was obtained without problem.

While the tibiofemoral range of motion did not change in 15 knees, it decreased by 5 to 10 degrees in seven knees post-operatively. Mild pain (VAS 2) was developed in one patient during stair claimbing. In one patient, mild complaint of pain (VAS 1) in pre-opertaive period increased (VAS 2-3) in post-operative period. In one patient limitation of patellafemoral joint mobility developed. No correction loss or deep infection was observed.

The patients were asked about their satisfaction of operation and it was found out that 12 knees were meaningfully better in comparison with the preoperative period. On the other hand, 10 patients did not feel significant difference.

## Discussion

A number of studies have shown that proximal tibial osteotomy is an affective and timebuying technique in selected cases having one-compartment osteoarthritis.[3-5,8,13,19,20,23] Even though proximal tibial osteotomy indications have been limited by the cause of good results obtained after total knee arthroplasty and developing of uni-compartment knee prosthesis in technical and conceptional terms; proximal tibial osteotomy is still the gold standart especially in young patients at whom osteoarthritis have affected one compartment. This technique, which figured out by various studies gives us the chance to gain a period of time from 6 to 15 years depending on the grade of the osteoarthritis, is of a great importance among today's treatment procedures without dispute.[4,13,15,19,20,24] Although the affect of the changes on coronary plane after proximal tibial osteotomy has been widely appraised, changes on sagittal plane and their affect in the conclusion has not been argued out sufficiently. Recently, studies which investigate the affects of the proximal tibial osteotomy on the proximal tibial slope angle have been published and it has been emphasized that proximal tibial slope angle is of great importance for stabilization of the knee.[16,17,21] Each increase of 10 degrees in tibial slope causes a 6 mm increase in the tibial translation.[16] It has been determined by Hernigou et al[4] that a complete correction in the coronary plane stops the progress of gonarthrosis while an insufficient correction is not able to stop the disorder. When considered the fact that changes in tibial plateau causes knee instability and tibial translation, changes which may occur on the saggital plane after proximal tibial osteotomy, although they basically were aimed at angular corrections on the coronary plane, may be another cause of osteoarthritis.

In patients who were planned to perform proximal tibial osteotomy, osteoarthrosis may be caused by degenerative osteoarthritis having an onset in elder ages, as well as it may be due to anterior cruciate ligament injury in the more active and younger patients. Impaired knee kinematic in patients with anterior cruciate ligament injury may be compensated to some degree by the rehabilitation of quadriceps and hamstring muscles. [25] However, the geometry of the knee joint and especially changes in tibial slope

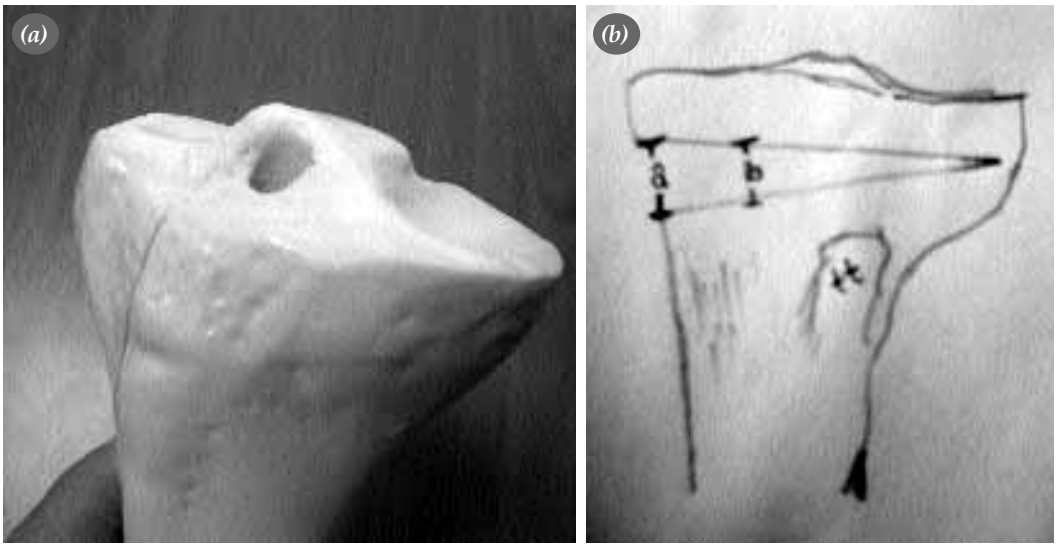


**Figure 3.** Upper end of the tibia resembles a triangle top of it at the tuberositas tibia. The change of opening distance on the medial side is seen from posteromedial corner to the anterior (tt: tuberositas tibia) by open wedge osteotomy.

have been affecting the tibial translation and the compensation of hamstring muscles very closely. Under these circumstances, proximal tibial slope angle becomes much more important. [18]

Increase of PTSA after open wedge osteotomy is related to the triangular shape of proximal tibia. In openings carried out in one plane by taking one of the corners of the triangle as a support, heights in other two corners can never be equal. Consequently the interval between the edge joining the two corners and the osteotomy line across will change from posterior to anterior and from lateral to median zone. In this case; osteotomy support plate placed in anteromedial zone may cause an increase in posterior tibial slope (Figure 3). Hernigou et al [4,27] have emphasized that in order to avoid some undesirable tibial slope changes, posterior edge of the wedge should be equal to the interval planned to be opened and that this interval should shorten while going towards the anterior. In our study, after open wedge osteotomy carried out by using standart Puddu plates, proximal tibial slope angle has significantly increased (means of PTSA were 7.2 degrees and 10.8 degrees in preoperative and postoperative periods sequentially). It is not possible to obtain planned opening when the plate at the desired height has been put in the middle of medial surface of the tibia. In order to minimize the changes in posterior tibial slope angle; as Hernigou et al[4,27] have emphasized, it is necessary to place the plate of required height as close as to the posterior medial corner as well as performing a complete posterior osteotomy.

In case normal PTSA decreases, tibia is expected to change position compared with femur towards posterior on coronary plane. Although this condition is to be preferred in cases having anterior cruciate ligament rupture, it will increase knee instability in cases posterior cruciate ligament injury. On the other hand; increase in tibial slope will cause forward translation of tibia and will extremely increase instability in patients having anterior cruciate ligament rupture. Giffin et al [17] revealed the effects of tibial slope on the knees having ligament lesion by a biomechanic study. Having these findings, osteotomy methods in knees with ligament lesion should be planned according to the nature of lesion. That potential of changing in proximal tibial slope angle is a property that can also be used to decrease the instability of the knee with ligament injury. It has been announced that open wedge osteotomy carried out with cruciate ligament reconstruction gives successful results in providing knee stability, decreasing pain and stopping osteoarthritis in early phases.[28]

Unavoidable fate of some of the cases to which proximal tibial osteotomy was applied, is total knee arthroplasty. Vainonpaa et al[19] have declared that, 16 (15.5 %) out of 103 patients who underwent proximal tibial osteotomy needed total knee arthro-

plasty, at average of 7.6 years after osteotomy. In the study of Kaper et al,[20] total knee arthroplasty was applied to 23.9% of the cases. Increased PTSA is of great importance when planning knee arthroplasty following proximal tibial osteotomy. Because it is known that increase of PTSA causes forward translation of the tibia in the even normal knees.[16] This situation may cause earlier arthrosis and deeper bone tissue loss, due to focusing of the load in a particular region. Truly, in knees with high PTSA, bone tissue loss of tibial plateau is more often seen in posterior part.[4] Furthermore; in patients, who have undergone the surgery of total knee arthroplasty, though excessive tibial slope can be corrected with the cut through performed for prosthesis, additional ligament lesions will possibly develope in the knees undergone excessive translation, are a subject which merits to be researched. [4,20]

Changes between patella and patellar tendon after proximal tibial osteotomy have been known. [29,30] Scuderi et al [29] established that in 89% of 66 knees, which had undergone proximal tibial osteotomy, patella height has decreased. Kaper et al [20] showed that changes in PTSA may cause "patella baja". Also in this study three patients complained of limitation of motion or pain of patellofemoral joint. Although patellofemoral complaints are not absolute contraindications, it must be kept in mind that these problems might occur after osteotomy.

Findings of our study confirm that increase in PTSA occurs after proximal tibial osteotomy. In open wedge osteotomy procedures, placing of the support plate in the way to open the posteromedial edge of tibia in the planned amount can prevent undesirable sagittal plane abnormalities. Furthermore, the arrangement of the plate as it will keep the osteotomy line in a height that decreases from posterior to anterior might also be effective. Changes in the sagittal plane may decrease the effectivity of the present osteotomy as well as later surgeries. Longer-term clinical studies which are focused on sagittal plane changes are needed in order to put forward this point certainly.

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