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Assessment of the vulnerability of the proximal tibiofibular joint to injury during osteotomies

Osteotomilerde proksimal tibiofibular eklemin yaralanma riskinin değerlendirilmesi

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Amaç: İnsan kadavra ve amputat dizlerinde proksimal tibiofibular eklemin (PTFE) boyutları ve anatomik konumu ölçülerek değerlendirildi. Proksimal tibia medial açık kama osteotomisi (PT-MAKO) uygulanmış hastaların diz grafilerinde, osteotomi hattı ile PTFE arasındaki ilişki ve osteotomilerde PTFE'nin yaralanma riski değerlendirildi.

Çalışma planı: Çalışmanın birinci aşamasında, altı insan kadavra tibiası ile altı taze amputasyon materyalinde (4 kadın, 8 erkek; ort. yaş 57), PTFE'nin lateral tibial kondille fibula başı arasındaki tibial bölümünün boyutları dijital kompas ile ölçüldü ve eklemin tibial yüzünün lateral tibia platosu posterior bölümüyle ilişkisi değerlendirildi. İkinci aşamada, PT-MAKO uygulanmış ardışık 44 hastanın (6 erkek, 38 kadın; ort. yaş 51) 46 dizine ait ön-arka, yan ve iç oblik grafilerde osteotominin PTFE ile ilişkisi değerlendirildi.

Sonuçlar: Anatomik ölçümlerde, PTFE'nin tibia kondilinin posterolateralindeki kısmının elipsoid görünümlü eklem yüzünün uzun ekseninin ortalama 18.8 mm (dağılım 13 mm-20 mm), kısa ekseninin ortalama 14.9 mm (13 mm-17 mm) olduğu; eklem üst sınırının, lateral tibia platosu eklem yüzü posterior kenarından ortalama 6.3 mm (2 mm-11 mm) aşağıdan başladığı saptandı. İç oblik grafilerde, PTFE'nin proksimal yerleşimli olduğu olgularda, özellikle lateral korteks devamlılığı bozulan üç dizde (%6.5) osteotomi hattının PTFE'ye uzandığı gözlendi.

Çıkarımlar: Oblik grafiler çekilmeden ve lateral tibia platosuna ait eğime paralel olarak yapılmayan osteotomi hattının posterolateral bölümü PTFE içerisine yönlenebilir. İyi değerlendirilmeden yapılan PT-MAKO uygulamalarında, lateral korteksin kırılması PTFE'ye hasar riskini artırmaktadır.

Anahtar sözcükler: Kadavra; fibula/anatomi ve histoloji; diz eklemi/cerrahi; osteoartrit; osteotomi/yöntem; tibia/anatomi ve histoloji.

Objectives: We evaluated the dimensions and anatomic localization of the proximal tibiofibular joint (PTFJ) in human cadaver and amputated knees. In addition, we assessed the relation between the osteotomy line and the PTFJ and its vulnerability to injury on radiographs of patients after proximal tibial medial open wedge osteotomy (PT-MOWO).

Methods: In the first phase, dimensions of the tibial part of the PTFJ lying between the lateral tibial condyle and the fibular head were measured by digital calipers in six human cadaver and six fresh amputed tibiae (4 females, 8 males; mean age 57 years) to evaluate the relation between the tibial surface of the PTFJ and the posterior part of the lateral tibial plateau. In the second phase, anteroposterior, lateral, and medial oblique radiographs were assessed with respect to the relation of the osteotomies with the PTFJ following PT-MOWO in 46 knees of 44 consecutive patients (38 females, 6 males; mean age 51 years).

Results : On cadaver and fresh amputation materials, the mean long and short axis dimensions of the ellipsoidal articular surface of the PTFJ in the posterolateral aspect of the tibial plateau measured 18.8 mm (range 13 mm to 20 mm) and 14.9 mm (13 mm-17 mm), respectively. The upper articular border lied at a mean of 6.3 mm (2 mm to 11 mm) distal to the posterior border of the articular surface of the lateral tibial plateau. Medial oblique radiographs showed that the osteotomy line extended to the PTFJ in cases in which it was proximally located, particularly in three cases (6.5%) where lateral cortex continuity was interrupted.

Conclusion: The osteotomy line may encroach upon the PTFJ unless preoperative oblique radiographs are evaluated and a parallel course to the tibial slope of the lateral tibial plateau is followed. In addition, insufficient evaluation of PT-MOWO candidates may result in damage to the lateral cortex, which increases the risk for injury to the PTFJ.

Key words: Cadaver; fibula/anatomy & histology; knee joint/surgery; osteoarthritis; osteotomy/methods; tibia/anatomy & histology.

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Proximal tibial osteotomy is a surgical method which has been accepted and commonly used in the treatment of medial unicompartmental osteoarthrosis in the presence of axial malalignment, particularly in young and active patients.[1-10] Valgus corrective osteotomy of proximal tibia can be carried out by eather lateral closing wedge,[1,6,8,11-15] "dome" (barrel vault)[8,16-18] or medial opening wedge[2-7,9,10,18-27] osteotomies. The most commonly used procedure is closing wedge osteotomy.[1,6,8,11-15] However, one of the complications of this method is fibular (peroneal) nerve injury due to fibular osteotomy.[1,8,11,13-15,28] Dome osteotomy, which Maquet[17] made widespread, may also lead to fibular nerve injury during fibular osteotomy or the insertion of Steinmann pins or fibular nerve paralysis may develop due to anterior compartment syndrome.[8,16-18] Proximal tibia medial opening wedge osteotomy procedure, which is gradually becoming common, has minimum or no risk of fibular nerve injury since there is no need for fibular osteotomy.[2-7,9,10,19-21,23-27]

Dimensions and anatomic localizations of the proximal tibiofibular joint (PTFJ) in human cadaver and amputated knees were measured and evaluated in the present study. Relation between the osteotomy line and the PTFJ and its vulnerability to injury was assessed on radiographs of patients who had undergone proximal tibial medial opening wedge osteotomy (PT-MOWO).

Materials and methods

The study was performed in two phases. In the first phase, dimensions of the tibial part of the PTFJ and the distance of the upper border of this joint to the posterior border of lateral tibial plateau were measured by digital calipers.

In the second phase, anteroposterior, lateral, and medial (internal) oblique radiographs of 46 knees belonging to 44 consecutive patients who had undergone PT-MOWO were assessed.

Anatomic study

Tibial part of the PTFJ between posterior part of the lateral tibial plateau (condyle) and the fibular head were evaluated in six human cadaver and six fresh amputated tibiae (4 females, 8 males; mean age 57 years; range 40-72 years). Measurements were carried out by digital calipers of 0.01 sensitivity.

Clinical assessment

Between December 2001 and April 2005 PT-MOWO was applied to 46 knees of 44 consecutive patients who had medial compartment osteoarthrosis (38 females, 6 males; mean age 51 years; range 36-66 years) with axial malalignment. The surgery was performed bilateral in two female patients.

Plates with wedge-shaped triangular parts and with 5-15 mm wedge heights on the bone contact part, designed and developed by the first author (Hipokrat/Turkey, TR2002 02021Y) were used for fixation in order to prevent a future collapse and to support the osteotomy surfaces from inside.[19]

Surgical technique

The surgical technique[19] was applied regarding the recommendations of the authors who apply medial opening wedge osteotomy.[2,3,20,25]

After exploring the proximal part of tibia, the osteotomy line, varying according to patient's height and tibia length, was determined under C-arm of the image intensifier (fluoroscopy) control. This line was planned to start 3-4 cm distal to the articular surface of medial tibial plateau, passing superior to the attachment point of the patellar tendon to the tibial tubercle, and extending superolaterally to the point 1-1.5 cm distal to the articular surface of lateral tibial plateau and 1 cm medial to lateral tibial cortex. If appropriate, two or three more K-wires (Kirschner wires) were sent considering the posterior slope. The K-wires were sent considering the PTFJ position, shown in routine medial (internal) oblique radiographs prior to surgery to assess PTFJ, and the posterior slope. If the proximal tibiofibular joint is too close to the posterior border of the articular surface of lateral tibial plateau, K-wires sent without considering the slope on sagittal plane came too close to the posterior part of lateral tibial plateau. In such cases osteotomy was not performed in the direction of the tip of the fibular head, but was drifted more distally (to the level of the PTFJ). If the direction of the guide wires was considered appropriate under C-arm of the image intensifier (fluoroscopy) control, anterior, medial and posterior cortices were cut with a thin and narrow ended osteotome under these wires. Then the osteotomy line was distracted and plate(s) with wedges with was(were) used in appropriate heihgt.[19,29] Fibular osteotomy was not performed in any of the patients.

Results

Anatomic measurements

Assessment on cadaver and amputee knees showed that the long axis of the ellipsoid-shaped articular surface of PTFJ in the posterolateral aspect of the lateral tibial plateau (condyle) was 18.8 mm in average (range 13 mm-20 mm), and the short axis was 14.9 mm in average (range 13 mm-17 mm); and that the upper end of the joint started in average 6.3 mm (range 2 mm-11 mm) below (distal) the posterior edge of the articular surface of lateral tibial plateau (Figures 1 and 2). Distance between the widest points of medial and lateral tibial plateaus of these bone samples were 78 mm in average (range 67 mm-89 mm).

Clinical results

Assessment of direct radiographs of patients revealed that, depending on the posterior slope and the inclination of the posterior part of lateral tibial plateau at transition to the metaphyseal region, PTFJ seen more distal of the articular surface of lateral tibial plateau on anteroposterior radiographs was seen close to the posterior border of the articular surface of lateral tibial plateau on medial (internal) oblique radiographs (Figure 3). It was shown that particularly while planning osteotomy line for PT-MOWO the rule "1-1.5 cm distal of the articular surface of lateral tibial plateau and 1 cm medial of lateral cortex" is not always applicable, and that it is not always possible to send the lateral part of the guide wire to the tip of the

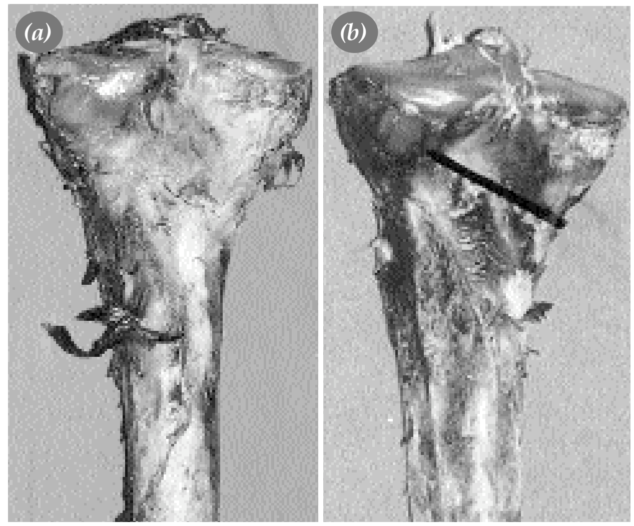

Figure 1: **(a,b)** Relationship between proximal tibiofibular joint (PTFJ) and the posterior border of the articular surface of lateral tibial plateau on two left cadaver proximal tibia sample. (b) On left cadaver proximal tibia, due to the proximity of tibial part of PTFJ and posterior edge of lateral tibial plateau, classical osteotomy line (shown as bold black line) on mediolateral plan according to the "1-1.5 cm distal of the articular surface of lateral tibial plateau and 1 cm medial of lateral cortex" rule apparently entering into PTFJ.

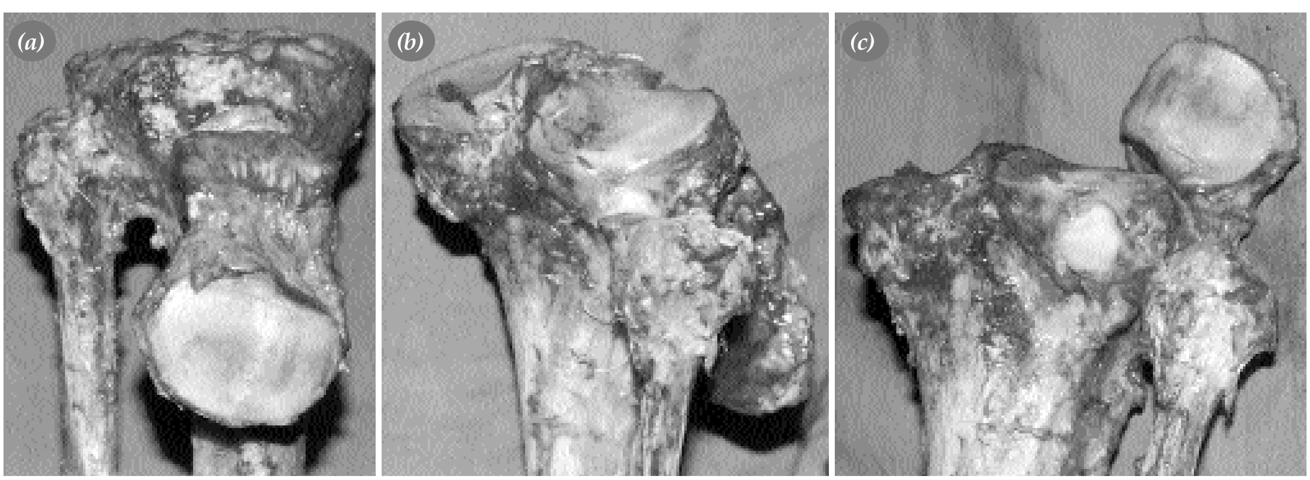

Figure 2. Relationship of proximal tibiofibular joint (PTFJ) and in particular its tibial part with lateral tibial plateau: **(a)** Fibular head located more distally in comparison with the upper articular border of lateral tibial plateau on anteroposterior plan. **(b)** On posterolateral view, proximity of PTFJ to posterior border of lateral tibial plateau due to the lateral tibial plateau slope and the inclination on transition to metaphyseal region (after separating of PTFJ). **(c)** Proximity of tibial part of PTFJ to the posterior border of lateral tibial plateau evaluated from posterior (after separating of PTFJ and pulling proximal fibula to lateral).

Figure 3. The tip of the fibular head seen below (distal) lateral tibial plateau on **(a)** anteroposterior radiograph, is seen closer to posterior border of the articular surface of lateral tibial plateau on **(b)** lateral or **(c)** medial (internal) oblique radiographs, due to the tibial slope (inclination to posterior). **(b)** Medial plateau seen with relatively sharp corner on lateral radiograph is conforming to inclined and round posterior border of lateral plateau.

fibular head due to the proximity to the joint and the risks involved. It was shown that, if it was performed without taking medial (internal) oblique radiographs and not parallel to the lateral tibial plateau slope (posterior slope), the lateral part of the osteotomy line may go into the joint.

Osteotomy applied below guide wires sent towards the tip of the fibular head in knees where upper border of PTFJ was close to posterior border of the articular surface of lateral tibial plateau on medial (internal) oblique radiographs (in PTFJ cases considered to be located proximally), was stated to get too close to tibial plateau on posterior. But if the osteotomy was applied on distal, osteotomy line was entering PTFJ in three knees of three patients (6.5%) especially with deformed continuity of lateral cortex (Figure 4).

Even in osteotomies definitely applied under C-arm of the image intensifier (fluoroscopy) control and

Figure 4. **(a-c)** Views of three cases of osteotomy line entering proximal tibiofibular joint on medial oblique radiographs.

without extending lateral cortex, nondisplaced lateral cortex fracture was observed on anteroposterior radiographs in 11 knees (23.9%). In these knees where the osteotomy line was extending the lateral cortex (osteotomy line extended to lateral cortex), there was no need for lateral fixation considering that periost and surrounding soft tissues remained intact since no separation or step-off of lateral cortex continuity was observed especially on internal oblique radiographs.[19,29] In three knees especially with interrupted lateral cortex continuity where osteotomy was applied more distal due to proximity of PTFJ and the posterior border of the articular surface of lateral tibial plateau, the osteotomy line was observed to be extending to PTFJ on medial (internal) oblique radiographs (Figure 4).[19]

Discussion

Commonly applied closing wedge osteotomies above tibial tubercle[1,6,8,11-15] require fibular osteotomy or division of PTFJ, and generally carry the risk of fibular (peroneal) nerve injury.[1,8,11-15,28] Also in dome osteotomy, particularly during fibular osteotomy and the placement of Steinmann pins, damage of motor, sensorial or both functions of fibular nerve were reported with a high rate of 27%.[16]

A two-dimensional correction can be provided by the PT-MOWO procedure which becomes more and more widespread.[21,23] An application starting approximately 3.5-4 cm distal of medial joint articular surface, passing superior to the attachment point of the patellar tendon to the tibial tubercle, reaching 1-2 cm distal of lateral joint articular surface towards the fibular head or the tip, leaving an intact bone of 0.5-1 cm is generally recommended by several authors for the selection of the osteotomy line.[2,3,19,20,25] Medial opening wedge osteotomy does not require fibular osteotomy. Fibula and tibiofibular joint are not damaged, therefore it involves no or minor risk of fibular nerve paralysis.[2-7,9,10,19-21,23-27] Lateral cortex is left intact in order to benefit from its hinge effect during the osteotomy.[3-5,7,9,10,18-20,22,23,26,29] However, Hernigou et al.[3] reported a fully recovered fibular (peroneal) nerve paralysis in one knee in their study including 93 open wedge osteotomy cases. Nakamura et al.[18] indicated fibulectomy in order to protect the fibular nerve, to prevent from any discordance in PTFJ due to the proximal displacement of the fibular head, and to prevent irregularity in the joint relation in cases with hemicallotasis requiring a correction of more then 15 degrees. Sangwan et al.[9] applied external fixator following osteotomy to 40 knees and reported osteotomy or excision to fibula in two of them. We do not apply fibular osteotomy. However, we determined on internal oblique radiographs that the osteotomy line was extending to PTFJ in three knees especially with interrupted lateral cortex continuity in cases showing proximal located PTFJ (knees with close relationship of PTFJ upper border to posterior border of the articular surface of the lateral tibial plateau) (Figure 4).

Our clinical assessment revealed that the fibular head, seen more distally compared to upper border of the joint surface of the lateral tibial plateau on anteroposterior plan, can be close to posterior border of the joint surface of the lateral tibial plateau on medial (internal) oblique radiographs due to the posterior slope on lateral plateau and the inclination on transition of lateral plateau from articular surface to metaphyseal region (Figure 3). This closeness is varying depending on the inclination angle (slope) of lateral tibial plateau. In cases with high inclination angle, the tip of the fibular head can be close to posterior border of the joint surface of the lateral plateau on medial oblique radiographs even if the tip of the fibular head is seen more distally compared to upper border of the joint surface of the lateral tibial plateau on anteroposterior radiographs. In cases with low inclination angle and proximally located PTFJ, the fibular head is seen closer to upper border of the joint surface of the lateral tibial plateau on anteroposterior radiographs. Particularly in these patients, no sufficient bone stock is left between joint surface and the tip of the fibular head if the osteotomy line is applied towards the tip of the fibular head. Despite the low number of samples, we determined in our anatomical study that the tibial part of PTFJ was very close to posterior border of the joint surface of the lateral plateau (Figures 1 and 2). This distance was 2 mm in the knees of two patients. Considering that osteotomy below the guide wires directed towards the tip of the fibular head could come too close to the posterior part and border of the joint surface of the lateral plateau, we applied a more distal osteotomy.

PTFJ covered with a synovial membrane is a sliding joint. It is frequently communicated with the knee joint (10%-14%).[30-33] Bozkurt et al.[30] determined this rate as 64.3% in their study on cadavers and defined it as the fourth compartment of the knee. Proximal tibiofibular joint is dissipating the torsional stresses applied at the ankle and the lateral tibial bending moments, and is more under the impact of tensile forces rather than compressive forces during weight-bearing. Approximately one-sixth of the static load applied at the ankle is transmitted to the fibula.[32] Takebe et al.[34] reported that, according to the position of the ankle, 2.3%-10.4% of the load can be transmitted to the fibula. This load can vary depending on the inclination angle (slope) of the proximal tibiofibular joint;[34] knee and ankle movements allow a limited mobility of PTFJ.[32,35] Degenerative changes are common in this joint, too.[31,33,36] If lateral cortex fracture occurs, it can extend into PTFJ in PT-MOWO without carefully assessment of pre-operative radiographs. If the PTFJ is penetrated during the osteotomy in such applications, it should be kept in mind that, due to the characteristics of this joint, the injury occurred may lead to degenerative changes later on. On the other hand, Jerosch et al.[37] indicated that due to the suitability of the cartilage tissue of PTFJ, this area may be used as a donor site in mosaicplasty surgeries (autologous osteochondral transplantations), they did not experience any problems in the early follow-up of their low number of patients. Although there is no clinical finding on PTFJ region in our patients at the moment, long-term follow-ups will guide us in that issue. On the other hand, in osteotomies with lateral cortex fracture accompanied by penetration of PTFJ, there is no displacement despite lateral cortex fracture. We suppose that this displacement does not occur due to the compressive effects of the capsule and the ligaments surrounding the joint.

In conclusion, while planning osteotomy line for PT-MOWO the rule "1-1.5 cm distal of the articular surface of lateral tibial plateau and 1 cm medial of lateral cortex" is not always applicable, and it is not always possible to send the lateral part of the guide wire to the tip of the fibular head due to the proximity to the joint. Posterolateral part of the osteotomy line planned without taking medial (internal) oblique radiographs and not applied parallel to the slope of lateral tibial plateau may be directed towards the joint. In PT-MOWO applied without carefully assessment, if lateral cortex fracture occurs, it can extend into PTFJ.

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