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Fixation of proximal tibia medial opening wedge osteotomy using plates with wedges

Proksimal tibia medial açık kama osteotomisindekamalı plak uygulaması

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Amaç: Proksimal tibia medial açık kama osteotomisinde tespit için kamalı plak uygulamasında endikasyonlar, cerrahi teknik ve sonuçlar değerlendirildi.

Çalışma planı: Medial kompartman osteoartrozu olan ardışık 38 hastanın (5 erkek, 33 kadın; ort. yaş 51; dağılım 36-65) 40 dizine proksimal tibia medial açık kama osteotomisi uygulandı. Tüm dizlere artroskopi uygulandıktan sonra, medial eklem aralığının 3-4 cm distalinden laterale ve proksimale doğru oblik bir hat üzerinden osteotomi uygulandı; lateral korteks kesilmemeye çalışıldı; tespit için tasarımı yazar tarafından yapılan, osteotomi yüzeylerini plak üzerindeki kama şeklindeki çıkıntılarla destekleyen plaklar kulanıldı. Plaklar 2 ve 4 delikli dikdörtgen ile 4 delikli ters "L" şeklinde idi; kama yüksekliği 5-15 mm arasında değişmekteydi. Plaklar, üzerindeki deliklere tam uyum sağlayan vidalarla sabitlendi. Greft olarak sekiz dizde trikortikal, 25 dizde bikortikal iliyak kemik otogrefti, yedi dizde allogreft kullanıldı. Klinik ve fonksiyonel değerlendirme HSS puanlama sistemine göre yapıldı. Ortalama izlem süresi 17 ay (dağılım 9-36 ay) idi.

Sonuçlar: Ameliyat öncesinde ortalama 4.3° (0°-10°) varus olan tibiofemoral açı, son kontrolde 5.8° (3°-11°) valgus olarak ölçüldü. Ameliyat öncesinde ortalama 59 (dağılım 52-75) olan HSS skoru ameliyat sonrasında 90 (dağılım 79-96) bulundu. Komplikasyon olarak, ameliyat sırasında üç dizde (%7.5) lateral plato kırığı, 11 dizde (%27.5) yer değiştirmemiş lateral korteks kırığı oluştu. Bir hastada (%2.5) yara iyileşmesinde ve kaynamada gecikme ve distal vidalardan birinde kırılma görüldü.

Çıkarımlar: Tek kompartman tutulumlu dizin medial osteoartritinde, proksimal tibia medial açık kama osteotomisinin tespitinde kamalı plak kullanılması, elde edilen düzeltme derecesini korumakta ve fonksiyonel rehabilitasyon için erken harekete izin verecek yeterli stabiliteyi sağlamaktadır.

Anahtar sözcükler: Diz eklemi/cerrahi/radyografi; osteoartrit/cerrahi; osteotomi/yöntem/enstrümantasyon; tibia/cerrahi/ radyografi.

Objectives: The indications, surgical technique, and the results of fixation using plates with metal wedges were assessed in proximal tibia medial opening wedge osteotomy.

Methods: Forty knees in 38 consecutive patients (5 men, 33 women; mean age 51 years; range 36 to 65 years) with medial compartment osteoarthritis of the knee were treated with proximal tibia medial opening wedge osteotomy using plates with wedges. Following arthroscopic debridement, medial proximal tibial osteotomy was performed laterally and proximally on an oblique line and 3-4 cm distal to the medial joint space. Disruption of the lateral cortex was avoided. Fixation of the osteotomy was performed using plates with wedges. The plates which were designed by the author were either rectangular in shape with two or four holes or had an inverse "L" shape with four holes, bearing metal wedges at varying heights from 5 to 15 mm. The plates were fixed with screws. Tricortical (n=8) or bicortical (n=25) iliac bone autografts and allografts (n=7) were used. Clinical and functional evaluations were made using the HSS scoring system. The mean follow-up was 17 months (range 9 to 36 months).

Results: The mean preoperative and postoperative tibiofemoral angles were 4.3° varus (0°-10°) and 5.8° valgus (3°-11°), respectively. The mean HSS score increased from 59 (range 52 to 75) preoperatively to 90 (range 79 to 96) on final evaluations. During surgery, lateral tibial plateau fissures and lateral cortex fractures occurred in three (7.5%) and 11 (27.5%) knees, respectively. Delayed healing and delayed union and breakdown of a distal screw were encountered in one patient (2.5%).

Conclusion: Fixation of proximal tibia medial opening wedge osteotomy using plates with wedges provides adequate stabilization to maintain the desired correction and to allow early functional rehabilitation in the treatment of medial osteoarthritis of the knee.

Key words: Knee joint/surgery/radiography; osteoarthritis/surgery; osteotomy/methods/instrumentation; tibia/surgery/radiography.

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Corrective osteotomies are gradually becoming common to avoid total knee prosthesis and to delay the age for this operation because of the increasing life span (longevity) and higher activity levels of the aged population.[1,2] Proximal tibial osteotomy (PTO)/high tibial osteotomy (HTO) is a procedure which has been accepted and commonly used in the treatment of medial unicompartmental osteoathrosis in the presence of axial malalignment, particularly in young and active patients.[1,3-15] Jackson first defined the upper tibial end and lower femoral end (supracondylar) osteotomy in degenerative osteoarthritis in 1958.[16] Later in 1965, Coventry modified the previous techniques and defined the lateral closing wedge osteotomy proximal to the tibial tubercle.[17] Since then proximal tibial osteotomy has been used under several names and techniques. Valgus corrective osteotomy of proximal tibia can be performed by either lateral closing wedge,[3,7,8,12,14,15,17-23] dome (barrel-vault), [15,24,25] focal (reverse) dome [2,21] or medial opening wedge [1,4-6,9-13,25-42] osteotomies. Closing wedge osteotomy (CWO) is the most common procedure. [3,7,8,12,14,15,17-23] The possible complications of closing wedge osteotomy techniques are as follows: neurovascular injuries, particularly the injury of the anterior tibial artery and the fibular nerve, compartment syndrome, intra articular fractures of the proximal fragment, deep vein thrombosis, pulmonary thromboembolism, infection, delayed union or nonunion (pseudarthrosis), instability, staple loosening, recurrence of varus deformity, over correction of valgus, knee stiffness (motion loss), avulsion of the collateral ligament, and decrease in tibial slope. [3,15,17-20,23,43] The dome osteotomy, which has been extensively used by Maquet, [24] protects bone stock; however, it causes patella infera and decrease in the tibial plateau inclination angle. [25] Early results of medial opening wedge osteotomy (MOWO) techniques, which are becoming gradually widespread, are encouraging. Because of its relatively easier surgical technique and enough stabilization provided by the procedures used for the fixation of the osteotomy surfaces, medial opening wedge osteotomy techniques enables exercise applications to open knee movements in early postoperative periods. Apart from its advantage of protecting the bone stock theoretically, open wedge osteotomy also has superiority as correcting the deformity close to its source. These features facilitate arthroplasty applications which can be necessary in the future. No muscle dissection, as well as fibular nerve injury risk is necessary during surgical procedure because of no need to fibular osteotomy. Deformities in both coronal and sagittal planes improve during the operation; no extremity shortness occurs. For fixation, several plates or external fixators are used. [1, 4-6, 9-13, 25-42, 44]

After Debeyre's definition and application of medial opening wedge osteotomy from the proximal part of tibial tubercle [5], Goutallier et al. [28] supported the osteotomy surface with cement and used buttress plate for fixation in medial opening wedge osteotomy. Opening wedge osteotomy has become widespread by Hernigou et al. [5] Puddu invented a plate which was a metal block with 5-17.5 mm height (spacer tooth) in early 1990's, which was named after him, to internally support the osteotomy surfaces from further collapse (Puddu plate, Arthrex plate). [4] Later on, various plates with different designs were applied for osteotomy fixation. [6, 29-31, 36, 37, 44]

In our clinic, we have been applying proximal tibial medial opening wedge osteotomy in the treatment of medial compartment osteoathrosis in the presence of axial malalignment since December 2001. For fixation, we have been using plates of three different types which have been designed by the author (Hipokrat, Turkey, TR2002 02021Y). Two of them are rectangular and they have a inclination to accommodate the medial surface of the proximal part of tibia. They have two or four holes on them as well as wedge shape projections of 5-15 mm height over their parts touching the bone, in order to internally support the osteotomy surfaces from further collapse. The third one is in reverse "L" shape and has four holes on it (Fig. 1a-c). The preliminary results of the usage of these plates were reported in our previous studies.[26, 39]

Patients and method

In our clinic, proximal tibia medial opening wedge osteotomy was applied to 40 knees of 38 patients (5 men, 33 women; mean age: 51 years; ranging between 36 and 65 years) by the author or under his control, between December 2001 and April 2004. Two female patients were operated on both knees. The mean preoperative HSS score reflecting the patients clinical and functional evalu-

ation [23,38] was 59 (range 52-75). The tibiofemoral angle with the anatomical axis was evaluated along the long axis of 30x40 cm radiographs which was taken with the patient standing (weight-bearing position) and showing the distal part of femur, knee and the proximal part of tibia. [7,10,11,15,18,19,23,25,30] Measurements on the weight-bearing radiographs were done regarding that the normal tibiofemoral angle is 175° or 5° valgus [10] and 180°= 0°is anatomical varus.[30] The mean varus angle was found 4.3° (range 0°-10°). Apart from the pre- and post-operative antero-posterior and lateral radiographs, internal rotation (internal oblique, medial oblique) radiographs which showed the proximal tibiofibular joint were also taken.

The joint component angle (joint line convergence angle "JLCA") which is the varus angle may be due to arthrosis because of either the loss of articular cartilage and bone, or the ligamentous laxity of lateral structures, or both. So, in order to determine the amount of deformity, ligaments were evaluated as it was suggested in the literature.[2,5,12,14,19,31,40] Obesity, which was thought to have negative effect on the results, was considered as relative contraindication.[4,40] Surgical plan was developed to perform proximal tibia medial opening wedge osteotomy in patients with predominantly unicompartmental medial osteoarthrosis. As the some other studies [5,13], cartilage fibrillation detected in the arthroscopy of the patellofemoral joint was not accepted as contraindication.

Surgical technique

All the operations began with arthroscopy as it has been recommended in the literature. [1,4,13,31,35,36,38] When necessary, degenerated meniscus and irregular cartilage parts were debrided, lose bodies and osteophytes were removed, and chondroplasty (microfracture) was performed.

We applied our surgical technique regarding the suggestions of the authors who apply medial opening wedge osteotomy.[4,5,29,33]

A longitudinal skin incision of 5-7 cm length, changing according to the plate length that was planned to use, was performed anteromedially beginning from an inferior level to the knee joint line. After exploring the proximal part of tibia, an osteotomy line, which was changing according to the patient and tibia length, was determined. This line was starting 3-4 cm distal from the medial joint line, 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 lateral articular surface and 1 cm medial to the lateral tibial cortex.

This application can be performed by either directly sending a K-wire obliquely from medial to lateral, or a guide which was designed by the author (Fig. 2a, b). Level and direction control are done by C-arm of the image intensifier (fluoroscopy). Two or three more K-wires are sent in appropriate conditions. K-wires are sent regarding

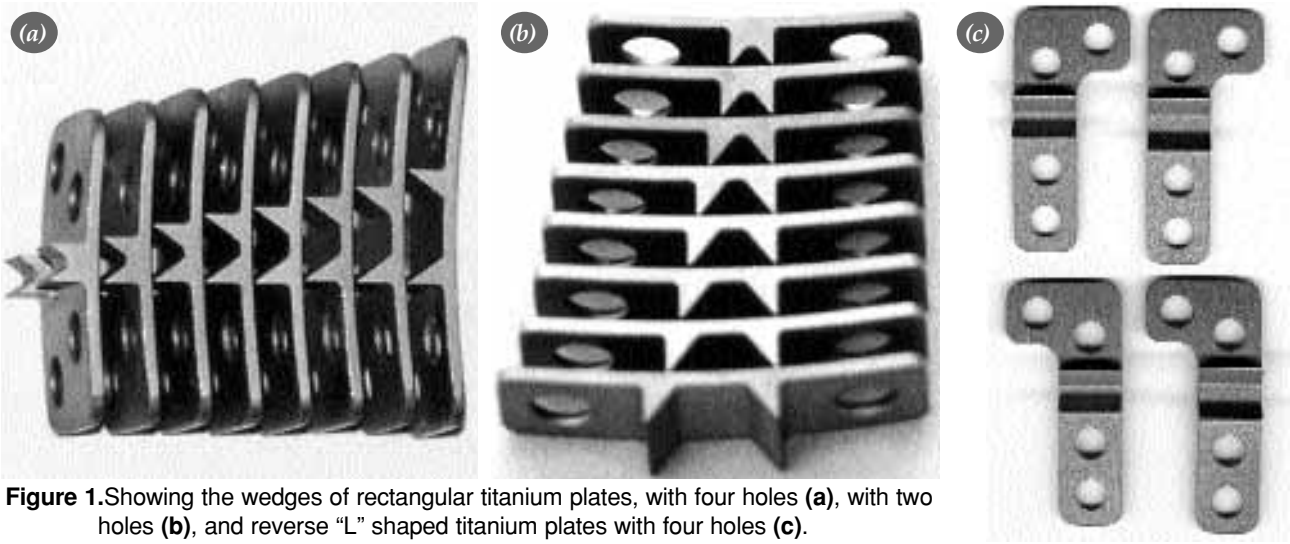

Figure 1. Showing the wedges of rectangular titanium plates, with four holes **(a)**, with two holes **(b)**, and reverse "L" shaped titanium plates with four holes **(c)**.

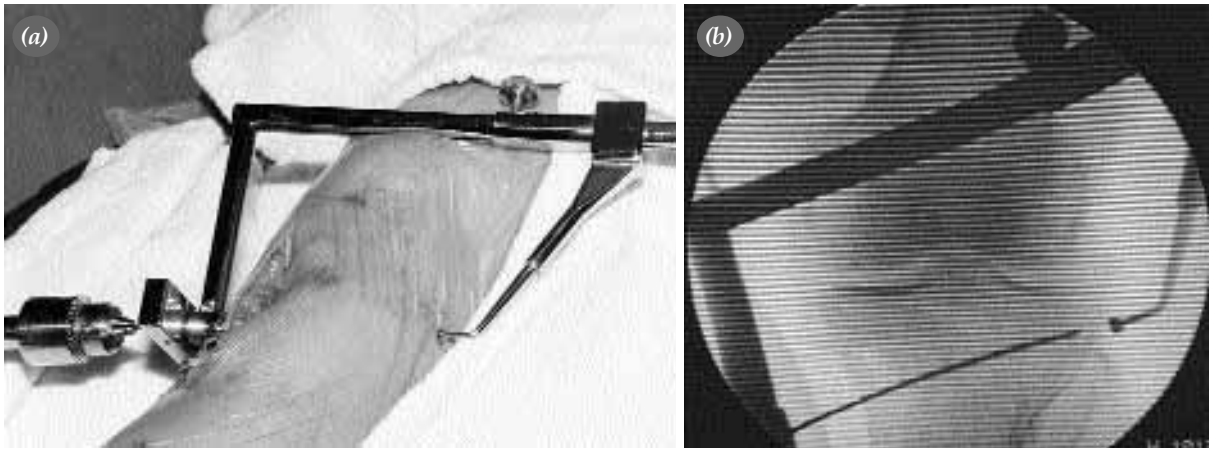

Figure 2. Determination of the osteotomy line by sending K-wire with a guide, in application **(a)**, and view on fluoroscopy **(b)**.

the position of the proximal tibiofibular joint and the posterior slope (posterior slope of the lateral tibial plateau) in the internal rotation radiographs, which are taken to evaluate the tibiofibular joint preoperatively. If the proximal tibiofibular joint is located more proximally, in such cases, osteotomy is performed more distally to the level of the proximal tibiofibular joint, not towards the tip of the fibular head. When the direction of the guide wires are found appropriate under fluoroscopic control, the medial, anterior and posterior cortices are cut under these wires with a thin and narrow ended osteotome (chisel). During the osteotomy of the posterior cortex, in order not to damage the posterior neurovascular structures, we used a special osteotome which was designed by the author one side blunt ended. Maximum care was given to protect the lateral cortex in order to use its hinge characteristic. The cutting procedure (osteotomy) was completed by using a "U" shaped osteotome which was designed by the author and does not cut the lateral cortex. So, the first distraction which was as thick as the osteotome was done (Fig. 3). Then, the cut bone surfaces were distracted.

For controlled distraction, a third and if necessary a fourth osteotome was located between the first located two osteotomes (as wood-cutter wedge) within the osteotomy gap under fluoroscopic control and the distraction was performed (Fig. 4). In more recent operations, an angle-scale distractor, which was designed by the author, has been used in order to perform a controlled distraction from the plastic deformation zone that is close to the lateral tibal plateau, to evaluate the correction by seeing it from the angle scale part and to prevent the lateral cortical bone fractures (Fig. 5). [45]

Figure 3. Completion of the osteotomy with "U" shaped osteotome which does not cut the lateral cortex.

Figure 4. Distraction which was performed by locating a third osteotome (as wood-cutter wedge) between the first located two osteotomes within the osteotomy gap.

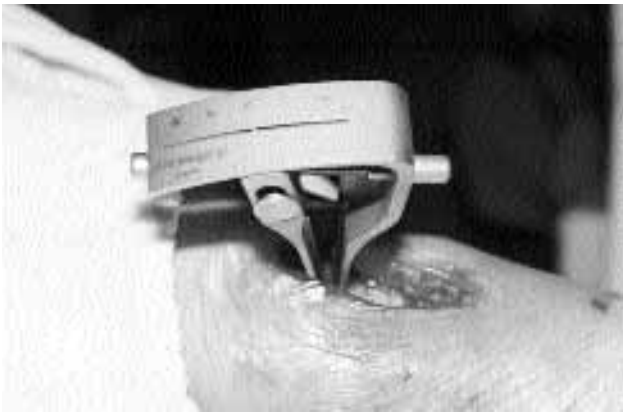

Figure 5. Controlled distraction which was performed by using an angle-scale distractor.

Before operation, height of the wedge of the plate was calculated regarding the amount of the deformity. For this, the chart (table) which was defined by Hernigou and Ma [29] and Hernigou [37] and which shows the relation between the width of the tibia at osteotomy level and the desired correction angle, was used. The osteotomy gap was distracted and controlled under fluoroscopic control according to this chart. Plate(s) was (were) used in appropriate height. During closure, superficial fibers of the medial collateral ligament were not sutured because of their likely compressive effect, but only fixed by closing sutures. No fibular osteotomy was performed in any patient.

Plates

Plates have wedge shaped triangular parts with 4 mm depth, in order to internally support the osteotomy surfaces. The steel "316L/1.4441" and "Ti-6Al4V/IMI 318" titanium plates were produced in accordance with the anatomical proximal slope of tibia (R=173mm) (Hipokrat/Turkey, TR2002 02021Y). There are two or four holes on the rectangular shaped ones. For right and left knees, reverse "L" shaped plates with four holes are used as the short leg of "L" facing anteriorly. The wedge heights are 5, 6, 7.5, 9, 10, 11, 12.5 and 15 mm (Fig. 1).

In steel plates, normal cancellous screws were used, while in titanium plates, cancellous screws which do not cause swelling over the plate or skin and totally locate (fitted) to the screw hole, were preferred. Wedges were along the entire width of the plate in two-holes rectangular and reverse "L" shaped plates. In four-holes rectangular plates they were separated to either side in order to locate a graft in between. This characteristic of the plates enables the continuation of the bony tissue formation after the bone union phase in the area between the wedges (Figs. 6c, 7c). Two two-holes plates with different heights were used both anteriorly and posteriorly in cases which the tibial slope should be arranged.

Graft application

During 40 osteotomies on 38 patients; tricortical iliac autograft, bicortical iliac autograft, and human–originated cubic-cancellous allografts were applied on eight, 25 and seven knees, respectively.

Bicortical iliac bone grafts with intact internal cortex were applied to the recent autograft patients, because of the pain complaints on the donor site of our patients after tricortical graft application. We terminated allograft application after we encountered lateral cortical fracture during the operation, delayed union in follow-up and break in one of the inferior screws, in one case with allograft.

Postoperative care

Since our patients are usually overweight, the application of low-molecular-weight heparin for prophylaxis that we started preoperatively was continued till their discharge on 10-12th day and oral antiaggregane agents were prescribed to reduce the rate of deep vein thrombosis. Cephalosporin, which we applied the first dose in the operation room was prescribed for five days. After the operation, high thigh brace with knee-hinge was applied. Drains were removed on the 2nd day. On the 3rd day, passive knee exercises of 0°-30° were begun on CPM and 90° range of motion was obtained usually on the 10th day. However, three patients (3 knees), who had lateral tibial plateau fractures during operation, were discharged with 70° range of motion. After the removal of the drains, patients were allowed to stand up with crutches or a walker without weight-bearing. The mean follow-up time was 17 months (range 9-36 months).

Results

Patients, particularly the ones who had chondroplasty, were not allowed to weight-bearing for 45 days after the operation. At the end of this period,

partial and after 60-75 days, full weight-bearing was performed. The preoperatively mean 4.3° (0°-10°) varus tibiofemoral angle was measured 5.8° (3°-11°) valgus postoperatively. In some of the cases with more proximally located proximal tibiofibular joint in the internal rotation radiographs, it was observed that the osteotomy, which was performed under the guide wires that were sent toward the fibular head tip, was too close to the tibial plateau posteriorly. When a distal osteotomy was performed, due to their location, it was detected in three knees that we entered into the proximal tibiofibular joint although the lateral cortex could be intact (in one case the lateral cortical continuation was intact, while in two others it was interrupted).

Functional evaluation was made by using the HSS scoring system.[23, 38] The mean preoperative score was 59 (range 52-75), while it was found 90 (range 79-96) in the last control postoperatively. So, nine knees were evaluated as good while the other 31 knees were excellent. Decrease in pain during walking and particularly at rest as well as a prominent increase in the walking distance was observed in all patients. No loss in the knee range of motion was detected in any of the patients, in comparison with the preoperative period.

As complications, lateral tibial plateau fracture during operation without deplacement in three knees (7.5%), lateral cortical fracture during operation without deplacement in 11 knees (27.5%), delayed in wound healing in one knee (2.5%), and delayed union of one knee and break of one of the distal screws of the same patient, were detected (lateral cortical fracture during operation was observed in the same patient).

Wound healing was delayed in one overweight female patient who had great amout of subcutaneous fatty tissue, but she recovered without any problem by dressing. Two of the three fractures extending to the lateral tibial plateau during operation were the 4th and 11th patients of the study. The ages of these female patients were 55 and 56 respectively, and their ankles were uncontrollably enforced to valgus during the extension of the osteotomy region (gap) by distractor. In the third patient (a 50-year-old female patient), the fracture occurred after the distraction which we applied with an insufficient cutting of the posterior cortex. No additional fixation was applied to one of these three knees; the fracture which was not displaced was fixed with upper screws. In one of the other two, a cancellous screw was sent in addition to four screws through the plate. In the last knee, one two-holes plate and two cancellous screws were additionally used (3 two-holes plates and 6 cancellous screws in totally). In 11 knees, lateral cortical fracture without displacement was detected in the antero-posterior radiographs, although osteotomies were performed under fluoroscopic control and without reaching the lateral cortex. We did not observe any displacement or stepping of the cortical continuity in oblique radiographs of these knees in which the osteotomy line was extending the lateral cortex. So, we assumed that the periosteum and surrounding soft tissue were intact and had protective effects, and we did not consider the lateral fixation necessary. We applied a follow-up procedure to these patients similar to that of the other knees (patients); they were discharged with 70° range of motion instead of 90°. All the tibial plateau and lateral cortex extending fractures were healed without any problem. In the 5th month control radiograph of one overweight female patient who had four-holes titanium plate, allograft and lateral cortical fracture during operation, it was detected that the osteotomy line had delayed union. In her 6th month radiographs, the delayed union was consistent and one of the distal screws was broken. The patient did not accept the suggested revision operation. In the control 10 months after the operation, the osteotomy line healed and the patient had no complaints. No deep vein thrombosis, infection or union problems were encountered in any of the other patients. Except for one patient with delayed union, all osteotomies had bone union in their 2-2.5 month follow-up without any problem (Figs. 6a-d, 7a-d).

In three knees (3 patients), plates were removed with patients' desire. No bone defect was detected in these cases except for the linear contact areas of the wedges where they pierced the bone. It was also detected that the gap between the wedges were filled with bony tissue (Figs. 6c, 7c).

Discussion

Appropriate patient and surgical technique preference in proximal tibial osteotomy increase

the success of the long term results. A perfect (excellent) result is the maintenance of a stable and painless knee, with saved or augmented range of motion and a corrected axial malalignment. Age, gender, range of motion, mediolateral and anteroposterior stability, and the stage of arthritis should be evaluated preoperatively. In order to achieve successful results in medial opening wedge osteotomy, patients who are under the age of 65-70 and not overweight, and who have unicompartmental involvement, varus malalignment, and 0°-120°[31] or 0°/10°-100°[36] range of motion should be preferred.

It has been reported that preoperatively determination of patella infera (patella baja) is a contraindication for medial opening wedge osteotomy.

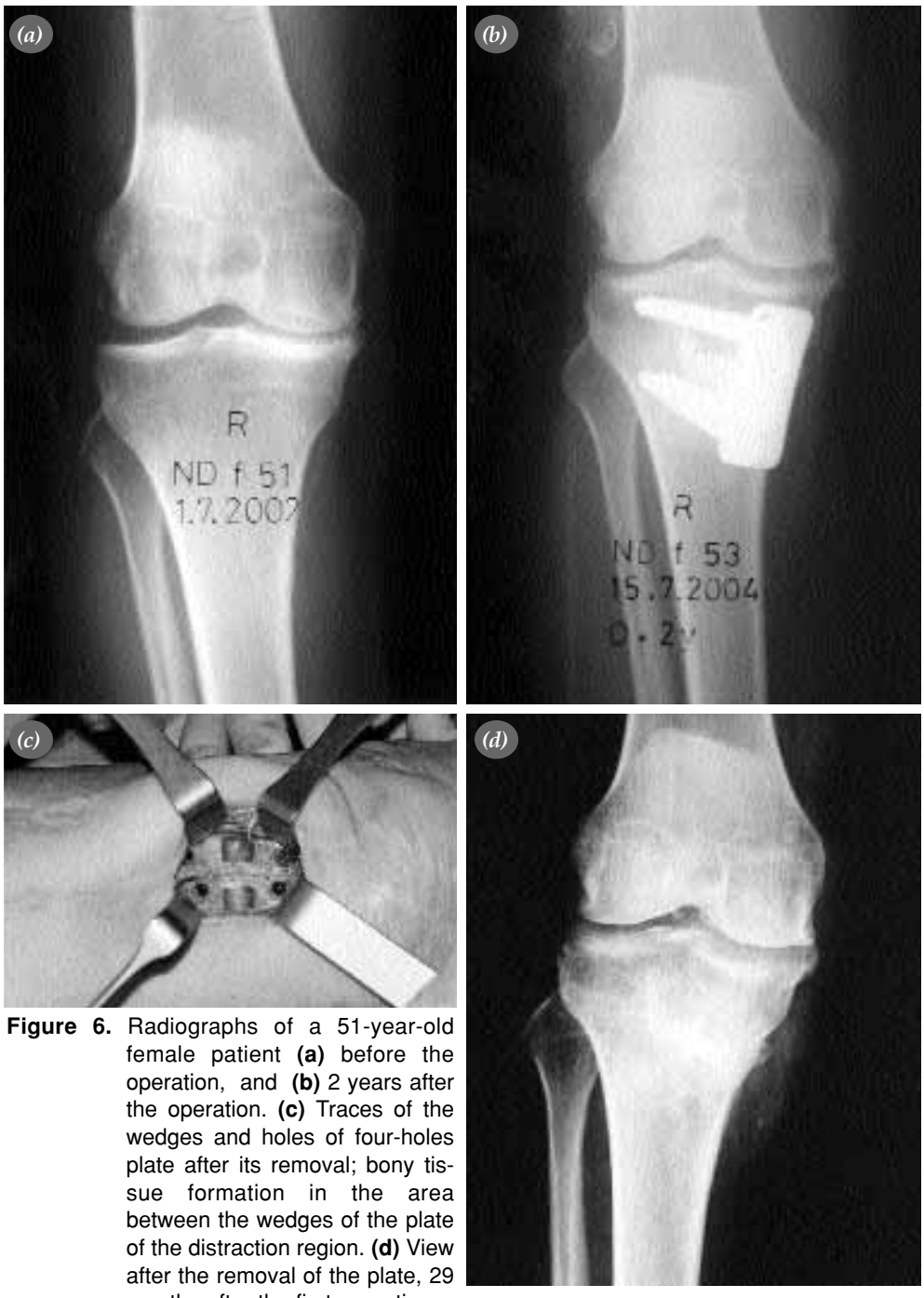

Figure 6. Radiographs of a 51-year-old female patient **(a)** before the operation, and **(b)** 2 years after the operation. **(c)** Traces of the wedges and holes of four-holes plate after its removal; bony tissue formation in the area between the wedges of the plate of the distraction region. **(d)** View after the removal of the plate, 29 months after the first operation.

[4,31] Sonneveld et al. [34] and Gaasbeek et al. [27] applied distal osteotomy technique, in which the tibial tubercle is stayed in the proximal fragment, to medial opening wedge osteotomy and showed that this technique prevents the formation of patella infera. Lobenhoffer et al. [31] suggested that in cases with patella infera by directing the bone cutting at the posterior side of the attachment of the patellar tendon downwards instead of upwards, possible changes in the extensor mechanism after osteotomy can be prevented. None of our patients had patella infera preoperatively. In the preoperative arthroscopic evaluation, in either patella or femoral sulcus of 11 knees, fibrillation (fringe-

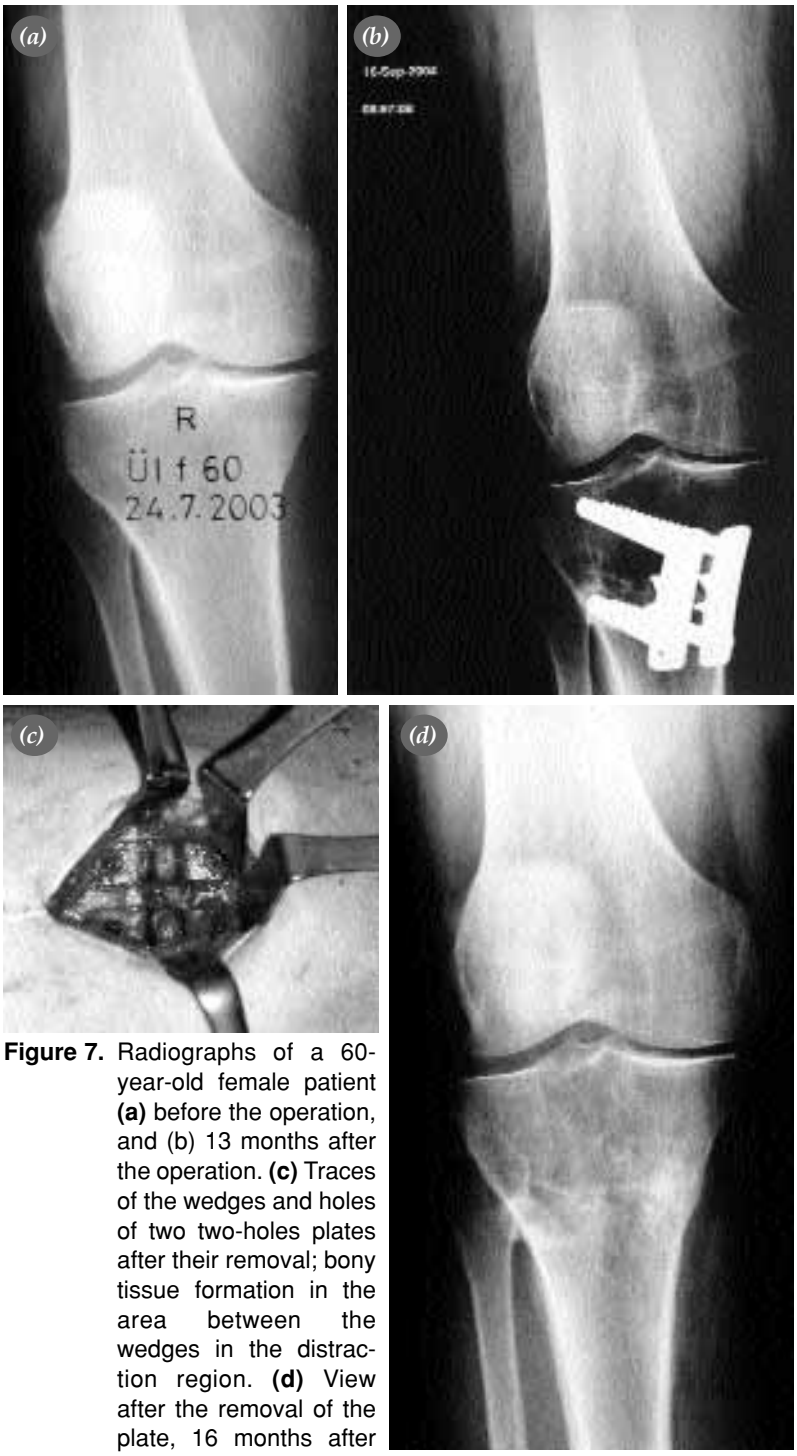

Figure 7. Radiographs of a 60-year-old female patient **(a)** before the operation, and (b) 13 months after the operation. **(c)** Traces of the wedges and holes of two two-holes plates after their removal; bony tissue formation in the area between the wedges in the distraction region. **(d)** View after the removal of the plate, 16 months after the first operation.

ment) in the cartilage was detected. In these knees, in order not to increase the weight to patellofemoral joint, we applied fixation keeping in mind not to incresase the tibial slope which was observed before the operation. To do that, in our application of two two-holes plates, we use the plate which has one or two mm higher wedge height to the back and the one with lesser wedge height to the front.

There is no need for fibular osteotomy in medial opening wedge osteotomy. Fibula and the tibiofibular joint are not damaged. Thus, there is no risk of fibular nerve palsy as well. [1,4-6,10,12,13,29,31,32] However, Hernigou et al. [5] reported a case of temporary peroneal nerve paralysis, which disappeared later, among 93 medial opening wedge osteotomy applications. Nakamura et al. [25] performed fibulectomy in cases which there were hemicallotasis and a need for a correction of more than 15°, in order to protect the fibular nerve, to prevent from any discordance in the proximal tibiofibular joint due to the proximal displacement of the fibular head, and to prevent irregularity in the joint relation. Sangwan et al. [11] used fibular osteotomy or excision in two knees among the 40 knees in which they applied external fixation after osteotomy. Fibular osteotomy was not applied in neither of our cases. Yet, on the internal rotation radioghraphs, in cases with proximally located proximal tibiofibular joint, in three cases, particularly with interrupted lateral cortical continuity, we observed that the osteotomy line extended to the proximal tibiofibular joint.

Osteotomy gap is filled with iliac autograft, allograft or substitute bone materials. Autograft can be obtained from the same side iliac crest or bank or synthetic bone grafts can be used. [4-6,29-31,33,35,36,38,42] Graft usage in distractions under 7.5 mm were reported unnecessary by some authors, [4] while Spahn [35] finds it unnecessary for corrections under 12°. On the other hand, there are authors who use local cancellous (spongiosus) graft obtained from tibia in 7.5-10 mm opening, [6] cancellous bone grafting augmented with a hydroxyapatite/tricalcium phosphate wedge in cases of an opening of the osteotomy of more than 12.5 mm [6,31], or graft from the same side iliac crest in cases which need more than 12.5° correction.[35] Autograft usage may lead to postoperative pain and hematoma in the donor site, sepsis or discomfort during dressing. [29,36] We used tricortical iliac autograft, bicortical iliac autograft, and human–originated cubic-cancellous allografts on eight, 25 and seven knees, respectively. Because of the pain complaints on the donor site of the patients with tricortical grafts, bicortical iliac bone grafts were used in further cases as to protect the medial cortex. We began to use allograft in our recent cases, however, we returned to use bicortical iliac autograft usage after we encountered bone delayed union in one out of seven knees that we applied allograft. In our recent applications, in cases which need 11° or more distraction (not included in this study), particularly in patients with thin bone structure, we began to use a mixture of autograft and allograft if the gap could not be filled with iliac autograft alone.

The main effect of proximal tibial osteotmy is mechanical. A slightly more (over) correction of the mechanical or anatomical axis prevents the recurrence of the deformity and revision surgery and provides better results in long term.[4,12] However, the relation between the results and alignment is consistent in the studies; there is no consensus on most appropriate alignment. The tibiofemoral angle according to the anatomical axis was evaluated pre- and postoperatively in our cases.[7,10,11,15,18,19,23,25,30] In recent studies it has been concluded that it is necessary to maintain a postoperative 3°-6° [29], 2°-8° [38], and 5° [1] valgus angle for hip-knee-ankle (mechanical axis), respectively. Also, a correction which provides a mechanical axis fitting 62% of the lateral tibial plateau and 5° mechanical valgus and a 9°-10° anatomical valgus angle with 5° overcorrection, are necessary for successful results. [4,36] We measured the mean preoperative tibiofemoral anatomical angle as 4.3° (0°-10°) varus while it was 5.8° (3°-11°) valgus, postoperatively. It was detected that average 10.1° valgus was obtained, regarding the preoperative values.

Partial vascular injury, intraarticular lateral tibial plateau fracture, lateral cortical fracture, subluxation, delayed wound healing due to fatty necrosis, hematoma, superficial and deep infection, deep vein thrombosis, tibial slope changes,

excessive correction, loss in the correction degrees, graft collapse, delayed union, nonunion (pseudoarthrosis) or implant insufficiency are the reported complications in medial opening wedge osteotomy. [4-6,9,29,31,35,38] Except for these complications, Hernigou et al. [5] reported a case of temporary peroneal nerve paralysis among 93 cases. Leg length may be slightly long after open wedge osteotomy. [30]

During osteotomy, lateral cortex is left intact in order to benefit from its hinge effect. [1, 4-6,10,11,13,25,29,30,32,35,38] Paccola and Fogagnolo [9] suggested percutaneous lag screw application from the lateral cortex to the medial tibial plateau in order to avoid correction loss after lateral cortical bone fracture during medial opening wedge osteotomy. In subluxation due to the opposite side cortical bone fracture, staple fixation with opposite side incision has been suggested. [4] In their study on 93 knees, Hernigou et al. [5] reported displacement due to lateral cortical fracture before union in 11 knees (11.8%) and lateral tibial plateau fracture without displacement in 10 knees. In our study, lateral cortex fracture was occurred in 11 cases. Lateral cortex fracture was detected when 10 mm and over distraction was performed without using an angle-scale distractor and 12.5 mm distraction was performed after using an angle-scale distractor. No additional fixation was done regarding the compressive effects of intact periost and surrounding soft tissue. In the follow-up, no correction loss or negative effect on stabilization were detected. In our applications, we detected that this complication was minimum when a third osteotome was inserted between the other two ones into the cancellous bone area under the opposite plateau which is defined as plastic deformation zone [6] or when we performed a distraction with an angle-scale distractor[45] very slowly which allows the bone to stretch and rest.

Lateral plateau fracture was reported as 6.6%-14.6% and 5% during operation by Spahn [35] and Kılıç [38] respectively. In our study, in three knees (7.5%) out of 40 knees lateral plateau fracture occurred during the operation. Two of these fractures occurred after the uncontrollable distraction and the forcing valgus from the ankle; and the third one took place as a technical error after our distraction which was applied without cutting the posterior cortex completely. The lateral tibia plateau would be protected if the osteotomy and distraction of osteotomy zone is done below the guide wires which are sent. These wires could be left till the end of the distraction. To prevent any fracture in lateral cortex or lateral plateau, a third osteotome could be used between the two osteotomes. [6,26,35,39] Controlled and gradual opening is obtained through plastic deformation zone. Moreover, it has been stated that spreader-chisel [6] or osteotomy jack (bone separator jack) [33] could be used. No lever force should be applied to osteotomy zone. [35] We perform controlled distraction either by angle-scale distractor or as in the recent cases, in addition to leaving the 2 K-wires which we sent parallel to the joint and 1 cm below the articular surface in which we applied a distraction of 10° or more.[26, 39, 45] We have never encountered intraarticular plateau fracture in patients that we took this precaution.

Spahn[35] encountered nine (%16.4) implant insufficiencies out of 55 Puddu plate applications (2 plate and 7 screw breaks). However, this author mentions that he applies osteotomy usually located below the tibial tuberosity (tubercle), near the center of the varus deformity and with a right angle to the tibial cortical bone. This technique is not consistent with the one that Puddu defined as a supratubercle, mediolaterally oblique osteotomy in the cancellous bone structure in which the bone healing occurs faster. We think that Spahn's technique leads to implant insufficiency. In our study, we detected a break of one of the distal screws in the radiographs which was taken at the postoperative 6th month of one patient (2.5%) with delayed union. 164 screws in total were used in 40 knees in 22 four-holes, 36 two-holes and one four-holes reverse "L" shaped plates. Implants insufficiency were found as 1/164 (0.6%) regarding all the screws used in all the plates.

Lobenhoffer and Agneskirchner[6] reported nonunion in six (5.9%) out of 101 cases of Arthrex plate application. These patients were the ones with 12.5 mm and over distraction and correction. For not having a delayed union, in addition to using stable osteosynthesis procedures, it was suggested not to use high speed motor cutters which

lead to thermonecrosis. [31] It should be benefited from the hinge characteristic. [1,4-6,10,11,13,25,29,30,32,35,38] No suction drain should be applied to osteotomy zone. [31] Only in one of our patients, we encountered delayed union and one distal screw breakage in the 6th month radiographs. This was an overweight patient, in which we applied allograft by using 12.5 mm wedge height plate and detected a lateral cortical fracture during operation. We observed in the 10th month radiographs of this patient that the bone union was realized without any other screw-plate failure, and all the complaints were totally disappeared.

Many authors reported successful short term results of knees with varus deformity and medial compartment osteoarthritis. These results are deteriorated gradually, however. In many studies, the first five year success ratios were given as 80-90%, whereas it has been decreased to 60-65% after 10 years.[4,42] Hernigou et al. [5] applied medial opening wedge osteotomy in 93 knees of 66 patients, among which they followed 76 for 10-13 years. In five years follow-up, 90% successful scores were obtained in 93 knees, whereas it was decreased to 42 knees (45%) after 10 years; revision was needed in 17 knees within an average of seven year-time (revision with second osteotomy in 8 of them because of the average age of 63 and 9 arthroplasty); 34 patients did not want any additional treatment although they have pain in their knees. In another study, it was reported that 3°-6° correction was obtained in 75% of 245 medial opening wedge osteotomy techniques in 197 patients supported with acrylic bone cement; possible survival periods of patients after five, 10 and 15 years were detected as 94%, 85% and 68% according to Kaplan-Meier application, respectively; 23 patients out of 87 who were followed for more than 10 years, were treated with total knee prothesis. [29]

In studies where medial opening wedge osteotomy is applied, the average HSS scores were announced between 61-71 before and 88-95.8±4.5 after the operation. [12,30,32,38] However, Franco et al. [4] reported that HSS score which was poor in seven knees, fair in 18 knees, and good in five knees before the operation turned out to be fair in three knees, good in 17 knees, and excellent in 10 knees after the operation. The mean HSS score in our cases was found to be 59 (ranging, 52 to 75) before the operation, and 90 (ranging 79-96) in the last control after the operation. The HSS score rised by 31 points. In all patients, a considerable reduction was detected in their pains while walking and particularly while resting, their walking distance prominently increased as well. Considering the fact that the results which were taken in the nine-month control were better than that of six-month [26], we assume that the continuity of the diet and muscle strengthening exercise programs are beneficial for the patients.

In the past, many proximal tibial osteotomy techniques were applied only regarding the radiographic evaluation, even in patients with severe osteoarthritis and deformity. In those patients, usually no internal fixation were performed, if done no sufficient stabilization was obtained, and after operation a long period of immobilization was applied. [3,17,19,20,23] It is usual having poor results in some of these cases of which we consider that they should be out of indication. In contemporary proximal tibial osteotomy techniques, the contralateral compartment is evaluated by preoperative arthroscopy; osteotomy operation can be abandoned in inappropriate cases; if necessary, treatment can be applied to intraarticular pathologies in cases that osteotomy is decided.

Internal and external fixation systems after osteotomy operations make plaster application unnecessary because, they maintain sufficient fixation and enable rehabilitation in the early period. So, non prosthetic options which maintain activity without forming a synthetic joint should be remembered in unicompartmentally involved patient groups who have a profession that requires activity and have desire for sports. In the past, the patients who had osteotomy for severe osteoarthritis might be out of indication, at the beginning. We think that patients with proximal tibial osteotomy indication should be apart from the ones with total knee prosthesis who have tricompartmental involvement; total knee prosthesis is not an alternative to proximal tibial osteotomy but a further treatment stage; alternative for proximal tibial osteotomy is the unicompartmental knee prosthesis; arthroplasty procedures are not that innocent

regarding their possible complications. We think that in appropriate candidates, correctly applied surgical technique, maintenance of sufficient fixation, and a quick postoperative rehabilitation programme, lead to satisfactory mid and long term results. In sedentary patients who are over 60, particularly the ones with severe involvement, total knee prothesis can be applied.

Proximal tibial osteotomy procedures are the applications which protect the joint. Even though total knee prosthesis will be necessary in the future, proximal tibial osteotomy techniques are time-saving applications till then. proximal tibia medial opening wedge osteotomy is a commonly accepted and applied procedure in the treatment of particularly young and active patients with medial unicompartmentally involved osteoarthrosis in the presence of axial malalignment. For this procedure, application of wedged plates which were designed by the author and fix the osteotomy surfaces by the support of wedge-shaped prominences, is a fixation system that provides sufficient stabilization and rehabilitation in the early postoperative period.

References

1. Klinger HM, Lorenz F, Harer T. Open wedge tibial osteotomy by hemicallotasis for medial compartment osteoarthritis. Arch Orthop Trauma Surg 2001;121:245-7.
2. Paley D, Maar DC, Herzenberg JE. New concepts in high tibial osteotomy for medial compartment osteoarthritis. Orthop Clin North Am 1994;25:483-98.
3. Coventry MB. Osteotomy about the knee for degenerative and rheumatoid arthritis: indications, operative technique, and results. J Bone Joint Surg [Am] 1973;55:23-48.
4. Franco V, Cerullo G, Cipolla M, Gianni E, Puddu G. Open wedge high tibial osteotomy. Techniques in Knee Surgery 2002;1:43-53.
5. Hernigou P, Medevielle D, Debeyre J, Goutallier D. Proximal tibial osteotomy for osteoarthritis with varus deformity. A ten to thirteen-year follow-up study. J Bone Joint Surg [Am] 1987;69:332-54.
6. Lobenhoffer P, Agneskirchner JD. Improvements in surgical technique of valgus high tibial osteotomy. Knee Surg Sports Traumatol Arthrosc 2003;11:132-8.
7. Nakhostine M, Friedrich NF, Muller W, Kentsch A. A special high tibial osteotomy technique for treatment of unicompartmental osteoarthritis of the knee. Orthopedics 1993;16:1255-8.
8. Odenbring S, Tjornstrand B, Egund N, Hagstedt B, Hovelius L, Lindstrand A, et al. Function after tibial osteotomy for medial gonarthrosis below aged 50 years. Acta Orthop Scand 1989;60:527-31.
9. Paccola CA, Fogagnolo F. Open-wedge high tibial osteotomy: a technical trick to avoid loss of reduction of the opposite cortex. Knee Surg Sports Traumatol Arthrosc 2005;13: 19-22.
10. Weale AE, Lee AS, MacEachern AG. High tibial osteotomy using a dynamic axial external fixator. Clin Orthop Relat Res 2001;(382):154-67.
11. Sangwan SS, Siwach RC, Singh Z, Duhan S. Unicompartmental osteoarthritis of the knee: an innovative osteotomy. Int Orthop 2000;24:148-50.
12. Magyar G, Ahl TL, Vibe P, Toksvig-Larsen S, Lindstrand A. Open-wedge osteotomy by hemicallotasis or the closed-wedge technique for osteoarthritis of the knee. A randomised study of 50 operations. J Bone Joint Surg [Br] 1999;81:444.
13. Miller BS, Sterett WI. High tibial osteotomy utilizing distraction osteogenesis. Techniques in Knee Surgery 2003;2:184-9.
14. Murphy SB. Tibial osteotomy for genu varum. Indications, preoperative planning, and technique. Orthop Clin North Am 1994;25:477-82.
15. Naudie D, Bourne RB, Rorabeck CH, Bourne TJ. Survivorship of the high tibial valgus osteotomy. A 10- to -22-year followup study. Clin Orthop Relat Res 1999;(367): 18-27.
16. Jackson JP. Osteotomy for osteoarthritis of the knee. J Bone Joint Surg [Br] 1958;40:826.
17. Coventry MB. Osteotomy of the upper portion of the tibia for degenerative arthritis of the knee. A preliminary report. J Bone Joint Surg [Am] 1965;47:984-90.
18. Aglietti P, Buzzi R, Vena LM, Baldini A, Mondaini A. High tibial valgus osteotomy for medial gonarthrosis: a 10- to 21-year study. J Knee Surg 2003;16:21-6.
19. Insall J, Shoji H, Mayer V. High tibial osteotomy. A five-year evaluation. J Bone Joint Surg [Am] 1974;56:1397-405.
20. Jackson JP, Waugh W. The technique and complications of upper tibial osteotomy. A review of 226 operations. J Bone Joint Surg [Br] 1974;56:236-45.
21. Sen C, Kocaoglu M, Eralp L. The advantages of circular external fixation used in high tibial osteotomy (average 6 years follow-up). Knee Surg Sports Traumatol Arthrosc 2003;11:139-44.
22. Erdogan F, Kesmezacar H, Ogut T, Orak M, Tenekecioglu Y. The use of a modified Weber technique for high tibial osteotomy. [Article in Turkish] Acta Orthop Traumatol Turc 2003;37:26-32.
23. Insall JN, Joseph DM, Msika C. High tibial osteotomy for varus gonarthrosis. A long-term follow-up study. J Bone Joint Surg [Am] 1984;66:1040-8.
24. Maquet P. Valgus osteotomy for osteoarthritis of the knee. Clin Orthop Relat Res 1976;(120):143-8.
25. Nakamura E, Mizuta H, Kudo S, Takagi K, Sakamoto K. Open-wedge osteotomy of the proximal tibia with hemicallotasis. J Bone Joint Surg [Br] 2001;83:1111-5.
26. Esenkaya I, Elmalı N, Mısırlıoğlu M. Fixation of medial opening wedge osteotomy for medial osteoarthritis of the knee using the buttress plate with wedge. In: Abstract Book. 7th Congress of the Turkish Society of Sports Traumatology Arhroscopy and Knee Surgery combined with the 3rd Congress of Asia-Pacific Knee Society; November 1-4, 2004; Ankara, Turkey. p. 115-8.
27. Gaasbeek RD, Sonneveld H, Van Heerwaarden RJ, Jacobs WC, Wymenga AB. Distal tuberosity osteotomy in open wedge high tibial osteotomy can prevent patella infera: a new technique. In: Abstracts&Presentations. 11th ESSKA 2000 Congress and 4th World Congress on Sports Trauma;

May 5-8, 2004; Athens, Greece. 2000. p. 26.
28. Goutallier D, Julieron A, Hernigou Ph. Cement wedge replacing iliac graft for medial opening wedge tibial osteotomy. [Article in French] Rev Chir Orthop Reparatrice Appar Mot 1992;78:138-44.
29. Hernigou P, Ma W. Open wedge tibial osteotomy with acrylic bone cement as bone substitute. Knee 2001;8:103-10.
30. Koshino T, Murase T, Saito T. Medial opening-wedge high tibial osteotomy with use of porous hydroxyapatite to treat medial compartment osteoarthritis of the knee. J Bone Joint Surg [Am] 2003;85:78-85.
31. Lobenhoffer P, De Simoni C, Staubli AE. Open-wedge high-tibial osteotomy with rigid plate fixation. Techniques in Knee Surgery 2002;1:93-105.
32. Magyar G, Toksvig-Larsen S, Lindstrand A. Open wedge tibial osteotomy by callus distraction in gonarthrosis. Operative technique and early results in 36 patients. Acta Orthop Scand 1998;69:147-51.
33. Puddu G. High tibial osteotomy (The arthritic knee in the young athlete, SYM 15). In: Abstracts&Presentations. 11th ESSKA 2000 Congress and 4th World Congress on Sports Trauma; May 5-8, 2004; Athens, Greece. 2000. p. 446-7.
34. Sonneveld H, Wymenga AB, Lelivelt AB, Jacobs WC. Distal tuberosity osteotomy in open wedge high tibial osteotomy prevents patella baja: a new technique. In: Abstracts. 10th Congress of European Society of Sports Traumatology, Knee Surgery and Arthroscopy, ESSKA 2000; April 23-27, 2002; Rome, Italy. 2002. p. 300.
35. Spahn G. Complications in high tibial (medial opening wedge) osteotomy. Arch Orthop Trauma Surg 2004;124:649-53.
36. Staubli AE, De Simoni C, Babst R, Lobenhoffer P. TomoFix: a new LCP-concept for open wedge osteotomy of the medial proximal tibia-early results in 92 cases. Injury 2003;34 Suppl 2:B55-62.
37. Hernigou P. Open wedge tibial osteotomy: combined coronal and sagittal correction. Knee 2002;9:15-20.
38. Kılıç B. Varus gonartrozunda Puddu plağı ile yüksek tibia osteotomisi [Uzmanlık Tezi]. İstanbul: İstanbul Üniversitesi İstanbul Tıp Fakültesi; 2004.
39. Esenkaya İ. Dizin medial osteoartritinde medial açık kama osteotomisinin tespitinde kamalı destek plağı kullanımı. In: Kuzgun Ü, editör. XVIII. Milli Türk Ortopedi ve Travmatoloji Kongresi Kitabı; 18-23 Ekim 2003; İstanbul, Türkiye. İstanbul: Turgut Yayıncılık; 2003. s. 271-2.
40. Marti CB, Gautier E, Wachtl SW, Jakob RP. Accuracy of frontal and sagittal plane correction in open-wedge high tibial osteotomy. Arthroscopy 2004;20:366-72.
41. Stoffel K, Stachowiak G, Kuster M. Open wedge high tibial osteotomy: biomechanical investigation of the modified Arthrex Osteotomy Plate (Puddu Plate) and the TomoFix Plate. Clin Biomech 2004;19:944-50.
42. Naudie DD, Amendola A, Fowler PJ. Opening wedge high tibial osteotomy for symptomatic hyperextension-varus thrust. Am J Sports Med 2004;32:60-70.
43. Kettelkamp DB, Leach RE, Nasca R. Pitfalls of proximal tibial osteotomy. Clin Orthop Relat Res 1975;(106):232-41.
44. Spahn G, Wittig R. Primary stability of various implants in tibial opening wedge osteotomy: a biomechanical study. J Orthop Sci 2002;7:683-7.
45. Esenkaya I. A new distractor with angle-scale for proximal tibia medial opening wedge osteotomy. Knee Surg Sports Traumatol Arthrosc Epub 2005 Jun 15.