

# Monoplanar versus biplanar medial open-wedge proximal tibial osteotomy for varus gonarthrosis: a comparison of clinical and radiological outcomes

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## Abstract

**Purpose** We compared clinical and radiological results of two proximal tibial osteotomy (PTO) techniques: monoplanar medial open-wedge osteotomy and biplanar retrotubercle medial open-wedge osteotomy, stabilised by a wedged plate.

**Methods** We evaluated 88 knees in 78 patients. Monoplanar medial open-wedge PTO was performed on 56 knees in 50 patients with a mean age of  $55 \pm 9$  years. Biplanar retrotubercle medial open-wedge PTO was performed on 32 knees in 28 patients with a mean age of  $57 \pm 7$  years. Mean follow-up periods were  $40.6 \pm 7$  months for the monoplanar PTO group and  $38 \pm 5$  months for the biplanar retrotubercle PTO group. Clinical outcome was evaluated using the hospital for special surgery scoring system, and radiological outcome was evaluated by the measurements of femorotibial angle (FTA), patellar height and tibial slope changes.

**Results** In both groups, post-operative HSS scores increased significantly. No significant difference was found between groups in FTA alteration, but the FTA decreased significantly in both groups. Patellar index ratios decreased significantly in the monoplanar PTO group (Insall-Salvati

Index by 0.07, Blackburne-Peel Index by 0.07), but not in the biplanar retrotubercle PTO group. Tibial slopes were increased significantly in the monoplanar PTO group, but not in the retrotubercle PTO group.

**Conclusions** Biplanar retrotubercle medial open-wedge osteotomy and monoplanar medial open-wedge osteotomy are both clinically effective for the treatment for varus gonarthrosis. Retrotubercle osteotomy also prevents patella infera and tibial slope changes radiologically.

**Level of evidence** Therapeutic study, prospective comparative study, Level II.

**Keywords** High tibial osteotomy · Proximal tibial osteotomy · Medial open-wedge osteotomy · Biplanar retrotubercle osteotomy · Patella infera · Tibial slope

## Introduction

Medial open-wedge proximal tibial osteotomy (PTO) has gained popularity in recent years as a valuable treatment option for young, active patients with lower extremity varus osseous malalignment and symptomatic medial tibiofemoral compartment arthrosis [11, 14].

Although PTO is performed mainly in the frontal plane, both the sagittal and axial planes are differently influenced [16, 24, 35]. Classic monoplanar PTO leads to a decrease in patellar height (PH) and an increase in posterior tibial slope (PTS) in the sagittal plane [4, 5, 8, 13, 20, 28, 30]. In the monoplanar PTO technique, the attachment of the tibial tuberosity to the distal part of the tibia is maintained by performing a proximal tuberosity osteotomy or by positioning the osteotomy above the level of the tuberosity. In this condition, a decrease in PH (patella baja or infera)

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occurs due to distalisation of the tibial tuberosity as a result of wedge opening [11–13]. The resulting alterations in patellofemoral (PF) congruency and contact stress thus increase cartilage pressure and lead to PF osteoarthritis [1]. Furthermore, shortening of the patellar ligament often prevents eversion of the patella, and surgical exposure may be difficult during subsequent possible total knee arthroplasty (TKA). The increased risk of avulsion of the patellar tendon is a significant concern [25]. Another concern related to changing the sagittal plane for PTO is the PTS, a bony factor contributing to anteroposterior (AP) stability [4, 5, 8, 13, 30]. An increase in the PTS has been demonstrated to affect tibiofemoral cartilage pressure [1]. Therefore, consideration of the sagittal plane is important when making coronal plane corrections in PTO. Several surgical tibial osteotomy techniques have been described since the first definition of PTO [6, 11, 18, 22]. In the biplanar retrotubercle osteotomy technique, which was recently described by Gaasbeek et al. [12], the tuberosity remains attached to the proximal part of the tibia. Wedge opening does not change the position of the tuberosity; consequently, it does not affect PH and subsequently prevents PF problems [12, 33].

In this study, the clinical and radiological results of two PTO techniques (monoplane vs. biplanar retrotubercle medial open-wedge osteotomy) were compared. The study hypotheses were that the clinical results of biplanar retrotubercle medial open-wedge osteotomy would be better than those of monoplane medial open-wedge osteotomy, and that biplanar retrotubercle medial open-wedge osteotomy would prevent patella infera and tibial slope changes.

## Materials and methods

This study was performed in the Department of Orthopaedics and Traumatology, School of Medicine, İnönü University. Classic monoplane PTO procedures included in this study were performed between 2001 and 2008, and retrotubercle osteotomy procedures were performed between 2005 and 2009. Informed consent was obtained from the patients before the procedures. Preoperative data, including sex, age and body mass index (BMI), which was calculated using patients' height and weight, were recorded. Inclusion criteria for the study were varus deformity with pain at the medial side of the knee in patients with medial compartment arthrosis. An exclusion criterion for the study was the diagnosis of a lateral compartmental cartilage lesion (grade 3 or 4) during arthroscopy. A total of 109 patients with medial compartment arthrosis were treated with high tibial osteotomy (HTO). Twenty-four and seven patients in the monoplane PTO and biplanar retrotubercle PTO groups, respectively, were lost to follow-

up. Clinical and radiological assessments were performed for 88 knees in 78 patients. Among the 88 knees, 50 were right-sided, 18 were left-sided and 10 were bilateral. Monoplane PTO was performed on 56 knees in 50 patients (6 men and 44 women) with a mean age of  $55 \pm 9$  years. Biplanar retrotubercle osteotomy was performed on 32 knees in 28 patients (4 men and 24 women) with a mean age of  $57 \pm 7$  years. The average follow-up periods were  $40.6 \pm 7$  months for the monoplane PTO group and  $38 \pm 5$  months for the biplanar retrotubercle PTO group. Clinical outcomes were evaluated using the 100-point rating scale of the Hospital for Special Surgery (HSS) scoring system [23]. Arthrosis was evaluated according to radiological Ahlback and arthroscopic Outerbridge classifications [2, 27]. Preoperative, early post-operative (3 months) and late post-operative radiographic assessments were performed using the following parameters. The femoro-tibial angle (FTA) was evaluated according to the anatomical axis on  $30 \times 40$ -cm AP radiographs taken with the patient in a weight-bearing position, as described previously [15, 22, 36]. The normal FTA on radiographs taken under a load at  $175^\circ$  or  $5^\circ$  valgus and a  $180^\circ = 0^\circ$  anatomical varus angle was considered. Lateral radiographs were performed using a standard technique with the knee in  $20^\circ$ – $30^\circ$  of flexion, with the central beam at the joint line and no rotation of the limb. The goal was to obtain overlap of the posterior condylar lines within a 5-mm tolerance. If this condition was not met, the radiograph was excluded to avoid errors of measurement [8]. On the lateral radiographs, the Insall-Salvati Index (ISI) and Blackburne-Peel index (BPI) were used to determine PH and PTS. ISI  $<0.80$  and BPI  $<0.54$  were accepted as indicating patella infera or baja [3, 17]. The posterior inclination of the tibial plateau, which is referred to as the PTS, was determined according to the method described by Dejour and Bonin [7]. According to this, PTS was measured as the angle between the joint line of the proximal tibia and the lateral longitudinal axis of the tibia. The proximal tibial joint line was determined as tangent to the uppermost anterior and posterior edges of the medial plateau. Finally, preoperative and post-operative measurements of PH and tibial slope were compared, and the relationships, if any, between variation in the PH and PTS alteration, age, BMI and HSS scores were analysed.

## Surgical technique

All surgical procedures were carried out by the first two authors or under their supervision. First, arthroscopy was performed to address any intra-articular lesions in all patients. During arthroscopy, debridement of the degenerate tissues and meniscal tears, if present, was performed. Microfractures were made as focal Outerbridge grade IV

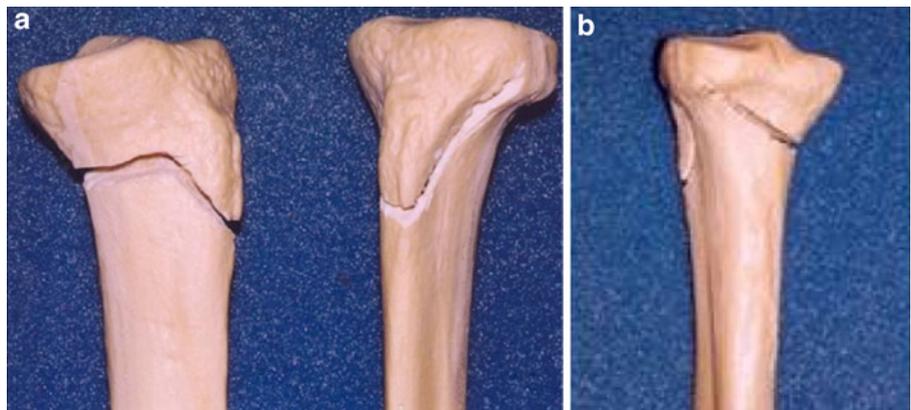
cartilage lesions. Arthroscopically, if the lateral compartment was significantly affected (Outerbridge grade III or IV), osteotomy was not performed. Both surgical techniques are reported in detail elsewhere (Figs. 1, 2) [11, 29]. The biplanar retrotubercle osteotomy technique, which was modified by one of the authors (I.E.), is similar to the osteotomy described by Gaasbeek et al. [12, 33]. In this modification, no screw is used to fix the proximal tibia, which contains the tibial tubercle, to the main body, and two plates with different wedge heights (TR2002 02021Y; Hipokrat Corp., Izmir, Turkey) are used to adjust the slope (Figs. 3, 4) [9, 10]. After completion of the osteotomy, bicortical iliac autografts were applied to the osteotomy gap in all patients.

A passive drain was inserted to avoid removal of growth factors in the bone grafts. A long-leg hinged brace was used post-operatively. Drains were removed on the second post-operative day, and walking with two crutches or a walker without weight-bearing was then allowed. Limited continuous passive motion (0°–30°) was begun on the third post-operative day, and 90° knee flexion was achieved on the 10th post-operative day. Low-molecular-weight heparin (LMWH) for deep vein thrombosis prophylaxis was given only for 10 days, and prophylaxis was then continued with an oral antiaggregant (aspirin, 100 mg). The same



**Fig. 1** Monoplanar proximal tibial osteotomy on the model, stabilised by wedge plates

**Fig. 2** Biplanar retrotubercle osteotomy on the model



rehabilitation programme was used in both groups. Non-weight-bearing was maintained until progression of bone healing was noted, typically at 6 weeks after surgery. Weight was then added in 25 % body weight increments each week until full weight-bearing was achieved.

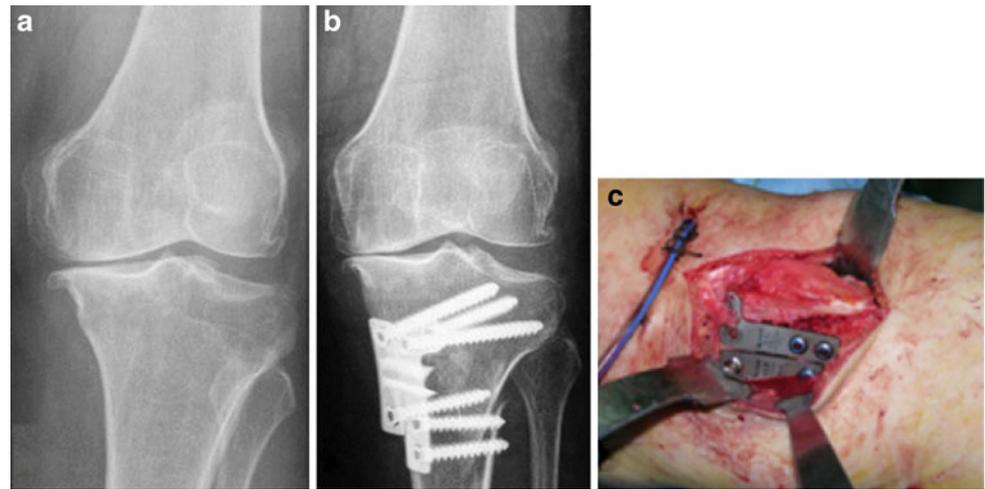
#### Statistical analysis

Statistical analysis was performed using SPSS software (ver. 13.0 for Windows; SPSS Inc., Chicago, IL, USA). The normality of continuous variable distribution was determined by the Shapiro–Wilk test. The variables showed normal distribution ( $p > 0.05$ ). Therefore, the preoperative and follow-up measurements were analysed using a paired-samples *t* test, and variables were compared between the study groups using an independent-samples *t* test. A value of  $p < 0.05$  was considered to be statistically significant.



**Fig. 3** Radiographs of a 48-year-old woman before operation and after monoplanar proximal tibial osteotomy procedure

**Fig. 4** **a, b** Radiographs of a 54-year-old woman before operation and after biplanar retrotubercle procedure.  
**c** Intraoperative view



## Results

Mean BMI was  $30 \pm 3 \text{ kg/m}^2$  in the monopolar PTO group and  $29 \pm 6 \text{ kg/m}^2$  in the retrotubercle PTO group. In comparison with preoperative clinical measurements, HSS scores increased significantly in the post-operative follow-up period in both groups ( $p < 0.05$ ). No significant difference in preoperative HSS score and clinical outcome was found between groups. Both groups showed a slight downward trend in HSS score with increasing age (Table 1), but neither BMI nor age had a significant effect on HSS score in either group. No patient had any correction loss due to rehabilitation or underwent TKA during follow-up.

**Table 1** Hospital for special surgery (HSS), femorotibial angle (FTA), Insall-Salvati Index (ISI), Blackburne-Peel Index (BPI) and posterior tibial slope (PTS) values for both groups

	Monopolar PTO	Biplanar PTO
HSS preop	$57.9 \pm 4.7$	$59.0 \pm 4.8$
HSS early postop	$92.0 \pm 3.5$	$88.6 \pm 6.5$
HSS last follow-up	$90.5 \pm 1.4$	$88.0 \pm 4.3$
FTA preop	$4.6 \pm 1.4^\circ$ varus	$5.1 \pm 2.8^\circ$ varus
FTA early postop	$8.4 \pm 2.3^\circ$ valgus	$6.5 \pm 2.2^\circ$ valgus
FTA last follow-up	$6.4 \pm 1.8^\circ$ valgus	$5.4 \pm 1.6^\circ$ valgus
ISI preop	$1.1 \pm 0.2$	$1.2 \pm 0.1$
ISI early preop	$1.0 \pm 0.1$	$1.2 \pm 0.1$
ISI last follow-up	$1.0 \pm 0.1$	$1.2 \pm 0.1$
BPI preop	$0.8 \pm 0.2$	$0.8 \pm 0.3$
BPI early postop	$0.8 \pm 0.1$	$0.8 \pm 0.1$
BPI last follow-up	$0.7 \pm 0.1$	$0.8 \pm 0.1$
PTS preop	$10.1 \pm 2.4$	$9.9 \pm 2.4$
PTS early postop	$11.5 \pm 2.7$	$10.7 \pm 3.0$
PTS last follow-up	$11.7 \pm 3.1$	$10.7 \pm 3.1$

## Radiological results

Differences in FTA measurements were significant in both groups ( $p < 0.05$ ; Table 1). Results obtained in both groups were mostly equal to or above physiological valgus. In both groups, a positive correlation between change in FTA and HSS score was found. In other words, the amount of correction loss adversely affected the HSS score ( $p < 0.05$ ). No relationship was found between the provided amount of correction and the degree of correction loss.

PTS increased post-operatively in both groups, but this change versus preoperative measurement was significant only in the monopolar PTO group ( $p < 0.05$ ; Table 1).

Both patellar index measurements showed significant decreases in PH ratios at the last follow-up examination in the monopolar PTO group. However, ISI values indicated patella infera in two patients, and BPI values indicated this condition in four patients in this group. In the biplanar retrotubercle PTO group, no patient was diagnosed with patella infera according to ISI and BPI measurements. Follow-up radiological changes of the PH are shown in Table 2. No correlation was found between the percentage of change and patient age or BMI.

**Table 2** Follow-up changes in patellar height according to Insall-Salvati Index (ISI) and Blackburne-Peel Index (BPI)

Patellar height	Monopolar PTO (knees)	Biplanar PTO (knees)
Lowering		
ISI	48	8
BPI	46	6
No change		
ISI	8	24
BPI	10	26

**Table 3** Degrees of osteoarthritis according to the criteria of Ahlback

	Monoplane PTO (knees)	Biplane PTO (knees)
Grade 2	30	14
Grade 3	22	16
Grade 4	4	2

The degree of osteoarthritis on preoperative radiographs, according to the criteria of Ahlback [2], is shown in Table 3.

Complications included two cases of fracture of the lateral tibial plateau in the monoplane PTO group. One complication was observed intraoperatively in an early case after opening a 12.5 mm wedge and was managed by lag screw fixation and compression of the lateral tibial fragments. In all subsequent cases, two Kirschner wires were placed parallel to the joint line at the start of the procedure. The second fracture was observed on a 6-week post-operative follow-up radiograph, during healing of the osteotomy. This complication was attributed to early weight-bearing before solid union, and full weight-bearing was delayed until complete union. Both osteotomies were healed after 12 weeks. One patient developed pulmonary embolism and was treated with LMWH in the Department of Chest Medicine. No other complication, such as superficial or deep infection, delayed union or non-union, was seen.

## Discussion

The most important finding of the present study was that the biplane retrotubercle open-wedge PTO technique prevents patella infera and tibial slope changes, in contrast to the monoplane open-wedge osteotomy technique.

PTO is a proven surgical technique for the treatment for unicompartmental varus gonarthrosis. It can provide symptomatic relief and mechanical realignment, and it is associated with a survivorship of approximately 80–90 % at 5 years and 60–70 % at 10 years [14, 15, 19, 34]. Different surgical techniques and new implants have been proposed since the first definition of PTO [11, 22, 26]. Moreover, although the biplane distal osteotomy cut was previously described, limited data are available on the clinical and radiological effects of this modification. In this study, clinical evaluation demonstrated significant post-operative functional improvement in both groups, as indicated by HSS scores, with no difference between groups. Although the short-term results of the procedure were usually excellent in this study, the results gradually deteriorated.

The main effect of PTO is the correction of mechanical alignment in the frontal plane. A slight over-correction of the mechanical or anatomical axis prevents the recurrence

of the deformity and provides better long-term results. A post-operative 5° mechanical valgus or 9°–10° anatomical valgus angle have been determined to be necessary for successful results. Hernigou et al. [14] achieved the best results in 20 knees in a series of 93 cases, indicated by an 8°–11° valgus anatomical axis after a 10–13-year follow-up period. Rudan and Simurda [31] considered that the degree of failure was higher when the post-operative FTA was <5° of anatomical valgus. According to them, the post-operative valgus value is the most prominent factor influencing prognosis. We believe that the mechanical or dynamic axis measurement methods on standing full-length radiographs of the lower extremity are more appropriate than anatomical axis measurement methods. However, in our clinic, we have no whole-length lower extremity (orthoroentgenography) system. Thus, we evaluated all cases only with 30 × 40-cm radiographs taken with the patient in a weight-bearing position, as previously described [14, 21, 35]; the FTA was evaluated preoperatively and post-operatively using the anatomical axis. In our patients, an average of 11° in the monoplane group and 10.5° valgus in the biplane group were obtained.

HTO, which is based on correcting frontal plane malalignment, can also create sagittal plane changes. An open-wedge osteotomy increases the PTS. The proximal anteromedial cortex of the tibia has an oblique triangular shape. Because of this configuration, open-wedge osteotomies that have equal anterior and posterior gaps increase the PTS. Giffin et al. [13] demonstrated an average increase of 4° in a cadaver study. In a clinical study, Marti et al. [24] found that the PTS increased by 4.2°. Other authors have confirmed these findings [1, 8]. A change in the sagittal plane of the tibial plateau is known to considerably influence the kinematics of the knee joint. Agneskirchner et al. [1] showed the influence of tibial slope on tibiofemoral cartilage pressure. Increase in the PTS causes a strain on the anterior cruciate ligament (ACL). In patients with an ACL-deficient knee, the resulting posterior shift of joint contact pressure could have an undesirable effect. Decreasing the tibial slope is recommended in ACL instability. In the present study, PTS was increased significantly (by 1.6°) postoperatively in the monoplane PTO group, but showed no significant change in the retrotubercle PTO group. The tibial slope can be controlled using differently sized wedge plates. We used a plate with a higher posterior wedge height and a lower anterior height [9, 10]. The lack of change in the retrotubercle PTO group may be due to the impact of the greater posterior wedge height of the plate in the majority of patients.

In the monoplane PTO technique, an osteotomy is performed from just proximal to the tibial tuberosity, as described by Debeyre and Patte [6] and popularised by Hernigou et al. [14], Fowler et al. [11] and Puddu et al. [29].

In the biplanar osteotomy technique, popularised by Lobenhoffer and Agneskirchner [22], the osteotomy is positioned above the level of the tuberosity. In the aforementioned monoplanar and biplanar PTO techniques, the tuberosity remains attached to the distal part of the tibia. However, this can result in a decreased PH, which may lead to patella infera, as shown in most previous studies [4, 20, 32, 36]. A preoperative determination of patella infera (patella baja) has been reported as a contraindication for PTO [22]. A decrease in PH associated with PTO has been attributed to distalisation of the tuberosity as a result of valgisation, shortening of the patellar ligament by scarring and a decreased distance between the patella and the tibiofemoral joint line as a result of joint line elevation. To prevent the formation of patella infera, some authors have suggested the use of a biplanar osteotomy technique in which the tibial tubercle is left in the proximal fragment and opening of the wedge does not change the position of the tuberosity. Consequently, it should not affect the PH [12, 33].

This study has certain limitations. First, we did not define PH quantitatively when identifying patients in whom we performed retrotubercle osteotomy; however, no subsequent change was observed in the length of the patellar tendon, as measured by the ISI and BPI. In the monoplanar PTO group, a statistically significant decrease in these indices occurred in the postoperative period. Another limitation of our study is that the follow-up period was relatively short. Previously, studies have shown that reduced PH may be associated with PF arthrosis, which causes anterior knee pain and shortening of the patellar ligament. This condition often prevents eversion of the patella, which makes conversion to subsequent TKA difficult after a failed HTO [25]. Therefore, prevention of patella infera is necessary for further intervention and good clinical results. The current study found that monoplanar PTO reduced PH, which did not lead to any negative clinical consequence. Measurements made at the last follow-up evaluation indicated no PH problem in the retrotubercle PTO group. However, a longer follow-up period is needed to determine whether this procedure effectively prevents anterior knee pain. Moreover, because none of our patients underwent TKA, we have not yet experienced the potential problems related to exposure and clinical outcome after failed osteotomy. We do not anticipate problems with PF exploration or PH difficulties in our patients; in such cases, the patients would need TKA. The results of this study indicate that biplanar retrotubercle osteotomy may be used in patients with PF osteoarthritis or patella infera.

## Conclusion

Both biplanar retrotubercle medial open-wedge osteotomy and monoplanar medial open-wedge osteotomy are

clinically effective in the treatment for varus gonarthrosis. In addition, the retrotubercle technique prevents patella infera and tibial slope changes radiologically.

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