Medial opening wedge high tibial osteotomy: a technique to avoid patella infera

Adham Elgeidi, Ahmed El-Hawary, Farouk Youssef

Department of Orthopaedic Surgery, Mansoura University, Mansoura, Egypt

Correspondence to Ass. Prof. Dr. Adham Elgeidi, MD (Orth & Trauma), PO Box 95, Mansoura University, Mansoura 35516, Egypt; Tel: +201061057973; Fax: +20502343232; e-mail: elgeidi@doctors.org.uk

Received 10 January 2013
Accepted 10 May 2013

The Egyptian Orthopaedic Journal
2016, 51:303–312

Background
High tibial osteotomy (HTO) is an established treatment for medial compartment osteoarthritis of the knee with varus malalignment. Medial opening wedge osteotomy eliminates most of the disadvantages of the lateral closing wedge osteotomy. Nevertheless, the changes in tibial slope and patellar height after opening wedge HTO with frequent occurrence of patella baja make subsequent knee arthroplasty more difficult.
Purpose
The purpose of this study was to evaluate the results of a simple technique for medial opening wedge HTO with internal fixation and early mobilization in patients with combined medial compartment osteoarthritis and varus alignment of the knee.
Patients and methods
Opening-wedge HTO and internal fixation with a standard AO large-fragment T plate with posterior tricortical iliac bone autograft was assessed. Forty-five patients with 61 knees with combined medial femorotibial osteoarthritis and varus deformity of the knee were treated with opening wedge HTO. There were 21 women with 29 knees, with a mean age 45.5 years (30–58 years), and 24 men with 32 knees, with a mean age 41.63 years (30–55 years). Mean follow-up was 35.9 months (13–62 months). Radiographic measurements [femorotibial angle, tibial slope, Insall–Salvati, and Blackburne–Peel (BP) ratios] were taken preoperatively and postoperatively and on follow-up. Preoperative and postoperative (last follow up) values of these parameters were compared.
Results
Fifty of the 61 (82%) knees had an excellent or good result, whereas in 11 knees there was recurrent pain. There were no implant failures, loss or correction, delayed union, or nonunion. Femorotibial angle was changed from a mean of –7.2° of varus into a mean of 8.3° of valgus (P=0.000). Tibial slope was significantly decreased from a mean of 11.4° to a mean of 9.2° (P=0.002). Insall–Salvati ratio was significantly increased from a mean of 1.1 to a mean of 1.2 (P=0.000). There was a significant decrease in the BP ratio from a mean of 0.9 to a mean of 0.7 (P=0.005). Twenty-five percent of postoperative BP values satisfied the criteria for patella infera (BP$<$0.54).
Conclusion
Opening wedge HTO using a simple technique with rigid fixation and early mobilization decreased the posterior inclination of the tibial slope, straightened the patellar tendon, and elevated the tibiofemoral joint line. The decrease in the inclination of the posterior slope of the tibia and the stretching of the patellar ligament compensate for the elevation of the joint line. This together with the early mobilization protocol resulted in the low incidence of patella infera.

Keywords:
high tibial osteotomy, opening wedge osteotomy, osteoarthritis, varus knee

Egypt Orthop J 51:303–312

1110-1148

Introduction

It is common experience that high tibial osteotomy (HTO) is a reliable procedure for the treatment of medial compartment osteoarthritis of a knee with varus malalignment with proper patient selection and a precise surgical technique. HTO is performed to stop or inhibit progression of osteoarthritis and to avoid or postpone total knee arthroplasty. To unload the medial compartment, a valgus producing correction is applied by performing either a closing wedge osteotomy or an opening wedge osteotomy [1,2].

The original technique of HTO is commonly credited to Jackson [3], who reported on eight procedures in 1958. This description involved a dome osteotomy and was later changed to a closing wedge osteotomy, both below the level of tibial tuberosity. Difficulties with bone healing below the tubercle led to popularization of a

 DOI: 10.4103/1110-1148.209009

closing wedge osteotomy proximal to the tibial tuberosity described by Gariépy [4] and by Coventry [5] to allow for more adjustability while maintaining the osteotomy at the same level proximal to the tuberosity.

Many techniques have been developed (i.e. closing wedge, opening wedge, dome, and Chevron osteotomies), but opening (medial) and closing (lateral) wedge osteotomies are the most commonly used [6–8].

Opening wedge osteotomy is a relatively new technique and is less involving in terms of surgical technique than closing wedge osteotomy. Opening wedge HTO offers several advantages over closing wedge procedure, including the single-cut osteotomy, and correction can be carefully adjusted intraoperatively in both the coronal and sagittal planes. Opening wedge HTO also restores the proximal tibial anatomy by addition of bone stock to the medial proximal tibia, preserves proximal tibiofibular joint, and does not violate the anterior muscle compartment. However, the principle disadvantages of opening wedge HTO are as follows: bone graft is often necessary, hence the associated morbidity of autograft or allograft bone, increased risk of delayed union or nonunion, and possible collapse or loss of correction. In opening wedge HTO, there is a concern about fracture of proximal tibia lateral aspect and the development of a potentially unstable construction and implant failure [1].

Although HTOs were initially used to correct deformities in the coronal plane, opening wedge osteotomies can simultaneously alter the tibial slope in the sagittal plane, which can happen inadvertently or deliberately [9].

Total knee replacement after HTO presents more technical problems and complications because of scars, valgus alignment, and patella baja [10].

In a 10–13-year follow-up of 92 patients, Hernigou *et al*. [11] described a simple opening wedge technique with favorable long-term outcome results. We describe a modification of the technique to decrease the occurrence of patella infera.

Purpose

Our aim was to evaluate the outcome of a simple technique for medial opening wedge HTO with internal fixation and early mobilization in 45 consecutive patients with combined medial compartment osteoarthritis and varus alignment of the knee and to compare our results with other series reported in the literature.

Our hypothesis was that through decreasing the posterior tibial slope and encouraging early postoperative mobilization we can decrease the incidence of patella baja, thus improving the results of any subsequent knee arthroplasty.

Patients and methods

Patients

A medial opening wedge HTO using a tricortical iliac bone autograft and fixed with a low-profile T-plate was performed at Mansoura University Hospitals, Egypt, on 61 knees in 45 consecutive patients with combined medial femorotibial osteoarthritis and varus deformity of the knee between 2007 and 2011. The study was approved by the local ethical committee and all patients were consented. There were 21 women with 29 knees and 24 men with 32 knees involved, ranging in age from 30 to 58 years, with a mean age of 43.4 years (SD=7.4 years). Sixteen patients underwent bilateral osteotomy. Mean follow-up was 35.9 months (13–62 months). The criteria for inclusion was osteoarthritis of the medial compartment with medial pain and varus malalignment. Varus alignment was defined as being present in those patients whose mechanical axis, as drawn on long leg standing radiographs, passed medial to the tip of the medial tibial spine [12]. All patients included in the study had intact cruciate ligaments as determined by clinical examination and confirmed by arthroscopy. The criteria for exclusion were symptomatic osteoarthritis of the lateral compartment, rheumatoid arthritis, diabetes mellitus, systemic steroid use, a range of movement of less than 100°, flexion contracture greater than 10°, lateral collateral ligament laxity of grade three, lateral tibial subluxation greater than10 mm, and history of previous open operation of the knee. Radiographic measurements [femorotibial angle (FTA), tibial slope, Insall–Salvati (IS), and Blackburne–Peel (BP) ratios] were taken preoperatively and postoperatively and on follow-up. Preoperative and postoperative (last follow-up) values of these parameters were compared.

Radiographic measurements

Standardized radiography was performed preoperatively and postoperatively on day 1, and then subsequently 6 and 12 weeks after the surgery and then as required, until the bone healing was evident. The presence of consolidation at the osteotomy site was assessed in both the anteroposterior (AP) and lateral radiographs. The patients were subsequently evaluated annually.

All patients obtained AP and lateral radiographs in 30° of knee flexion, a 45° patellar axial view, and a double long leg standing AP alignment radiograph. The

weight-bearing line and the mechanical axis were determined on long leg film as the line between the center of the femoral head and center of the ankle joint. The FTA were measured on long leg film as the angle that was formed by lines drawn from the midpoint between the tibial spines to the center of the femoral head proximally and to the center of the ankle joint distally. Tibial slope has been defined as the angle between a line perpendicular to the tibial shaft axis and the posterior inclination of the tibial plateau on the lateral film (Fig. 1) [13,14]. We chose the IS index and BP ratio for measurement of patellar height on the lateral radiograph. The IS ratio was calculated by dividing the length of the patellar ligament by the length of the patella [15]. The BP ratio was determined by dividing the perpendicular distance between the proximal tibial articular surface and the distal articular surface of the patella by the articular surface of the patella [16].

Radiographic linear distances or angular values were measured with a goniometer and recorded to the nearest 0.5 mm.

Preoperative planning

The method for the preoperative determination for the correction wedge was the same as previously described by Dugdale *et al.* [17]. The mechanical axis was calculated to be shifted from the medial tibial plateau to pass through the lateral tibial plateau at 62% of the width of the plateau. This will result in 2–4° valgus overcorrection. In full-length standing radiographs, a line drawn from the center of the femoral head to the midpoint of the ankle joint represents the mechanical axis of the leg. A second line is drawn from the center of the femoral head to a point located at 62% coordinate on the tibial plateau. A third line is drawn from the center of the ankle joint to the previous point. The angle formed by the intersection of the second and third lines determines the degree of correction required [17].

Surgical technique

We modified the standard operation technique previously described by Hernigou *et al.* [11]. A diagnostic knee arthroscopy was performed on every patient to ensure an intact lateral compartment and to treat additional intra-articular lesions.

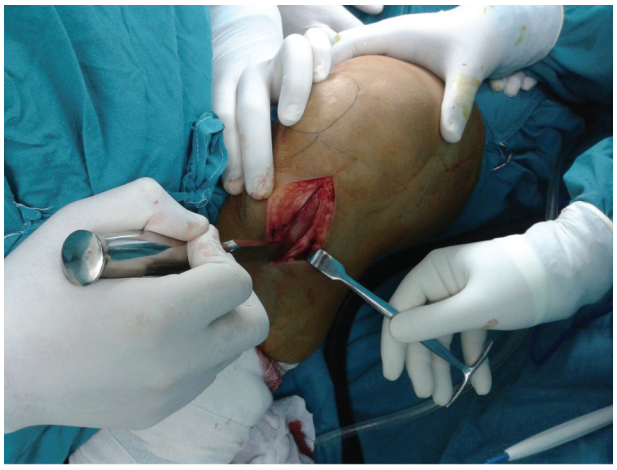
With the patient in supine position, both the involved limb and ipsilateral iliac crest were prepared and draped. Care was taken to maintain the leg in neutral rotation throughout the procedure.

The osteotomy procedure was performed through a vertical incision centered between the anterior tibial tubercle and the posteromedial border of the tibia, extending 10 cm distally from the medial joint line. The pes anserinus and the superficial medial ligament were incised in line with the skin incision, and sharp dissection was carried out to expose the medial surface of the tibia (Fig. 2). A blunt retractor was placed deep to the superficial medial collateral ligament to expose the posteromedial border of the proximal tibia, and the posterior surface of the tibia was fully exposed while knee is in flexion. A second retractor is placed under the patellar tendon to expose the anterior tibia. The most superior fibers of the patellar tendon insertion were released to improve exposure. Two K-wires were inserted subcutaneously parallel to the direction of the joint surface in the tibiofemoral joint line to mark the tibial slope. The level of the osteotomy was marked with electro cautery below the horizontal limb of the plate just

Figure 1

Tibial slope.

Figure 2



Pes anserinus and medial collateral ligament release.

placed abutting the joint line. This is ~2 cm distal to the medial joint line, along which another two K-wires were inserted parallel to the joint line guide pins just proximal of the tuberosity. The osteotomy was performed using a small oscillating saw parallel to and below the guide pins to help prevent intra-articular fractures or misdirection of the osteotomy. The lateral cortex was left intact as the saw-cut stopped 10 mm short off the lateral cortex. The gap was opened gradually by stepwise insertion of three chisels to avoid intra-articular fractures (Fig. 3). A 3-cm incision was made over the anterior iliac crest and dissection was deepened to the periosteum of the inner and outer ilium. The periosteum was sharply incised and reflected. The tricortical iliac crest bone wedge marked on the bone using electrocautery was harvested by a small oscillating saw (Fig. 4). The appropriate wedge of tricortical iliac bone autograft was inserted and impacted posterior to the plate with some cancellous bone anterior and posterior to it (Fig. 5). Internal fixation was performed using a four-hole conventional low-profile AO T-shaped plate and 4.5-mm cortical screws. The plate is fixed proximally, whereas the knees are in flexion with screws with appropriate length directed parallel to the K-wires in the joint line. Thus, we can avoid intra-articular placement of the screws and at the same time we checked that the screws are not in the osteotomy gap. We fixed the plate distally with the leg held in full extension aiming to avoid any flexion contracture. Full extension had to be achieved and was of uppermost importance. The wound was irrigated. No drain was used as a rule, and the incision was closed in layers. A soft Robert Jones bandage was applied for 24 h.

Intraoperatively, the limb alignment was checked with a metallic rod or a diathermy cable extended from the hip to the ankle. Care was taken not to break the lateral cortex during the tibial osteotomy in order to preserve some degree of stability between bone fragments [11,18]. All patients received antibiotic prophylaxis, and antithrombotic therapy (low-molecular-weight heparin) was given for 6 weeks.

Postoperative radiographs were taken after the operation, and then subsequently 6 and 12 weeks after the surgery and then as required, until the bone healing was evident. Full radiological consolidation was defined as bridging of the osteotomy gap with bone on both sides of the osteotomy, with no radiolucencies around the wedge [18]. In the current study, the average radiological consolidation was 12 weeks following the osteotomy.

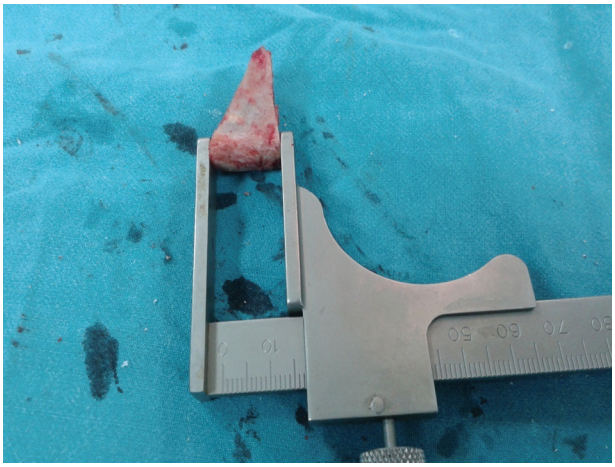
Postoperative rehabilitation

The patient is allowed touchdown weight-bearing in a knee brace for the first 6 weeks to prevent excessive

Figure 3

Three-chisel technique.

Figure 4



Graft sizing.

Figure 5

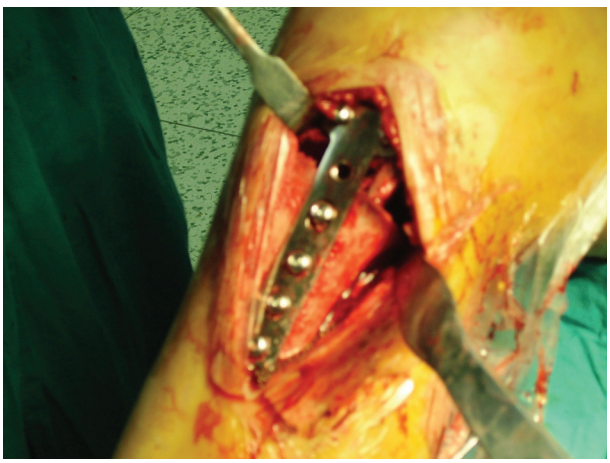


Plate is fixed anterior to the graft.

forces at the osteotomy site. Early knee range of motion and isometric quadriceps exercises were initiated. This has been shown to benefit joint healing and articular cartilage nourishment and prevent adhesions around patellar tendon, thus avoiding patella baja. After 6 weeks, weight-bearing is increased. Full weight-bearing is allowed when radiographic consolidation has taken place from the 12th week onward.

Statistical analysis

Statistical comparison between preoperative and postoperative data (at last follow-up) was performed using a paired sample *t*-test. A *P*-value of 0.05 was considered to be statistically significant.

Results

Clinical evaluation

The assessment method of Hernigou and colleagues was used in this study. Before operation and at the most recent follow-up, the severity of the patients' pain was assessed. The patients were also asked to indicate the maximum distance they could walk without stopping. Finally, the range of motion and stability of the knee were determined by clinical examination [11,19].

Pain relief

At a mean follow-up of 35.9 months (range: 13–62 months) after the osteotomy, 50 of 61 (82%) knees were pain-free during walking, whereas 11 knees were painful during weight-bearing and walking. The patients with the 50 pain-free knees could walk at least 1 km, and there was no limitation of activities because of the knee. Of the 11 painful knees, pain was slight in three, was moderate enough to restrict walking to less than 1 km and require occasional analgesics in six, and severe enough to restrict activity and require regular analgesics in two. No patient required revision surgery.

Range of motion

Before the operation, the average flexion of the knee was 125° (range: 100–145°). Postoperatively, the average was 120° (range: 95–145°). At the last follow-up, there was no correlation between flexion of the knee and the presence or absence of pain.

Stability

Laxity was determined by passive varus–valgus testing. Instability was established with varus–valgus excursion of 5° or more in full extension and 10° or more in 30° of knee flexion. Preoperatively, 18 knees were considered to be unstable; at the last follow-up, only five knees were unstable, and only one knee of the 18 preoperative unstable knees showed increased instability. At the final follow-up examination, all pain-free knees were stable and all unstable knees were painful.

Radiographic analysis

The comparative results of preoperative and postoperative FTA, posterior tibial slope, IS, and BP ratios are summarized in Table 1. FTA was changed from a mean of −7.2° of varus to a mean of 8.3° of valgus (P=0.000). Tibial slope was significantly decreased from a mean of 11.4° to a mean of 9.2° (P=0.002). IS ratio was significantly increased from a mean of 1.1 to a mean of 1.2 (P=0.000). There was a significant decrease in the BP ratio from a mean of 0.9 to a mean of 0.7 (P=0.005). Twenty-five percent of postoperative BP values satisfied the criteria for patella infera (BP<0.54). There was no correlation between the opening angle and the change in the degree of tibial slope inclination (FTA change vs. tibial slope change, P=0.061) or patellar height (FTA change vs. IS change, P=0.500; FTA change vs. BP change, P=0.130). There was no correlation between the change in the tibial slope and the patellar height (tibial slope change vs. IS change, P=0.277; tibial slope change vs. BP change, P=0.097).

Complications

There were seven major and four minor complications. The major seven complications were in seven patients. Two had intra-articular lateral plateau fracture, which was fixed at the time of surgery with no influence on the final clinical results. Four patients had ruptures of the opposite cortical hinge that was treated conservatively in Plaster of Paris immobilization for 4 weeks. The last one had intra-articular screw placement that was surgically rectified. The minor four complications occurred in four patients. Two had superficial infections that were treated conservatively with antibiotics with no influence on the final clinical results. The other two patients had irritation from the plate that required a separate surgery for plate and screw removal. During the whole period of the study, we did not report any case of implant failure, loss or correction, delayed union, or nonunion.

There were five complications in our series at the iliac graft site: two hematomas and one deep infection that

Table 1 Ratio comparisons (preoperative and postoperative)

	Mean		*P*-value
	Preoperative	Postoperative	
Femorotibial angle	−7.2	8.3	0.000
Tibial slope	11.4	9.2	0.002
Insall–Salvati ratio	1.1	1.2	0.000
Blackburne–Peel ratio	0.9	0.7	0.005

were cured by surgical lavage and antibiotics; one superficial infection was successfully treated with antibiotics; and one lateral cutaneous nerve damage. We noticed that iliac bone autograft harvesting can cause pain with trunk flexion for up to 6 weeks postoperatively.

Discussion

In this study, we investigated the results of a simple technique of opening wedge HTO using a conventional low-profile AO T-shaped plate and tricortical iliac bone autograft with early postoperative rehabilitation with view to decrease the incidence of postoperative patella infera. The data confirmed that this technique fulfilled the preconditions and stability criteria required for bone healing and consolidation. There were no cases of delayed or nonunion or implant failure. This technique decreased the angle of inclination of the posterior tibial slope, straightened the patellar tendon, and elevated the tibiofemoral joint line (Figs 6 and 7). The elevation of the joint line was compensated for by the relaxation of the patellar ligament and the decrease in the inclination of the posterior slope of the tibia. Patella infera occurred in 25% of cases in our series.

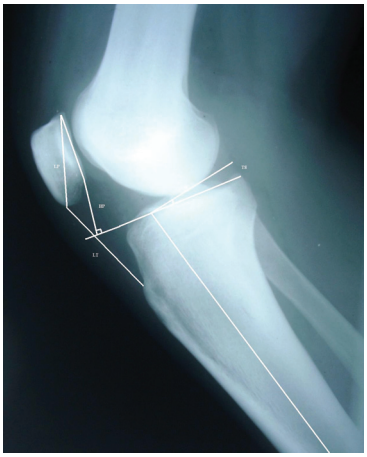
We modified the original technique described by Hernigou *et al.* [11] in three ways. First, we used a transverse cut parallel to the joint line instead of the oblique cut heading proximally toward the tip of the fibula. This is done to avoid the osteotomy extending into the lateral tibial plateau, especially with the large corrections that we achieved in this study (mean correction FTA: 15.5°) (Figs 8–10). Second, we achieved a full posteromedial soft tissue release instead of the full medial release as far as the level of the osteotomy. This is done with view to facilitate the posterior opening of the osteotomy gap and hence decreasing the posterior inclination of the tibial plateau. Third, we used one tricortical iliac bone graft inserted posteriorly instead of three bicortical grafts with the large one posterior and the two smaller ones anterior to it. This seems to give the needed stability criteria for bony consolidation and at the same time help closing the osteotomy gap anteriorly, thus helping in decreasing the slope and avoiding relative shortening of the patellar ligament.

Opening wedge HTO is, in fact, a simple procedure. It has a biomechanical purpose, and it is able to decrease the stresses on the medial compartment and to widen the joint space for several years. With neither special instruments nor expensive implants its cost is acceptable. Nevertheless, some issues remain that need resolutions; these include the graft selection in opening wedge osteotomies, and the type of fixation. Noyes *et al.* [18] concluded that opening wedge HTO problems can be avoided with proper selection of the patient, surgical technique, and the implant material or bone graft to be used to fill the osteotomy defect. Nelissen *et al.* [20] stated that 'surgical technique and implant stability are important factors for successful outcome'.

Many methods have been used to fill the gap, and these include bone grafts (autograft or allograft), synthetic bone substitutes (hydroxyapatite, β-tricalcium phosphate, a combination of both, bone cement) with or without platelet-rich plasma, growth factors, and bone marrow stromal cells [1].

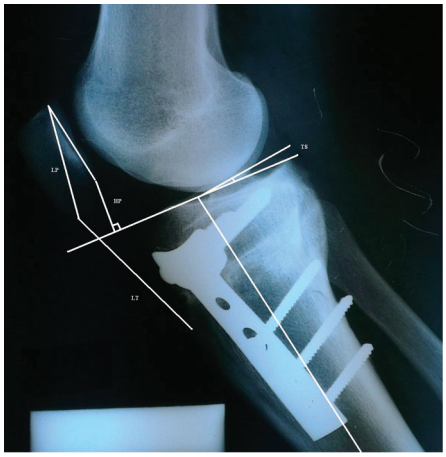
Bone graft is generally considered to be the most successful bone filling material because of its

Figure 6



Preoperative tibial slope=15°, Insall–Salvati ratio=1.1, Blackburne–Peel ratio=1.

Figure 7



Postoperative tibial slope=10°, Insall–Salvati ratio=1.4, Blackburne–Peel ratio=0.8.

osteoconductive, osteoinductive, and osteogenic properties [21–23]. Nevertheless, autograft harvesting involves increased operative time and the donor site morbidity, whereas allograft has lower osteoinductive properties and carries disease transmission risk. The bone substitutes attempt to reduce these risks, but there are still some concerns about their resistance to compressive loads and biological degradability. The use of bone cement is not recommendable in order to achieve a more biological repair of the osteotomy site [24].

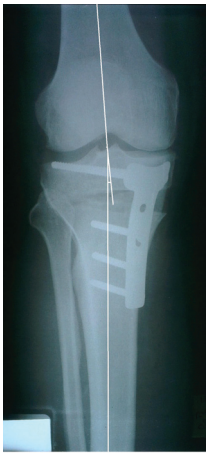
With opening wedge HTO, a stable fixation is required, and the most commonly used fixation devices include external fixators (both axial and circular) and plates (conventional, locking, long or short plates, with or without a spacer). A few biomechanical studies comparing the different fixation devices have been published, but the most reliable fixation system is still controversial [1]. Stoffel *et al.* [25] compared the biomechanical properties of the modified Puddu Plate (Arthrex, Naples, Florida, USA) and the Tomofix Plate (Synthes, Solothurn, Switzerland). The authors concluded that both plates create immediate stability, but with a lateral hinge fracture the Tomofix Plate showed enough residual stability, whereas the Puddu Plate required additional lateral fixation. Agneskirchner *et al.* compared four different plates: (i) short spacer plate, (ii) short spacer plate with multidirectional locking screws, (iii) long spacer plate with multidirectional locking screws, and (iv) long medial tibial plate fixator with locking screws. They stated that a rigid long plate fixator with angle stable locking screws yields the best results [26]. Zhim *et al.* [27] compared the biomechanical stability of the Puddu Plate (Arthrex) and the Hoffman II external fixator (Stryker Howmedica; Osteonics, Rutherford, New Jersey, USA) and concluded that plate fixation was superior in maintaining correction. Sphan *et al.* [28] in their biomechanical investigation on four different fixation devices (conventional plate, angle stable plate with or without spacer) concluded that spacer implants have superior properties and that angle stable plates may prevent fractures of the lateral cortex.

The results are still inconclusive and even if long-locking plates seem to show better biomechanical properties, they are bulky, expensive, and hardware removal is required in almost every case [20]. In our series, a conventional plate with 4.5 cortical screws was used. We had no implant failure and no loss of correction. This is a low-profile plate that did not cause irritation, with early removal for irritation in only two (3.3%) cases. However, it proved to be

Figure 8

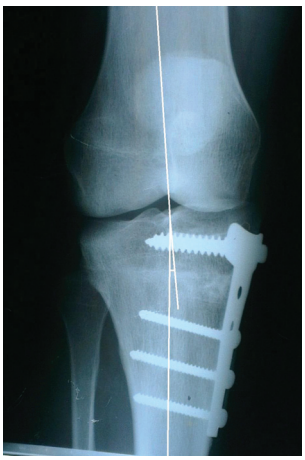
Preoperative femorotibial angle=−12°.

Figure 9



Postoperative femorotibial angle=+8°.

Figure 10



Femorotibial angle after bony consolidation remains+8°.

strong enough, in conjunction with tricortical iliac bone autograft, to enable early rehabilitation with no cases of delayed union or nonunion.

In this study, we investigated the effect of opening wedge HTO on both the tibial slope and patellar height. This technique decreased the angle of inclination of the tibial slope, straightened the patellar tendon, and elevated the tibiofemoral joint line. The elevation of the joint line was compensated for by the stretching of the patellar ligament and the decrease in the inclination of the posterior slope of the tibia. Patella infera occurred in 25% of cases in our series (BP<0.54).

In contrast to our study, many studies reported an increase in tibial slope after opening wedge HTO [29–32]. This tendency of the slope to enlarge during the operation is due to the strong posteromedial ligaments and the pes anserinus that act against the posterior opening of the osteotomy [32]. In our study, posterior tibial slope was significantly decreased from a mean of 11.4° to a mean of 9.2° (P=0.002). We achieved full posteromedial soft tissue release, inserted the bone graft wedge posteriorly, and fixed the plate in full extension in order to avoid any flexion at the osteotomy site. This seems to produce closure at the osteotomy opening anteriorly and widens the posterior gap. This decrease of the tibial slope sounds to be beneficial in two ways: first, it compensates for the effect of elevating the tibiofemoral joint line as a reference for patellar height, and, second, it decreases the likelihood of impingement of the patella against anterior tibia in patella infera situation.

Open-wedge osteotomy proximal to the tibial tuberosity has been reported to cause patella baja [30–35]. Patellar height loss may be due to three factors: joint line elevation, increased tibial slope, and patellar ligament shortening [34]. We chose the IS method because it is most frequently used. Second, we applied the BP method in accordance with the recommendation of Seil *et al*. [36].

The IS ratio is the index of patellar ligament length, whereas the BP ratio is a reference of patellar height relative to the tibiofemoral joint line. The IS ratio is a direct index of patellar ligament length and an indirect index of patellar height [35]. The IS index is independent of both the tibial slope and femorotibial joint line and hence the degree of osteotomy opening. IS ratio change is thus entirely a matter of patellar ligament shortening or stretching [34]. Brouwer *et al*. [33] reported a decrease in patellar ligament length (decreased IS ratio), but our procedure produced a significant increase in patellar ligament length from a mean of 1.1 to a mean of 1.2 (P=0.000). In this study, we used rigid fixation and applied early movement protocol that prevented retropatellar adhesions and allowed for patellar ligament stretching or straightening. The four cases with ruptures of the opposite cortical hinge that needed postoperative immobilization in the present study were associated with the greatest fall in patellar ligament length and patellar height. If the patellar ligament is seen in the sagittal view of MRI, we can see the lax and bowing patellar ligament. After opening wedge HTO, the patellar ligament straightens out from a lax and bowed state rather than lengthening [35].

The BP distance takes the three factors of patellar height loss – that is joint line elevation, altered tibial slope, and patellar ligament relaxation or shortening – into account [34]. Similar to our study, many studies reported almost systematic patellar lowering [18,30–35]. In our study, there was a significant decrease in the BP ratio from a mean of 0.9 to a mean of 0.7 (P=0.005). Opening wedge HTO increases the distance between the tibial tubercle and the tibiofemoral joint line. This elevates the tibiofemoral joint line relative to the patella. Wright *et al*. [31] reported that 64% of BP values satisfied the criteria for patella infera (BP<0.54). In our study, however, only 25% of postoperative BP values satisfied the criteria for patella infera (BP<0.54). We attribute this to the combined effect of the decrease in the tibial slope due to narrowing at the anterior osteotomy gap and the significant patellar ligament straightening. This may explain the absence of correlation between the degree of osteotomy opening and the patellar height loss in our series (FTA change vs. BP change, P=0.130). HTO with rigid fixation and early movement is advised to avoid patella baja.

The occurrence of patella infera in opening wedge HTO affects the patella–femoral biomechanics and has negative implications on subsequent revision to knee arthroplasty. However, these drawbacks could be lowered following opening wedge HTO if we can preserve patellar ligament length as in the current study. We agree with El Amrani [34] that it would be more logical to locate the patella with respect to the femur, not the tibia, as a reference. Miura *et al*. [37] reported no change in patellar height following tibial osteotomy using the femur as a reference. Hernigou *et al*. [19] briefly mentioned six conversions to total knee arthroplasty and noted that the prior opening wedge osteotomy did not jeopardize the result of the

arthroplasty. An adequate follow-up analysis of a series of total knee arthroplasy following opening wedge HTO has not been reported in the literature.

Limitations

One limitation of the current study is that this is a short-term study with a mean follow-up of 35.9 months. We recognize that longer follow-up is necessary to determine the efficiency of this procedure in patients for the long term. Another issue needs to addressed is the effect of slope change on the tibial translation and the cruciate integrity in the long term. With these issues in mind, we believe that the treatment protocol in this study improved the quality of life in the majority of patients (50 of 61; 82%).

Conclusion

The medial opening wedge HTO technique described here is a simple procedure. It is also less expensive and more suitable for some countries for socioeconomical reasons.

It meets the stability criteria necessary for bone consolidation with early functional postoperative rehabilitation with no implant failures.

The technique described here with complete soft tissue release off the posteromedial tibia, inserting the wedge posteriorly, and internal fixation in full knee extension with early mobilization decreased the posterior tibial slope, lengthened the patellar ligament, and elevated the tibiofemoral joint line with low incidence of patella infera.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1 Amendola A, Bonasia DE. Results of high tibial osteotomy: review of the literature. Int Orthop 2010; 34:155–160.

2 Jackson JP, Waugh W, Green JP. High tibial osteotomy for osteoarthritis of the knee. J Bone Joint Surg Br 1969; 51:88–94.

3 Jackson JP. Osteotomy for osteoarthritis of the knee. J Bone Joint Surg Br 1958; 40:826.

4 Gariépy R. Genu varum treated by high tibial osteotomy. J Bone Joint Surg Br 1964; 46:783–784.

5 Coventry M. Osteotomy of the upper portion of the tibia for degenerative arthritis of the knee: a preliminary report. J Bone Joint Surg Am 1965; 47:984–990.

6 Amendola A, Panarella L. High tibial osteotomy for the treatment of unicompartmental arthritis of the knee. Orthop Clin North Am 2005; 36:497–504.

7 Amendola A, Rorabeck CH, Bourne RB, Apyan PM. Total knee arthroplasty following high tibial osteotomy for osteoarthritis. J Arthroplasty 1989; 4 (Suppl):S11–S17.

8 Amendola A. Unicompartmental osteoarthritis in the active patient: the role of high tibial osteotomy. Arthroscopy 2003; 19:109–116.

9 Rodner CM, Adams DJ, Diaz-Doran V, Tate JP, Santangelo SA, Mazzocca AD, Arciero RA. Medial opening wedge tibial osteotomy and the sagittal plane. Am J Sports Med 2006; 34:1431–1441.

10 Haddad FS, Bentley G. Total knee arthroplasty after high tibial osteotomy: a medium term review. J Arthroplasty 2000; 15:597–603.

11 Hernigou P, Medevielle D, Debeyre J, Goutallier D. Proximal tibial osteotomy with varus deformity: a ten to thirteen year follow-up study. J Bone Joint Surg Am 1987; 69:332–354.

12 Arthur A, LaPrade RF, Agel J. Proximal tibial opening wedge osteotomy as the initial treatment for chronic posterolateral corner deficiency in the varus knee: a prospective clinical study. Am J Sports Med 2007; 35:1844–1850.

13 Giffin JR, Vorgin TM, Zantop T, Woo S, Harner CD. Effects of increasing tibial slope on the biomechanics of the knee. Am J Sports Med 2004; 32:376–382.

14 Giffin JR, Stabile KJ, Zantop T, Vorgin TM, Woo S, Harner CD. Importance of tibial slope for stability of the posterior cruciate ligament-deficient knee. Am J Sports Med 2007; 35:1443–1449.

15 Insall J, Salvati E. Patella position in the normal knee. Radiology 1971; 101:101–104.

16 Blackburne JS, Peel TE. A new method of measuring patellar height. J Bone Joint Surg Br 1977; 59:241–242.

17 Dugdale TW, Noyes FR, Styer D. Pre-operative planning for high tibial osteotomy. The effect of lateral tibio-femoral separation and tibiofemoral length. Clin Orthop 1992; 274:248–264.

18 Noyes FR, Mayfield W, Barber-Westin SD, Albright JC, Heckeman TP. Opening wedge high tibial osteotomy. An operative technique and rehabilitation program to decrease complications and promote early union and function. Am J Sports Med 2006; 23:1262–1273.

19 Hernigou P, Roussignol X, Flouzat-Lachaniette CH, Filippini P, Guissou I, Poignard A. Opening wedge tibial osteotomy for large varus deformity with Ceraver resorbable beta tricalcium phosphate wedges. Int Orthop 2010; 34:191–199.

20 Nelissen EM, van Langelaan EJ, Nelissen RGHH. Stability of opening wedge high tibial osteotomy: a failure analysis. Int Orthop 2010; 34:217–223.

21 Eid K, Zelicof S, Perona BP, Sledge CB, Glowacki J. Tissue reactions to particles of bone-substitute materials in intraosseous and heterotopic sites in rats: discrimination of osteoinduction, osteocompatability, and inflammation. J Orthop Res 2001; 19:962–969.

22 Gaasbeek RD, Toonen HG, van Heerwaarden RJ, Buma P. Mechanism of bone incorporation of beta-TCP bone substitute in open wedge tibial osteotomyin patients. Biomaterials 2005; 26:6713–6719.

23 LeGeros RZ. Properties of osteo-conductive biomaterials: calcium phosphates. Clin Orthop Relat Res 2002; 395:81–98.

24 Aryee S, Imhoff AB, Rose T, Tischer T. Do we need synthetic osteotomy augmentation materials for opening-wedge high tibial osteotomy. Biomaterials 2008; 29:3497–3502.

25 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 (Bristol, Avon) 2004; 19:944–950.

26 Agneskirchner JD, Freiling D, Hurschler C, Lobenhoffer P. Primary stability of four different implants for opening wedge high tibial osteotomy. Knee Surg Sports Traumatol Arthrosc 2006; 14:291–300.

27 Zhim F, Laflamme GY, Viens H, Saidane K, Yahia L. Biomechanical stability of high tibial opening wedge osteotomy: internal fixation versus external fixation. Clin Biomech (Bristol Avon) 2005; 20:871–876.

28 Sphan G, Mückley T, Kahl E, Hofmann GO. Biomechanical investigation of different internal fixations in medial opening wedge high tibial osteotomy. Clin Biomech (Bristol, Avon) 2006; 21:272–278.

29 Koshino T, Yoshida T, Ara Y. Fifteen to twenty-eight years follow-up results of high tibial valgus osteotomy for osteoarthritic knee. Knee 2004; 11:439–444.

30 Kesmezacar H, Erginer R, Ogut T, Seyahi A, Babacan M, Tenekecioglu Y. Evaluation of patellar height and measurement methods after high tibial osteotomy. Knee Surg Sports Traumatol Arthrosc 2005; 13:539–544.

31 Wright JM, Heavrin B, Begg M, Sakyrd G, Sterett W. Observations on patellar height following opening wedge proximal tibial osteotomy. Am J Knee Surg 2001; 14:163–173.

32 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:S-B55–S-B62.

33 Brouwer RW, Bierma-Zeinstra SM, van Koeveringe AJ, Verhaar JA. Patellar height and the inclination of the tibial plateaue after high tibial osteotomy. The open versus the closed-wedge technique. J Bone Joint Surg Br 2005; 87:1227–1232.

34 El Amrani MH, Levy B, Scharycki S, Asselineau A. Patellar height relevance in opening-wedge high tibial osteotomy. Orthop Traumatol Surg Res 2010; 96:37–43.

35 Chae DJ, Shetty GM, Lee DB, Choi HW, Han SB, Nha KW. Tibial slope and patellar height after opening wedge high tibial osteotomy using autologus tricortical iliac bone graft. Knee 2008; 15:128–133.

36 Seil R, Müller B, Georg T, Kohn D, Rupp S. Reliability and interobserver variability in radiological patellar height ratios. Knee Surg Sports Traumatol Arthrosc 2000; 8:231–236.

37 Miura H, Kawamura H, Nagamine R, Urabe K, Iwamoto Y. Is patellar height really lower after high tibial osteotomy. Fukuoka Igaku Zasshi 1997; 88:261–266.