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The oblique high tibial osteotomy technique without bone removal and with rigid blade plate fixation for the treatment of medial osteoarthritis of the varus knee: medium and long-term results

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Abstract Several high tibial osteotomy (HTO) surgical techniques for the treatment of medial osteoarthritis of the varus knee have been reported. Their main objectives are the achievement of the precise correction that is necessary for the lower limb mechanical axis realignment and the alleviation of the medial joint space. Early or late recurrence of the varus deformity must be avoided and various methods of fixation have been proposed to obtain this. We present a method of single level oblique HTO with no bone removal and with blade plate fixation for the treatment of medial osteoarthritis of the knee. One hundred seventeen patients (136 knees) were operated using this technique during a 12.2-year period. In 4.5 years follow-up there were 73.8% satisfactory results while in 8.4 years follow-up there were 61.1% satisfactory results. There were 11 complications: five patients with deep vein thrombosis, four with superficial wound infection and two with temporary peroneal nerve dysfunction. This study presents the operative technique in details, evaluates the results and assesses the advantages and disadvantages of the method in relation to other techniques described in the literature.

Keywords High tibial osteotomy · Mechanical axis · Unicompartmental osteoarthritis · Varus knee · Blade plate fixation

Introduction

High tibial osteotomy (HTO) remains a widely accepted method for the treatment of medial osteoarthritis of the varus knee. Since 1958, when Jackson reported on his first cases of HTO [19], many surgical techniques have been reported, combining different ways of pre-operative evaluation, correction and stabilization of the osteotomy [13, 26, 47]. All of them address the same principles: correction of lower limb malalignment, pain relief, ambulation improvement and retardation of the degenerative process [15]. With this study we present our experience with a single level oblique HTO.

Materials and methods

From March 1984 to May 1996, a total of 136 HTOs were performed in 117 patients for osteoarthritis of the medial compartment of the knee and have been kept under review. At the time of intervention, the patients, 42 men and 75 women, had an average age of 61.4 years (range 48–67).

Pain on the medial side of the knee that limited activities and decreased the quality of life of the patients, combined with radiographs that demonstrated unicompartmental joint space deterioration, associated with an abnormal lower extremity varus alignment were the main indications for HTO. In order to evaluate the degree of osteoarthritis of the medial compartment in the pre-operative radiographs, the Ahlbäck 5-degrees radiographic scale classification was used [1]. Degree I included patients with slight reduction of the cartilage height (joint space narrowing). Patients with obliteration of joint space were considered to have degree II of osteoarthritis, while bone loss (erosion) up to 5 mm with minor bone attrition corresponded to degree III of osteoarthritis. Moderate bone attrition, with bone loss between 5 and 10 mm was the main feature of degree IV, while major bone attrition with bone loss more than 10 mm (usually with subluxated position of the tibia in relation to the femur) delineated degree V of osteoarthritis. Only patients with degree I, II, and III of osteoarthritis were considered appropriate for HTO. A high level of pre-operative activity rather than the strict chronological age of the patients contributed also seriously in the decision to perform an HTO. Pre-operative exclusion criteria included varus deformity exceeding 15°, fixed flexion deformity more than 10°, range of motion less than 100°, ligamentous instability, Ahlbäck degree IV and V of medial osteoarthritis, inflammatory arthritis and advanced patellofemoral arthritis. Patients with incidental accompanying lateral joint pain but with no radiographic findings of osteoarthritis were re-evaluated by arthroscopy during the procedure and lateral compartment disease was excluded as this was also an absolute contraindication to a corrective osteotomy.

Operative technique

In the proposed method precise pre-operative planning is essential and is based on a long-leg weight-bearing AP radiograph of both limbs, as well as, standard AP and lateral radiographs of the affected knee. Mechanical axis measurement and the needed amount of correction are estimated in a conventional way as it was proposed by Coventry [7]. Since 1994, parallel to this method of pre-operative planning, we also started to use a spiral CT-scanner to obtain coronal scanogram of both lower limbs (Fig. 1). Using this implement the patient is placed in the scanner table with his/her patella facing the roof. The correct position of the limb is verified by the appropriate orientation of the posterior surface of the femoral condyles, as they are delineated in the axial images of the distal femur. To help maintaining the correct position a special adjustable radiolucent knee holder in the extended position is used. In this way any undesirable rotation of the limb is prevented as this could interfere with the real mechanical axis measurement. The scanogram provides all the necessary details for the pre-operative measurements. All the axes of the lower limb and the orientation of knee and ankle joints can be drawn and measured, as well as the length of the limb and any deformities in the coronal plane; the exact amount of correction needed is calculated in the same way as in the conventional long-leg AP radiograph. As no patients in this series had any kind of ligamentous insufficiency this way of mechanical axis measurement proved also to be as accurate as the traditional way of weight-bearing radiograph measurement, in the small number of cases that it was used [33]. However, long-leg weight-bearing AP radiograph is still the main method of pre-operative planning, while scanogram is reserved only for selective cases (i.e. patients who cannot tolerate or comply with the standing position).

Fig. 1 A typical scanogram of a patient with bilateral knee medial osteoarthritis. All the axes of the lower limb and the orientation of knee and ankle joint surfaces can easily be measured, as in the conventional long-leg weight-bearing AP radiograph

The operation is performed with a tourniquet on the thigh and the knee is flexed to 30°, to allow for the neurovascular structures to fall posteriorly. The fibula is osteotomized first at the junction of the middle to distal third through a separate incision. This is an area with a relative smaller danger for peroneal nerve lesion [10, 21]. Spoon-shaped Hohmann elevators are placed circularly

Fig. 2 **a** The patented osteotomy guide placed parallel to the lateral surface of a 12° varus synthetic composite tibia model (Sawbones Europe AB, Malmö, Sweden). Note the insertion of the K-wire in the Gerdy's tubercle in an obtuse angle equal to 90° plus the desired angle of correction. In the inset picture note the posteromedial direction of the wire (the hole on the posterior aspect of the tibial epiphysis is provided by the manufacturer of the model). **b** A radiograph of the tibia model after placement of the guiding chisel (the K-wire has been removed)

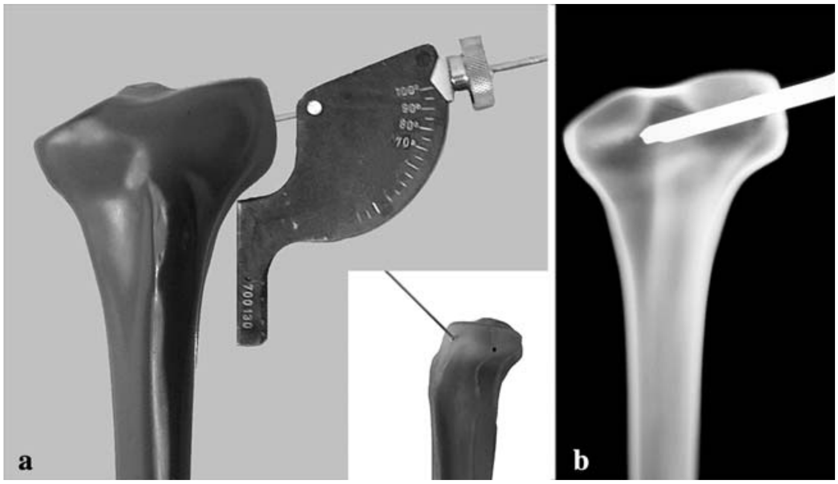
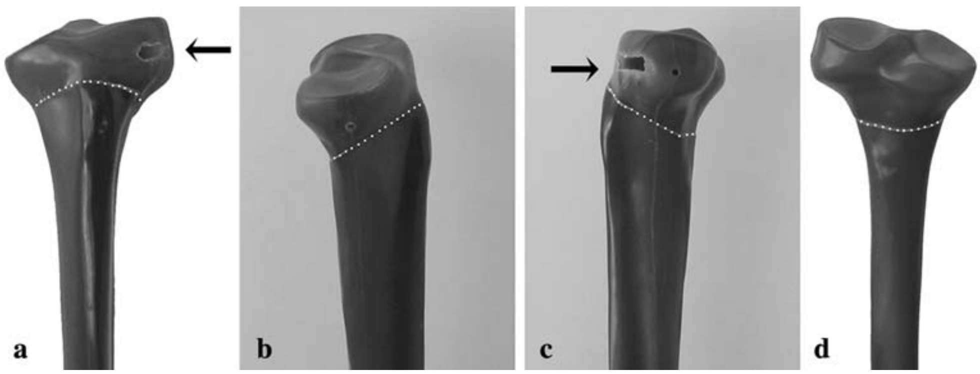


Fig. 3 The level and the direction of the osteotomy (dotted line): **a** anterior, **b** medial, **c** lateral and **d** posterior view. The blade plate insertion hole (*arrows*) has already been prepared with the chisel



around the bone to protect the soft tissues and the nerve when the fibula is divided in an oblique fashion.

The knee skin incision for the tibial osteotomy starts from the middle of the lateral margin of patella and is extended to the tibial tuberosity slightly curved. Then it is extended 4 cm distally to it, remaining 1 cm lateral and parallel to the anterior crest of the tibia. The anterior muscles and the periosteum are detached and the lateral surface of the proximal part of the tibia is exposed, as well as the patellar tendon insertion. During the evolution of this technique a patented osteotomy guide has been created in order to place a Kirschner guide wire (K-wire) in the area of Gerdy's tubercle. This osteotomy guide is placed on the lateral surface of the proximal part of the tibia and the K-wire is inserted at Gerdy's tubercle in a direction that formes an angle with the lateral cortex of the tibia—which is parallel to mechanical axis of the tibia—of 90° plus the necessary amount of correction, as measured pre-operatively (Fig. 2a). The wire is also oriented 15° posteromedially in order to be away from the smaller anterior part of the proximal tibia fragment that would be created after the osteotomy and to help in the accurate accommodation of the fixation plate on the lateral tibial surface. A guiding chisel is then driven through the special chisel mount hole of the osteotomy guide parallel to the K-wire in order to prepare the blade plate insertion pathway (Fig. 2b). Following this the osteotomy of the tibia is performed with an oscillating saw or a plain osteotome, usually in a free hand manner. The direction of the osteotomy is oblique, starting just above the tibial tuberosity, behind the insertion of the patellar tendon, extending obliquely, posteriorly and inferiorly towards the posterior cortex of the tibia, at an angle of about 30° related to the longitudinal axis of the tibia (Fig. 3). After the osteotomy has been completed an adolescent 90° blade plate is inserted in the hole that had been previously prepared by the chisel. When the blade is in place, the vertical part of the plate forms an angle with the lateral cortex of the tibia that is the angle of the desired correction. Next the tibia is shifted towards a valgus position and slightly internally rotated until its lateral cortex touches the plate, with the two surfaces of the osteotomy grinding (sliding) on each other in the coronal plane like the two buhrstones of a mill (Fig. 4). At this time, if indicated, we can displace the distal fragment of the osteotomy—and the tibial tuberosity that is attached to it—slightly anteriorly, achieving a decom-

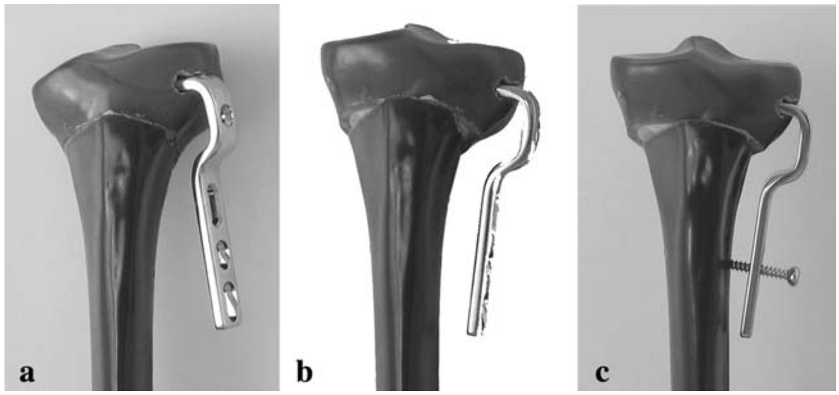


Fig. 4 Varus malalignment correction: **a** The osteotomy has been performed and the blade plate has been inserted. The angle between the vertical part of the plate and the lateral cortex of the tibia is the angle of correction that was estimated pre-operatively. **b** The distal part of the osteotomy is slided-shifted towards the plate in order to achieve the desired correction. **c** Fixation of the plate in the tibia diaphysis

pression of the patellofemoral joint as was described by Maquet [26]. The plate is then fixed on the tibia; the proximal part of the osteotomy is usually fixed with the use of a cancellous fully threaded screw through the proximal hole of the plate. If it is necessary, additional fixation can be achieved through a lag screw, which is inserted in anteroposterior direction compressing the oblique surfaces of the osteotomy. Meticulous haemostasis is done after tourniquet deflation and the two wounds are closed routinely. Drains in both wounds, as well as the decompression of the anterior compartment through the anterior incision are ordinarily used as preventive measures to avoid any compartment syndrome.

Fig. 5 Anteroposterior radiograph of a left varus knee managed with the proposed method of osteotomy 8.5 years ago. Note the proximal fully threaded cancellous screw and the anteroposterior lag screw. The osteoarthritic changes of the knee joint are obvious and the patient was finally treated with total knee arthroplasty

No cast or braces are used post-operatively as the blade plate provides sufficient stability. Passive motion of the knee is started as tolerated, usually from the second post-operative day. Active range of motion exercises are indicated as soon as the post-operative pain subsides. Partial weight bearing is allowed in accordance to osteotomy healing, usually 6 weeks post-operatively. Routine AP and lateral knee radiographs are performed immediately post-operatively, 6 weeks, 3, 6, and 12 months after the operation and during follow-up visits thereafter (Fig. 5). A long-leg weight-bearing AP radiograph of the limb (or scanogram) is obtained only after osteotomy had healed in order to assess the re-alignement of the mechanical axis definitively.

At a mean of 4.5 years (range 3.2–7.5) it was possible to review 107 HTOs (*Follow-Up A*) for a medium-term follow-up in 99 patients (34 men and 65 women) with a mean age of 64.8 years (range 51–71). At this stage six patients had died and 12 patients could not be located. In a second evaluation (*Follow-Up B*) at a mean of 8.4 years (range 5–11.2) it was possible to review 95 HTOs (group 2) in 87 patients (37 men and 50 women) with a mean age of 69 years (range 53–77). In this follow-up eight additional patients had died and four additional patients could not be located.

The results of this series were evaluated according to the Hospital for Special Surgery knee score [16]. A score of 85–100 points was considered to be an excellent result; 70–84 good; 60–69 fair and less than 60 poor. Furthermore, these results were subdivided in three sequenced categories corresponding to the obtained mechanical axis as it was measured after osteotomy healing. The first category was for patients in whom their mechanical axis was lower or equal to 180°, the second when the axis was 181–184° and the third when the axis was equal or bigger than 185°. Statistical analysis was performed using the Pearson chi-square test to detect if the results of the last follow-up were related or not with the mechanical axis, as it was measured in a long-leg weight-bearing AP radiograph (or scanogram) of the limb after osteotomy healing.

Results

The post-operative complications included five patients with deep vein thrombosis who required hospitalization for intravenous heparin therapy, four patients with superficial infection that responded to antibiotic treatment and two patients with a transient peroneal nerve palsy that recovered totally without any intervention after a period of 10 and 12 weeks, respectively. No cases of vascular injury, compartment syndrome, avascular necrosis of the proximal tibia and osteotomy site malunion or nonunion were noted. All the osteotomies showed radiographic signs of union in between 6 months post-operatively.

The review of the pre-operative charts of the patients of *Follow-Up A* revealed a varus mechanical axis of 172° (range 165–175°). This axis was corrected to 183° (range 178–189°) as was measured after osteotomy healing and at the last of our examination was found to be 178° (range 173–186°). Seventy nine of the HTOs (73.8%) were rated to have excellent and good results; 17 (15.9%) had fair result and 11 (10.3%) had poor result. In five HTOs (4.6%) in five patients the osteotomy was converted to total knee arthroplasty during this follow-up period. These patients were considered to have a poor result (Table 1).

The mechanical axis of the patients of *Follow-Up B* was 170° (range 165–174°) pre-operatively; was corrected to 183° (range 177–189°) as was measured after osteotomy healing and at the last of our examination was found to be 175° (range 170–185°). Fifty eight of the HTOs (61.1%) were rated to have excellent and good results; 16 (16.8%) had fair result and 21 (22.1%) had poor result. These poor results included 12 HTOs (12.6%) in ten patients, where the osteotomy had to be converted to total knee arthroplasty during this follow-up period (Table 2).

Further analysis of the results of *Follow-Up* groups *A* and *B* of this study reveals that mechanical axis realignment as was measured after osteotomy healing and medium and long-term post-operative results are not independent. In both of them, the chi-square criterion shows a significant relationship (respective values: $P < 0.0001$ and $P = 0.003$) between these variables. Of note should be that the larger contribution in forming the values of excellent and good results comes from the patients with the 181–184° mechanical axis after osteotomy healing.

Table 1 Results of 99 patients (107 osteotomies), who were available in *Follow-Up A* after a mean of 4.5 years

Follow-Up A 99 patients: 107 HTOs		Mechanical axis			Total
		≤ 180°	181–184°	≥185°	
Results	Excellent + good	6	52	21	79 (73.8%)
	Fair	5	8	4	17 (15.9%)
	Poor	7	2	2	11 (10.3%)
	Total	18	62	27	107 (100%) $P < 0.0001$

The obtained results (*rows*), as were evaluated according to the Hospital of Special Surgery knee score, were further subdivided in three categories (*columns*) corresponding to the mechanical axis as was measured after osteotomy healing

Table 2 Results of 87 patients (95 osteotomies), who were available in *Follow-Up B* after a mean of 8.4 years

Follow-Up B 87 patients: 95 HTOs		Mechanical axis			Total
		≤ 180°	181–184°	≥185°	
Results	Excellent + good	5	38	15	58 (61.1%)
	Fair	3	9	4	16 (16.8%)
	Poor	10	6	5	21 (22.1%)
	Total	18	53	24	95 (100%) $P = 0.003$

The results were subdivided similarly to Table 1

Discussion

The basic concept for any realignment osteotomy about the varus knee is to transfer the weight-bearing forces from the affected medial joint compartment to the healthier lateral joint compartment [28, 42]. Even though specific outlines have been drawn during the last decades concerning the appropriate indications for HTO, it seems difficult to separate the pre-operative status of the knee (varus malalignment and radiographic degree of osteoarthritis) from other factors such as the age, the pre-operative level of activity, or the personality and the general status of the patient [15, 16, 20, 27].

A considerable percentage of patients in this study derived from an agricultural and heavy-labour workers population with high-demand, active lifestyle. Therefore, their physiological rather than their chronological age, combined with their desire to keep on their pre-operative activities were influential in the decision to perform an HTO [2, 22]. In nowadays unicompartmental arthroplasty could have been another treatment option, but we still consider HTO to be the more appropriate procedure for ''reasonably younger'', active patients with medial osteoarthritis, as an arthroplasty implies limitations on post-operative physical activities and has a limited life expectancy. A high level of activity may have potential adverse effects on the durability of the polyethylene articular surface of a knee arthroplasty and on the fixation of the implant [2, 17]. Additionally, unicompartmental arthroplasty was technically more difficult and with debatable long-term results during the period that our patients were treated, and it is only recently that improved design of unicompartmental prostheses and the introduction of guide instruments for precise surgical techniques have improved the survival of the procedure [4, 29, 41]. As a result, we now reserve unicompartmental arthroplasty for the treatment of medial osteoarthritis, only for patients over 60 years of age, with low-activity demands and minimal malalignment that can be passively corrected pre-operatively [17].

The pre-operative radiographic level of osteoarthritis of the medial compartment was also weighty in our decision to perform an HTO. Many studies have shown that the best results in knees treated with HTO, were seen in patients with a minor or mild degree of osteoarthritis in the pre-operative radiographs [18, 35, 44]. In our series patients with Ahlbäck degree IV and V of medial osteoarthritis [1], which suggested moderate to major bone attrition, usually with lateral subluxation (translation) of the tibia in relation to the femur, were excluded from this kind of treatment.

Several special techniques for HTO of the varus knee have been described [5, 13, 20, 24, 25]. Their increasing number reflects the need to achieve precise correction intra-operatively and obtain long-term satisfying results. Lateral closing wedge osteotomy with staples fixation was popularized by Coventry [6–8]. In order better fixation and stability to be achieved and cast immobilization to be avoided, modifications with blade plate or other types of plate fixation have been reported [11, 13]. The main disadvantages of the method are the limited bone stock of the proximal tibia and the patella infera that follow after wedge removal, as the tibial tuberosity comes closer to the knee joint line [43, 45]. These may pose technical difficulties concerning patella eversion and tibial component placement if a total knee arthroplasty becomes necessary later on in the course of the disease [14]. In the medial opening wedge osteotomy technique the fibula is not osteotomized (as it is necessary in the closing wedge technique), there is no tibia shortening with consequent patella infera (but only a relative tibia lengthening) and many intra-operative modifications of the desired correction can be done [23]. A drawback of the method is considered to be the necessity for bone grafting and the possible union problems that may arise [12]. However, recent advances in new internal fixation plates seem to overcome the problem, giving promising results [24, 38, 40]. In the barrel-vault (dome shaped) HTO the amount of correction is theoretically unrestricted. The tibial tuberosity relative to the joint line is not affected as opposed to the closing or opening wedge osteotomy and the application of an external fixation permits post-operative adjustments of correction, if necessary, as well as compression [9, 36, 37]. Early mobilization and weight bearing is another advantage [36, 37]. The same benefits have been reported for the medial open wedge tibial osteotomy by callus distraction [25]. Nevertheless, external fixation is not well tolerated by many patients and the risk of infection and its late recurrence if the osteotomy has to be converted to a total knee arthroplasty must be kept in mind [27].

With the single level oblique HTO technique, which is proposed here no bone removal is required. The correction is achieved by shifting and slightly rotating the distal fragment in relation to the proximal. The center of shift—rotation is the geometric center of the two equal opposing surfaces of the osteotomy. In this way the mechanical axis of the lower limb is realigned, while the shape and bone stock of proximal tibia remains unchanged. It is also important to be noted that the so-called zig-zag deformity that is created by any kind of wedge or dome osteotomy, is prevented with the oblique osteotomy [34].

Several studies have reported that the achievement and maintenance of the desired amount of correction is related closely with the results of any kind of osteotomy [3, 30-32, 39, 44]. Under- and overcorrection are secondary to incomplete pre-operative planning or technical errors. In the presented technique, once the patented osteotomy guide is used properly, the blade plate accommodates in the lateral surface of the tibia suitably, producing the exact desired angle of correction while offering a stable internal fixation.

Although controversy still exists in the literature concerning the optimal amount of correction and the clinical outcome, an agreement seems to exist concerning the beneficial influence of overcorrection [13, 15, 16, 20, 31, 32, 42, 44]. During the analysis of the results of this series it was observed that the larger weight in forming the values of excellent and good results was derived from the patients with 181–184° post-operative mechanical axis (which had a respective contribution in the value of chi-square criterion). Therefore, we routinely perform 3° of overcorrection in all the varus knees that are operated using the above mentioned technique, irrespective to the amount of pre-operative varus malalignement.

Even though from the reported series of HTOs is extremely difficult to estimate precisely the medium and long-term results of the procedure as the materials and methods differ among the studies, it is considered that approximately 80% of the patients at 5 years and 60% at 10 years show a satisfactory result [27]. Coventry et al., in a classic series, reported that the overall survivorship of the osteotomy, as defined by need for total knee arthroplasty, was 87% at 5 years and 66% at 10 years [8]. Insall et al. in a long-term follow-up study showed 85% excellent or good results after 5 years and 63% excellent or good results after 9 years [16], while Ivarsson et al. in a study of 99 HTOs performed in 90 patients reported 75% acceptable results at 5.7 years and 60% at 11.9 years [18]. Yasuda et al. reported 88% satisfactory results at 6 years and 63% at more than 10 years follow-up [46], while Rinonapoli et al. in a study of 26 patients reviewed at 8 and 16 years post-

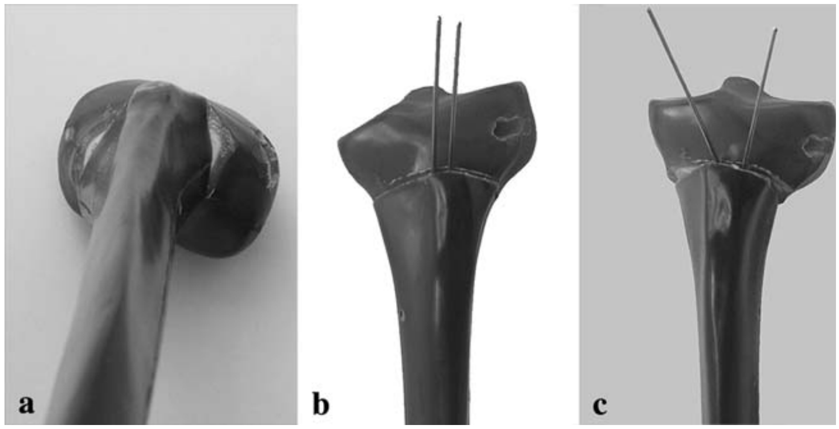


Fig. 6 The parallel K-wires before the completion of the osteotomy (**a**), and their limited divergence after the osteotomy (**b**), showing the small internal rotation of the tibia that ensues after the completion of the procedure. In the inferior view (**c**) of the model note the cortical contact between the osteotomy surfaces in the most part of the cortical circumference, which clinically has been proved to be sufficient enough to prevent early loss of correction

operatively reported 73% and 46% satisfactory results, respectively [35]. The overall rates of satisfactory results obtained with the presented technique in our series, as well as the deterioration of the results over time, are in consistency with the results of the literature.

However, there are some technical details concerning potential negative parameters that could be encountered during or after the procedure. The medial cortex of the tibia in this technique is not spared. Its controlled osteotomy (leaving the medial soft tissues undisturbed) is necessary in order the osteotomy surfaces to move freely. This could be argued as a likely disadvantage in the stability of the osteotomy, but we have not encountered such a problem during the evolution of the technique. As the distal fragment shifts and rotates in relation to the proximal fragment, there is constantly sufficient circumferential cortical contact between them (Fig. 6a), while the blade plate provides stable fixation. The completion of the osteotomy in the posterior tibia, away from the subchondral bone is another disadvantage. The cancellous bone in this area is not as dense as in the subchondral area but this is partially compensated by the posterior thickest cortical bone and the popliteus muscle and fibrous reinforcements that offer some kind of stability [27].

The complication of all oblique HTOs is the creation of a rotational deformity [27]. In the described technique a small internal rotation of the distal tibia always ensues in order to achieve the desired correction (Fig. 6b, c). The amount of this rotation depends on the inclination of the osteotomy surfaces and the estimated angle of correction. Even in extreme cases of varus knees this rotation of the distal tibia is limited and not clinically noticeable as it is well compensated by hip external rotation and adaptation of the foot.

Finally, if the osteotomy must be converted to a total knee arthroplasty, the presence of internal fixation material may induce technical difficulties during its removal and the curvilinear lateral incision may lead to compromised skin healing after an additional midline incision. We had not faced any of these problems in the cases when a HTO was converted to a total knee arthroplasty.

Conclusion

This technique of HTO is not considered to be the solution to the debate concerning the most appropriate method of treatment of medial osteoarthritis of the varus knee. It is considered to be an additional way of management with specific advantages and disadvantages. Above all it has been proved to be a safe and reproducible procedure permitting the desired amount of correction, while relieving the patellofemoral joint if it is needed. The long-term results which are presented in this study appear to meet those of other techniques, but longer follow-up may be necessary. A biomechanical evaluation of the method is under progress, as well as its application in sagittal plane deformities (like genu recurvatum), or in knees with ligamentous laxity and medial osteoarthritis.

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