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## Original article

### **Patellar height is not modified after isolated open-wedge high tibial osteotomy without change in posterior tibial slope**

Mathieu **Carissimi**<sup>1,2</sup>, Pierre **Sautet**<sup>1,2</sup>, Dimitri **Charre**<sup>1</sup>, Lukas **Hanak**<sup>3</sup>, Matthieu **Ollivier**<sup>1,2</sup>, Grégoire **Micicoi**<sup>4,5</sup>

<sup>1</sup>Department of Orthopedics and Traumatology, Institute of Movement and Locomotion, St. Marguerite Hospital, 270 Boulevard Sainte Marguerite, BP 29, 13274 Marseille, France

<sup>2</sup>Aix Marseille University, APHM, CNRS, ISM, Sainte-Marguerite Hospital, Institute for Locomotion, Department of Orthopedics and Traumatology, Marseille, France

<sup>3</sup>Orthopädie Maximilium, Donauwörth, Germany

<sup>4</sup>UR2CA, Université Côte d'Azur, 06000 Nice, France

<sup>5</sup>iULS-University Institute for Locomotion and Sports, Pasteur 2 Hospital, University Côte d'Azur, Nice, France

#### **Corresponding author:**

Grégoire Micicoi

iULS-University Institute for Locomotion and Sports, Pasteur 2 Hospital, University Côte d'Azur, Nice, France

Phone: +33 6 58 58 34 43

Email: greg\_micicoi@yahoo.fr

#### **ABSTRACT**

##### **Introduction**

Open-wedge high tibial osteotomy (OWHTO) corrects coronal deformity and can impact sagittal parameters such as posterior tibial slope and patellar height. The aim of the present study was to analyze change in patellar height after medial OWHTO with respect to tibial and femoral-referenced indices.

##### **Material and method**

This single-center retrospective study included 129 patients undergoing isolated posteromedial OWHTO, without change in tibial slope, using patient-specific cutting-guides. Patellar height was assessed on Caton-Deschamps (CD), Insall-Salvati (IS) and Schröter indices. Posterior tibial slope and coronal femoral and tibial angles were also measured. X-rays were taken preoperatively and at 12 months, and analyzed by 2 independent observers.

##### **Results**

OWHTO modified the global lower-limb alignment ( $\Delta = 6.3 \pm 0.95^\circ$ ,  $p < 0.0001$ ) and the proximal tibial deformity ( $\Delta = 7 \pm 0.88^\circ$ ,  $p < 0.0001$ ). Posterior tibial slope and tibial (CD and IS) and femoral (Schröter) patellar height indices were unchanged. Intra- and inter-observer reproducibility was excellent (ICC 0.79-0.91). There were no correlations between HKA or MPTA angles and change in patellar height.

### **Conclusion**

The present clinical series showed that patellar height was unchanged by isolated posteromedial OWHTO without change in tibial slope, using patient-specific cutting-guides, with whichever femoral or tibial reference index. The Schröter patellar femoral height index was highly reliable and is independent of proximal tibial changes in assessing patellar height, and can thus be recommended in the follow-up of OWHTO.

**Level of evidence:** III; retrospective cohort study.

**Keywords:** Patellar height; Open-wedge high tibial osteotomy; Posterior tibial slope; Deformity; Knee

### **Introduction**

Open-wedge high tibial osteotomy (OWHTO) is a well-established procedure correcting lower-limb deformities, notably in cases of medial compartment osteoarthritis with varus deformity [1–4]. The aim is to relieve load on the affected compartment, transferring forces to the healthy side by changing coronal alignment [5–7]. However, changes may also be induced in the sagittal plane affecting posterior tibial slope and patellar height. Thus, many authors reported increased posterior tibial slope and decreased patellar height after proximal tibial osteotomy [8–11], leading some surgeons to modify their operative technique [12–15]. These surgical variants remain controversial, as most patellar height measurement indices are based on a tibial landmark that is inevitably altered by proximal tibial osteotomy.

In 1997, Miura et al. [16] analyzed the inaccuracy of indices based on an anterior tibial landmark, favoring those based rather on a femoral reference.

Ihle et al. [17] recently described a patellar height measurement index based on a femoral reference, using the base of the patella, the femoral epicondyles and the joint surface of the femoral condyles as landmarks. Patellar height was unchanged by osteotomy according to this index, which, however, has yet to be validated in another clinical series.

The aim of the present study was to analyze change in patellar height after posteromedial OWHTO, based on tibial and femoral reference indices.

The study hypothesis was that patellar height is unchanged after isolated posteromedial OWHTO performed without changing tibial slope, using a patient-specific cutting-guide.

## **Material and method**

This single-center retrospective study prospectively analyzed the clinical files of patients operated on in our department between December 2016 and December 2019. There were 69 men and 60 women, with a mean age of  $45.8 \pm 5.8$  years and mean body-mass index (BMI) of  $25.1 \pm 4.2$  kg.m<sup>2</sup>. All underwent the same isolated OWHTO procedure. They presented with Ahlbäck grade I or II medial femorotibial osteoarthritis with  $>5^\circ$  excess metaphyseal varus (medial proximal tibial angle (MPTA)  $< 84^\circ$ ) and symptoms of more than 1 year's progression, without associated patellofemoral pathology.

The procedure consisted in an isolated posteromedial OWHTO with unchanged tibial slope and osteotomy site filled by bone allograft; fixation used a Newclip Activ-Motion plate. Postoperative rehabilitation was identical in all cases [18]. Holes were drilled in the proximal part of the tibia through the patient-specific cutting-guide. The cut was followed by progressive opening of the osteotomy site, according to the intended correction in the coronal plane. The guide reliably reproduces the preoperative plan, with a margin of error of  $0.2^\circ$  in the coronal plane and  $0.1^\circ$  in the sagittal plane [19]. X-rays were taken for the preoperative work-up and for the usual follow-up.

Exclusion criteria comprised: post-traumatic osteoarthritis, severe congenital or acquired bone abnormalities such as Blount's disease,  $>10^\circ$  preoperative flexion contracture, and previous surgery.

X-rays were analyzed for 129 patients, comprising weight-bearing knee views (AP in complete extension; lateral in  $30^\circ$  flexion) and long-leg view, preoperatively and at 12-months.

## **Radiographic measurements**

Pre- and post-operative radiographic measurements were taken twice, at a 2-month interval by 2 independent observers.

The usual angles were measured, following Paley et al. [20]: hip-knee-ankle (HKA) angle, lateral distal femoral angle (LDFA), medial proximal tibial angle (MPTA), joint line

convergence angle (JLCA) and joint line obliquity (JLO) (figure 1). Posterior tibial slope (PTS) was defined according to Amendola et al. [21,22] as the angle between the anatomic tibial axis and the tangent to the medial tibial plateau in the sagittal plane (figure 2).

Patellar height was measured sagittally on Caton-Deschamps (CD) [23] and Insall-Salvati (IS) [24] indices with proximal tibial reference (figure 3), and coronally on Schröter index with distal femoral reference [17] (figure 4).

### **Schröter index**

Change in tibial slope drastically affects the CD index without altering relations between joint line and real patellar height in the trochlea.

Consequently, a new method, referenced on the femur, was proposed in 2017 by Ihle et al. [17]: Schröter's Femoral Patella Height Index (FPHI). It is measured on weight-bearing AP view in full extension. The landmarks consist of the base of the patella, the femoral epicondyles and the femoral condyle joint surface. It is calculated by dividing distance A between 2 vertical tangents to the femoral epicondyles, by distance B between the horizontal lines from the base of the patella to the tangent of the femoral condyle joint surfaces (Figure 4).

This index was validated in a scientific paper [17] but to our knowledge has not since been used in a larger series.

### **Validation process**

Radiographic measurements, both pre- and post-operatively (first at 12 months), were taken twice by 2 independent observers at a 2-month interval for intra-observer reproducibility assessment.

To determine pre- to post-operative change, test-retest reliability was assessed; intra- and inter-observer reproducibility was described by intraclass correlation coefficient (ICC) with 95% confidence interval.

Analyses used JMP software. Normal distribution was checked on Kolmogorov-Smirnov test. Pre- to post-operative change was assessed on parametric or non-parametric tests according to distribution normality.

Post-hoc analysis based on mean patellar-height endpoint values with standard deviation checked that the sample size allowed differences of 0.04, 0.03 and 0.04 on CD, IS and Schröter indices to emerge as significant. The clinical significance thresholds for changes in these indices have not been reported.

All analyses respected legal and regulatory requirements with regard to review board approval and informed consent.

## Results

Table 1 shows intra- and inter-observer reproducibility, which was high, with ICC between 0.79 and 0.91.

Osteotomy significantly impacted HKA angle ( $\Delta = 6.3 \pm 0.95^\circ$ ,  $p < 0.0001$ ) and MPTA ( $\Delta = 7 \pm 0.88^\circ$ ,  $p < 0.0001$ ). Values for mechanical LDFA (mLDFA), PTS, and JLO were unchanged (Table 2).

Tibial and femoral referenced patellar height indices were unchanged (Table 3).

Multivariate analysis found no association between change in HKA angle ( $p = 0.5$ ) or MPTA ( $p = 0.4$ ) and change in patellar height. No demographic or preoperative angle or patellar height values showed significant correlation with changes in patellar height indices.

## Discussion

The present results showed no change in patellar height after isolated posteromedial OWHTO without change in tibial slope, using patient-specific cut-guides.

For the CD index, referenced on the proximal tibia, patellar height was shown to correlate with degree of coronal correction and PTS correction after medial OWHTO [14]. Greater changes in tibial slope may occur with OWHTO [25,26]. In the present study, changes in the sagittal plane ( $0.36^\circ$ ) were not significant, which may explain why the CD index was unchanged. The IS index is independent of posterior tibial slope, but may be altered by patellar tendon shortening caused by the postoperative scar and/or by peri-tendinous tissue retraction [11,27]; this index is unchanged by OWHTO. Schröter index [17] is unaffected by proximal tibial osteotomy, and enables reproducible follow-up of patellar height after OWHTO.

Many authors advocated for more distal osteotomy below the tibial tuberosity to reduce risk of patella infera [13,28,29]. Double-level osteotomy does not seem to prevent patellar descent [30] but does reduce the rate of non-anatomic correction [31,32]. According to Otsuki et al. [33], hybrid tibial osteotomy can be performed in case of pre-existing

patellofemoral osteoarthritis, associating 33% medial opening to 67% lateral closure to reduce the tibial tuberosity–trochlear groove (TT–TG) distance without lowering the patella. Patella infera can lead to patellofemoral incongruence and osteoarthritis [34], as can difficulties encountered in total knee replacement for preoperative patella infera [35]. Patellofemoral joint problems after OWHTO may be due to anterior translation of the proximal tibial fragment [36] or to medial patellar tilt increasing lateral patellofemoral pressure [37]. In contrast, a recent study with a mean 3 years' follow-up found no deterioration in patellofemoral cartilage associated with decreased patellar height [38].

The issue of post-osteotomy patellar height was raised by Miura et al. in 1997 [16]; the definition of patella alta or infera mainly depended on the index chosen to assess patellar height. The present values support the results of Ihle et al., who proposed normal values between 1.5 and 1.6, without change after OWHTO; however, these thresholds are to be taken with caution before drawing any therapeutic conclusions ahead of osteotomy, and individual patellofemoral symptoms should be given prime consideration.

The femoral-referenced Bernageau index [39] cannot be used if X-rays are poor-quality, and reproducibility seems to be poorer than for FPHI, which is measured on standardized views and can easily be calculated from long-leg weight-bearing X-rays and showed reliable reproducibility over time.

The present study had several limitations. Follow-up was too short to be able to estimate possible correction loss in the sagittal plane, notably due to change in patellar height, but the aim was to validate the FPHI rather than to assess changes over time. Secondly, the retrospective design did not include CT analysis, and subclinical preoperative extension deficit and rotational disorder may have induced error in angle measurements in the coronal plane [40,41].

## **Conclusion**

The present clinical series showed that patellar height was unchanged by isolated posteromedial OWHTO without change in tibial slope, using patient-specific cutting-guides, with whichever femoral or tibial reference index. The Schröter femoral patella height index was highly reliable and is independent of proximal tibial changes in assessing patellar height, and can thus be recommended for following up OWHTO.



**Ethical considerations:** As a category-3, non-interventional study under the terms of the French “Jardé” law of 2020, data protection authorization was not required. Data analysis was retrospective and anonymized. Data collection used an encrypted spreadsheet and was conducted as part of current care.

**Informed consent:** not required

**Conflicts of interest:** MC, PS, DC, LH and GM have no conflicts of interest to disclose. MO is a consultant for Newclip Technics.

**Funding:** None.

**Author contributions:** MO: study design; statistics. DC and LH: data collection. MC and PS: draft writing and subsequent re-editing. GM and MO: article writing and re-editing. All authors approved the final version.

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**Table 1. Reproducibility analysis of radiographic measurement of patellar height.**

<b>Criterion</b>	<b>Inter-observer ICC</b>	<b>Intra-observer ICC</b>
CD index	0.81, 95%CI (0.75-0.87)	0.9, 95%CI (0.87-0.92)
IS index	0.79, 95%CI (0.77-0.81)	0.86, 95%CI (0.81-0.91)
Schröter index	0.84, 95%CI (0.79-0.89)	0.91, 95%CI (0.85-0.97)

CD, Caton-Deschamps index; IS, Insall-Salvati index; CI, confidence interval; ICC, intraclass correlation coefficient

**Table 2.** Pre- and post-operative anatomic parameters and correction

<b>Parameters</b>	<b>Preoperative</b>	<b>Postoperative</b>	<b><math>\Delta</math></b>	<b><i>p</i></b>
HKA°	173.4±2.8	179.7±2.4	6.3±0.95	< 0.0001
MPTA°	83.4±0.7	90.4±0.7	7±0.88	< 0.0001
mLDFA°	89.2±1.4	89.39±1.5	0.2±0.5	0.7
JLCA°	1.55±0.15	1.2±0.16	-0.3±0.1	0.12
JLO°	3±0.29	2.9±0.3	0.09±0.42	0.9
PTS°	79.9±0.7	79.5±0.7	0.36±1	0.7

Mean values  $\pm$  standard deviation.  $\Delta$ : pre- to post-operative difference. Significance threshold:  $p < 0.05$

**Table 3.** Change in patellar height 12 months after posteromedial open wedge high tibial osteotomy

<b>Parameters</b>	<b>Preoperative</b>	<b>Postoperative</b>	<b><math>\Delta</math></b>	<b><i>p</i></b>
CD index	1.01±0.1	0.94±0.08	-0.06 ±0.003	0.058
IS index	1.05±0.02	1.03±0.02	-0.02±0.02	0.36
Schröter index	1.57±0.026	1.54±0.03	-0.03±0.04	0.4

CD index, Caton-Deschamps index; IS index, Insall-Salvati index; mean values ± standard deviation;  $\Delta$ : pre- to post-operative difference. Significance threshold:  $p < 0.05$

## Figure legends

**Figure 1** Long-leg weight-bearing view with angular values in coronal plane

HKA (Hip–Knee–Ankle): angle between center of femoral head, center of knee and center of ankle;  
LDFA (lateral distal femoral angle): distal femoral deformity; MPTA (medial proximal tibial angle):  
proximal tibial deformity; JLCA (joint line convergence angle): intra-articular deformity; JLO (joint  
line obliquity): joint line obliquity with respect to ground.



**Figure 2** Tibial slope according to Amendola

Posterior tibial slope was measured as the mean of anteroposterior tibial diameter 5 cm under the tibial tuberosity and 15 cm under the joint line. A line from halfway between the 2 landmarks to the tibial plateau, and a line from the highest points of the anterior and posterior medial plateaus defined the angle of the posterior tibial slope.





### Figure 3 Patellar height measurement

A. Caton-Deschamps index: calculated between the distance (a) from the inferior part of the patellar to the upper part of the tibia and the patellar articular surface (b).

B. Insall-Salvati index: calculated between the patellar tendon length (a – distance from the inferior part of the patella to its insertion) and the patellar length (b – greatest pole-to-pole distance)



### Figure 4 Schröter femoral patellar height index

Measured on AP view in extension: ratio of distance (A) between medial and lateral edges of the femoral epicondyles to distance (B) between base of patella and femoral condyle joint surface.

