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# The Tibia Plafond Horizontal Orientation Angle for Frontal Alignment Evaluation of the Distal Lower Extremity

## Hodnocení frontálního postavení distální části dolní končetiny podle sklonu horizontální linie kloubní štěrbiny hlezna

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## ABSTRACT

PURPOSE OF THE STUDY
Osteotomies around the knee are an established technique for treating knee osteoarthritis and other knee conditions by redistributing the body's weight and force within and around the knee joint. The aim of this study was to determine if the Tibia Plafond Horizontal Orientation Angle (TPHA) is a reliable measure for describing ankle alignment of the distal tibia in the coronal plane.

MATERIALS AND METHODS
This retrospective study included patients who underwent supracondylar rotational osteotomies for correction of femoral torsion. All patients had standing radiographs taken preoperatively and postoperatively with both knees pointed forward. Five variables, including Mechanical Lateral Distal Tibia Angle (mLDTA), Mechanical Malleolar Angle (mMA), Malleolar Horizontal Orientation Angle (MHA), Tibia Plafond Horizontal Orientation Angle (TPHA), and Tibio Talar Tilt Angle (TTTA), were collected. The preoperative and postoperative measurements were compared to each other using the Wilcoxon signed rank test.

RESULTS
A total of 146 patients were included in the study, with a mean age of 51.47 ± 11.87 years. There were 92 (63.0%) males and 54 (37.0%) females. MHA decreased from 14.0° ± 5.32° preoperatively to 10.59° ± 3.93° ($p < 0.001$) postoperatively, and TPHA decreased from 4.88° ± 4.07° preoperatively to 3.82 ± 3.10° ($p = 0.013$) postoperatively. The change in TPHA was significantly correlated with the change in MHA ($r = 0.185$, CI 0.023 – 0.337; $p = 0.025$). No differences were found between the measurements of mLDTA, mMA, and mMA pre- and postoperatively.

DISCUSSION
The orientation of the ankle should be taken into consideration during preoperative planning of osteotomies and should be measured in cases of postoperative ankle pain.

CONCLUSIONS
The TPHA is a reliable measure for describing ankle alignment of the distal tibia in the frontal plane.

**Key words:** osteotomy, ankle, realignment, coronal alignment, preoperative planning.

## INTRODUCTION

Realignment of frontal plane deformities of the knee, whether by knee arthroplasty or by osteotomy around the knee, often affects the alignment of the ankle in the coronal plane (2, 8, 9, 12, 13). Osteotomies around the knee are low-risk, effective treatments for bony deformities and osteoarthritis with a rapid recovery after the surgery (15). In order to achieve the desired clinical results, osteotomies redistribute joint reaction forces from a damaged area to an undamaged area. This could influence the overall orientation of not only the knee, but it could also affect the ankle joint, which may adversely affect clinical outcomes in general (6, 8, 9, 12).

The degree to which coronal alignment is restored postoperatively is thought to be predictive of clinical outcomes, and it also contributes to a considerable improvement in pain (4,7). Considering appropriate preoperative planning and a standardized operative technique, this would lower the risk of triggering an unfavorable conflict on a different level, reduce the possibility of ankle symptoms, and in many cases, prevent the development or progression of ankle arthritis (8, 13, 16). However, the relationship between genua vara or valga and the frontal plane of the ankle joint and the alteration of joint reaction forces is an area with limited research.

Several studies have demonstrated that osteotomies around the knee could lead to lateralization or medial-

ization of the weight-bearing line at the knee, a coronal reorientation of the ankle, and changes in the ankle pressure characteristics (2, 6, 12). This emphasizes the importance of preoperative imaging for planning and assessing lower extremity alignment to restore neutral alignment postoperatively. The aim of this study was to determine if the Tibia Plafond Horizontal Orientation Angle (TPHA) is a reliable measure for describing ankle alignment of the distal tibia in the coronal plane.

## MATERIAL AND METHODS

The study utilized a retrospective design over a period of five years, from 2017 to 2021, at a tertiary care teaching university hospital on patients who underwent supracondylar rotational osteotomies for correction of femoral torsion.

The appropriate institutional review board (IRB) of the University of Tuebingen approved the proposal for this study. The study was done in line with the Declaration of Helsinki, which is the code of ethics of the World Medical Association.

### Patients

The target population of this study consists of patients who underwent supracondylar rotational osteotomies for correction of femoral torsion, who performed a preoperative and postoperative standing X-ray with the knees pointing forward.

Exclusion criteria include patients with suboptimal image quality, insufficient depiction of the distal tibia, missing postoperative standing X-ray. Eventually, 146 patients were included in the analysis. The data were collected from our radiological database.

Realigment was performed as previously planned using standardized osteotomy principles and techniques at the distal femur.

### Radiographic parameters

Radiographic parameters were determined with an accuracy of 0.1 mm using mediCAD® (Hectec, Landshut, Germany). Radiographic imaging was performed at our institute, following a standard protocol that had patients stand with their knees pointing forward. A well-defined protocol for measuring all the radiographic parameters was determined in advance. The following radiographic parameters were measured at the ankle level (Fig. 1): Mechanical Lateral Distal Tibia Angle (mLDTA), Mechanical Malleolar Angle (mMA), Malleolar Horizontal Orientation Angle (MHA), Tibia Plafond Horizontal Orientation Angle (TPHA), and Tibio Talar Tilt Angle (TTTA).

Prior to surgery, preoperative radiographs were obtained for deformity correction planning, and they were repeated postoperatively following union at the osteotomy site and recovery of limp-free full weight-bearing. Radiologic technical assistants were instructed to position both legs with the patella centered between the

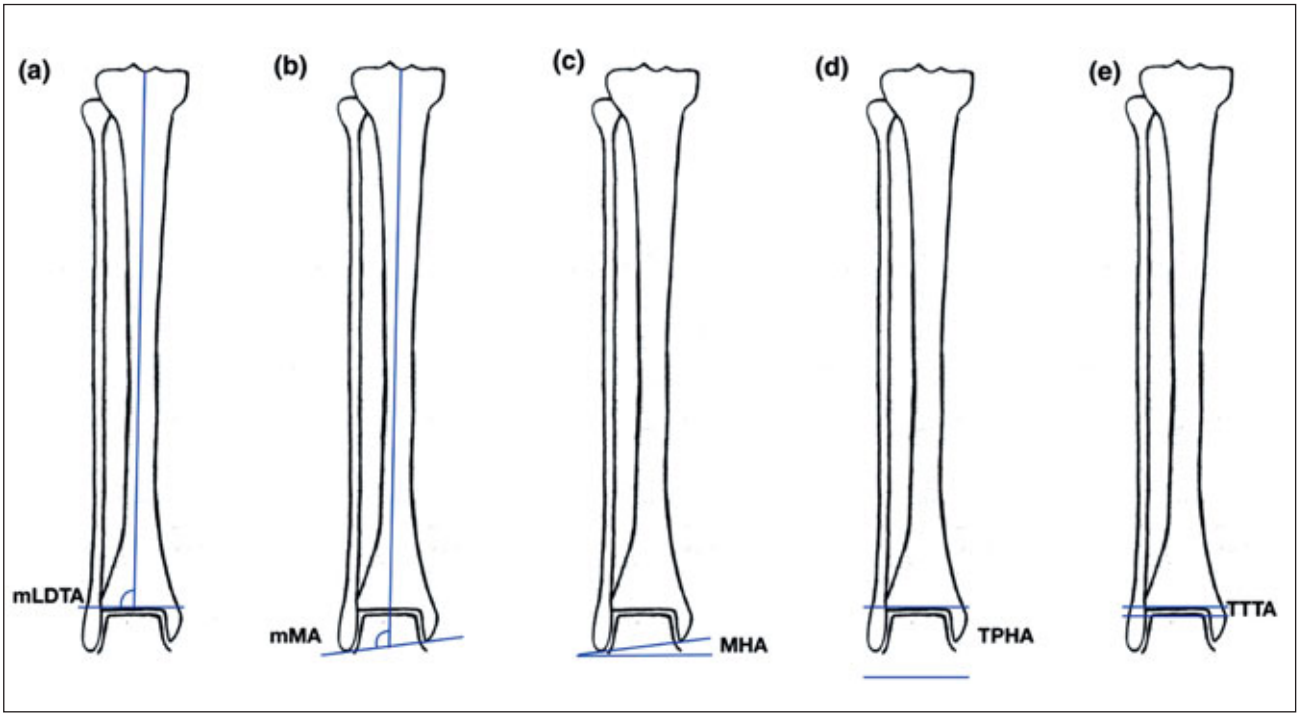


*Fig. 1. Illustration of the radiographic parameters measured at the ankle on a long-leg standing X-ray with the knees pointing forward; a – mLDTA: angle between tibiaplafond and mechanical tibia axis, b – mMA: angle between malleolar tips and mechanical tibia axis, c – MHA: angle between malleolar tips and floor, d – TPHA: angle between tibiaplafond and floor, e – TTTA: angle between tibio-talar joint surfaces.*
*mLDTA – Mechanical Lateral Distal Tibia Angle; mMA – Mechanical Malleolar Angle; MHA – Malleolar Horizontal Orientation Angle; TPHA – Tibia Plafond Horizontal Orientation Angle; TTTA – Tibio Talar Tilt Angle.*

*Table 1. Radiographic measures*

| Radiographic measure [°] | Preoperative mean ± SD (range) | Postoperative mean ± SD (range) | Δ | *p* value |
|---|---|---|---|---|
| mLDTA | 86.94 ± 3.29 (76.2–94.3) | 86.68 ± 3.72 (77.1–97.5) | -0.26 | 0.427 |
| mMA | 100.30 ± 3.62 (92.4–110) | 99.34 ± 5.46 (73–109.8) | -0.96 | 0.258 |
| MHA | 14.0 ± 5.32 (0–28) | 10.59 ± 3.93 (0.6–20.7) | -3.41 | <0.001 |
| TPHA | 4.88 ± 4.07 (0–18.3) | 3.82 ± 3.1 (0–15.2) | -1.06 | 0.013 |
| TTTA | 0.80 ± 1.01 (0–5.3) | 0.87 ± 1.25 (0–9.4) | 0.07 | 0.863 |

*mLDTA* – Mechanical Lateral Distal Tibia Angle; *mMA* – Mechanical Malleolar Angle; *MHA* – Malleolar Horizontal Orientation Angle; *TPHA* – Tibia Plafond Horizontal Orientation Angle; *TTTA* – Tibio Talar Tilt Angle

femoral condyles. All necessary steps to achieve a standardized radiography were of the utmost significance.

### Statistical analysis

SPSS version 28.0 (Chicago, USA) was used for statistical analysis. Continuous variables were described using mean (standard deviation) and range. Count (frequency) to describe other nominal variables (e.g. gender). The normality of the distribution of variables was examined using the Shapiro–Wilk test. Comparison between means was performed using the Wilcoxon signed rank test. Pearson correlation (r) was used to evaluate the degree of correlation between the change in TPHA and MHA postoperatively. A p-value < 0.05 was considered statistically significant.

## RESULTS

In total, 146 patients who underwent supracondylar rotational osteotomies for correction of femoral torsion were included in this study. There were 92 (63.0%) males and 54 (37.0%) females. The age ranged from 18 to 79 years, with a mean age of 51.47 ± 11.87 years. Radiologic imaging for patients pre- and postoperatively was obtained.

Several measures were used to compare pre- and postoperative limb alignment, including mLDTA, mMA, MHA, TPHA, and TTTA. Surgery led to significant changes in MHA (14.0 ± 5.32 preop, 10.59 ± 3.93 postop; p < 0.001) with a mean difference of 3.41 lower postoperatively. The TPHA (4.88 ± 4.07 preop, 3.82 ± 3.10 postop; p = 0.013) showed a mean difference of 1.06 - also lower postoperatively (Fig. 2). Other measures did not change significantly, including mLDTA (86.94 ± 3.29 preop, 86.68 ± 3.72 postop), mMA (100.30 ± 3.62 preop, 99.34 ± 5.46 postop), and TTTA (0.80 ± 1.01 preop, 0.87 ± 1.25 postop). Table 1 demonstrates the radiographic measurements of patients before and after undergoing the surgery.

The change in TPHA has a significant positive correlation with the change in MHA (r = 0.185, CI 0.023 – 0.337; p = 0.025) (Fig. 3).

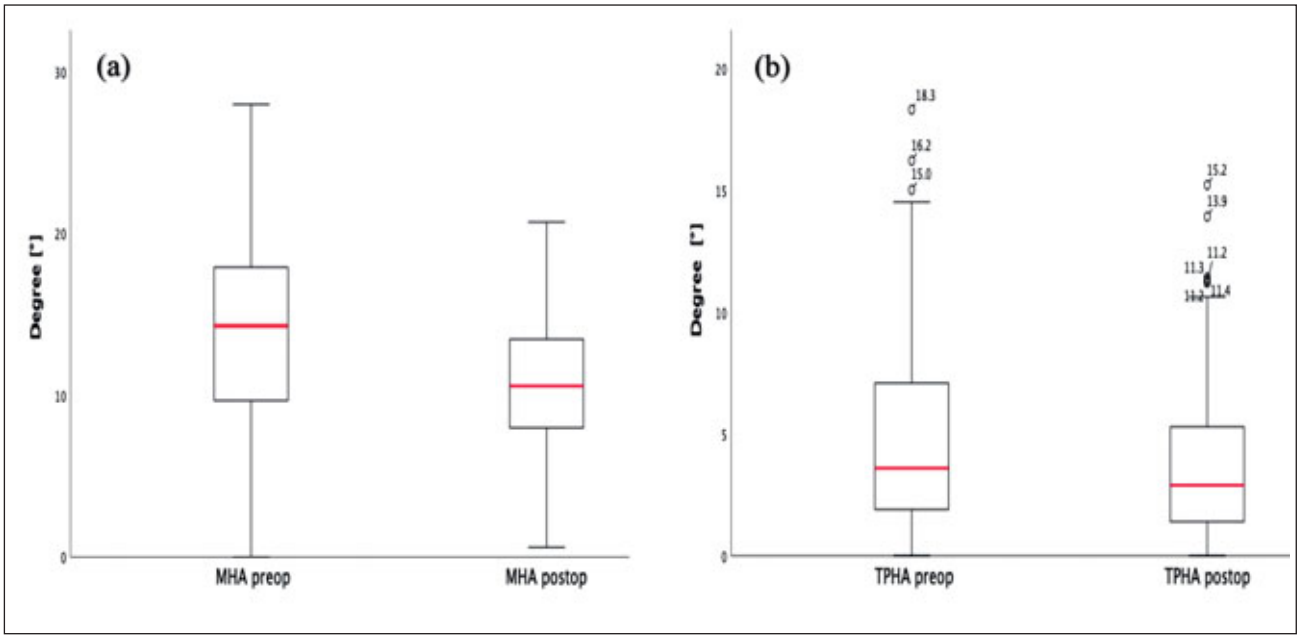


*Fig. 2. a – Malleolar Horizontal Orientation Angle, b – Tibio Talar Tilt Angle.*
*MHA – Malleolar Horizontal Orientation Angle; TPHA – Tibia Plafond Horizontal Orientation Angle.*

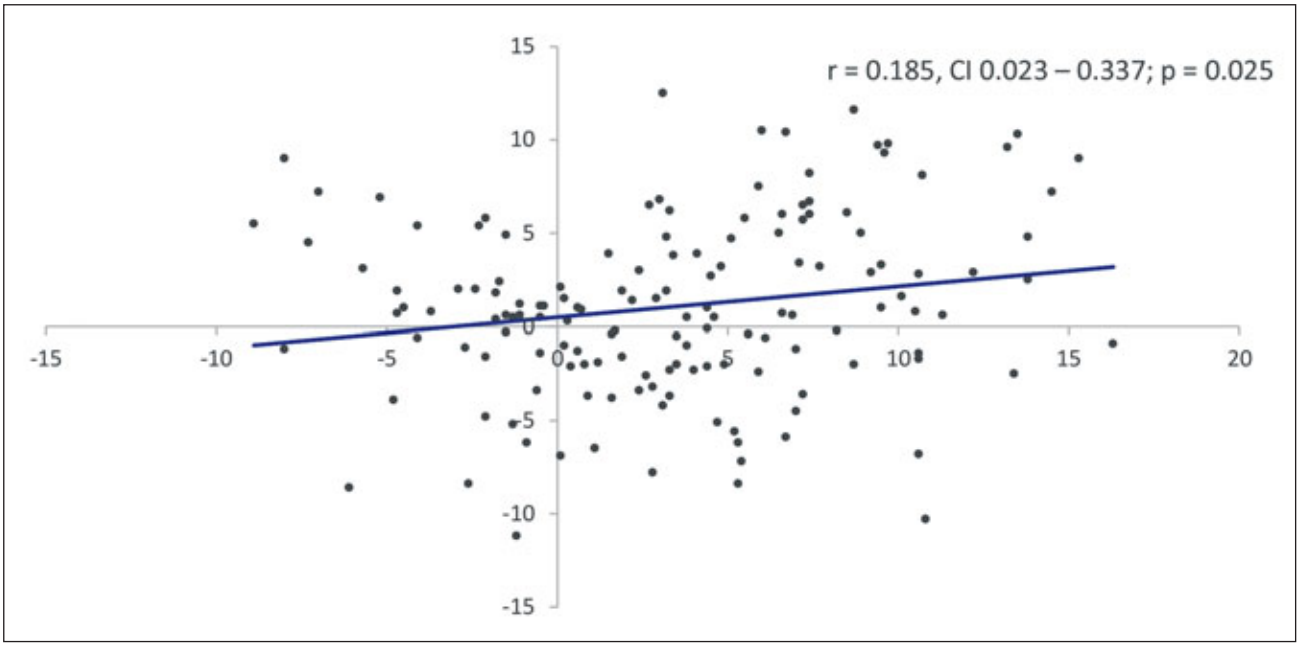


*Fig. 3. Correlation between the change in TPHA and MHA pre- and postoperatively.*
*MHA – Malleolar Horizontal Orientation Angle; TPHA – Tibia Plafond Horizontal Orientation Angle.*

## DISCUSSION

In this study, we used the change in mLDTA, mMA, MHA, TPHA, and TTTA to quantify the change created by the osteotomies and introduce a new angle for measurement of frontal ankle alignment: the TPHA. Our study demonstrated that MHA and TPHA decreased postoperatively. In addition, change in TPHA postoperatively was positively correlated with change in MHA postoperatively. That is, the greater the decrease in MHA caused by the surgery, the greater the decrease in TPHA. The mLDTA, mMA, and TTTA did not change significantly postoperatively.

Osteotomies around the knee are well established treatment modalities in many cases, including degenerative disease, reducing pain, deformity, and knee instability, and also as an adjunct to other complex joint surface and meniscal cartilage surgery (16). However, osteotomies around the knee have been reported to affect the hip, knee, and ankle joints, as well as the overall orientation of the femoral antetorsion and ischiofemoral space (1, 8, 10, 11). In addition, it could affect the anatomic and physiologic function of the extensor mechanism, including the quadriceps tendon, patella, and patella ligament (3). These alterations raise the risk of postoperative complications, such as the progression or development of new areas of pain that may necessitate additional surgical intervention.

Osteotomies performed around the knee to manage valgisation and varisation led to considerable modifications affecting the coronal limb alignment, not only at the knee but also at the ankle level (9). Lee and Jeong reported that radiographic evidence of ankle arthritis appeared or progressed after total knee replacement in 21.8% of the 142 included cases, and that the incidence of ankle arthritis increased in the case of greater varus deformity, where the preoperative talar tilt was increased medial to the ankle or the postoperative correction angle was large (13). This undesired change in the frontal alignment could lead to mechanical symptoms, including ankle pain resulting from changes regarding the distribution of joint reaction forces in the ankle joint (5). In another study that included 109 patients, it was reported that ankle symptoms were influenced by changes in ankle joint orientation after high tibial osteotomy (5). Also, they showed a worsening in the visual analogue scale for pain in the groups that had an increase in the absolute values of tibial plafond inclination or talar inclination postoperatively (2).

Our results showed that MHA and TPHA decreased significantly postoperatively. The findings of this study are supported by previous studies published earlier where they found the MHA and TPHA were significantly decreased postoperatively (8, 9). The decrease in TPHA leads the foot to react by inversion and supination (8). In addition, we found that the change in TPHA was positively correlated with the change in MHA. This is important from the perspective that MHA was reported previously to be a reliable and recommended approach for measuring coronal reorientation of the ankle (9). A recent retrospective study on 589 patients demonstrated that TPHA correlates with the constitutional knee alignment - particularly the varus or valgus alignment of the knee. The TPHA was therefore firstly recommended to be used during the planning process of osteotomies around the knee (8, 9). In a study of 43 people who had medial opening wedge high tibial osteotomy, it was found that inappropriate alignment of the hindfoot

is one cause of under-correction after surgery, even when the surgery was done as planned before surgery (14). It was also suggested that the hindfoot angle should be taken into account in the preoperative evaluation (14). Hence, we believe that TPHA could be used too to measure the changes in the ankle joint when planning for realignment surgeries around the knee.

The results should be interpreted with caution, owing to several limitations. The study was limited by its retrospective, single-center design, which meant we had to depend on retrospective patient records alone to rule out any deformities or previous trauma. In addition, as this was a retrospective study, we were unable to standardize the time from surgery to postoperative imaging. Moreover, this study may have been influenced by regional ethnic selection biases because all patients were recruited from a single center. Furthermore, 3-dimensional reality has been simplified using 2-dimensional radiography. Complex imaging would be necessary to solve this issue while in a functional standing position. Further prospective cohort studies are required.

## CONCLUSIONS

Osteotomies performed around the knee for correction of coronal limb malalignment alter not only the weight-bearing line at the knee but may also alter the frontal alignment of the ankle. Redistribution of joint reaction forces in the ankle joint could lead to progression or new symptoms at this level. The TPHA is a reliable tool to describe ankle alignment in the frontal plane. It can be used with other measurements to plan osteotomies of the lower extremities.

***Ethical approval***

*The study was approved by the Ethical Committee of the University of Tübingen.*

***Informed consent***

*Informed consent to use data and diagnostic images was obtained.*

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