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PŮVODNÍ PRÁCE

The Association between Constitutional Knee Alignment and the Horizontal Orientation of the Ankle Joint Line

Vztah mezi přirozenou osou kolenního kloubu a horizontální orientací linie hlezna

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ABSTRACT

PURPOSE OF THE STUDY
To characterize constitutional frontal alignment of the ankle in genua vara, valga, and norma.

MATERIAL AND METHODS
Long-leg standing radiographs of 589 patients presenting between 2011 and 2020 for knee-complaints because of any reason were chosen from our database. Cases with fractures or history of bony-realignment-surgeries were excluded. The Hip-Knee-Ankle angle (HKA), the mechanical Lateral Distal Tibia Angle (mLDTA), and the Tibia-Plafond-Horizontal-Orientation angle (TPHA) were measured in 354 patients. For this study, neutral frontal alignment of the leg was defined as HKA between -3.0° and +4.0°. HKA-values <-3.0° were defined as genua valga and values >4.0° were defined as genua vara. According to these cutoffs, data was categorized into the following three patient groups: genua vara (n=157), genua norma (n=106), genua valga (n=91). For each group, the ankle alignment in the frontal plane was compared to the HKA. Finally, the three groups were compared to each other.

RESULTS
In the varus-group, the HKA-value was 6.9°±2.4°, the TPHA-value was 4.7°±3.5°, and the mLDTA-value was 87.4°±4.8°. In the neutral-group, the HKA-value was 1.8°±2.0°, the TPHA-value was 2.5°±2.9°, and the mLDTA-value was 87.2°±4.6°. In the valgus-group, the HKA-value was -6.0°±2.7°, the TPHA-value was -0.2°±4.7°, and the mLDTA-value was 85.0°±4.7°.

DISCUSSION
The frontal alignment of the ankle joint line depends on the overall frontal alignment of the leg. The TPHA correlates with varus or valgus alignment of the knee, but the mLDTA does not. In patients with valgus-aligned long-leg axis, the TPHA demonstrated less valgus alignment than in patients with varus-aligned long-leg axis. This knowledge is especially useful when planning osteotomies for correction of lower extremity malalignment.

CONCLUSIONS
During the planning process of osteotomies around the knee, the TPHA should be appreciated because it correlates with the constitutional knee alignment.

Key words: valgus, varus, frontal alignment, coronal alignment, osteotomy.

INTRODUCTION

Varus or valgus alignment around the knee joint is known to predispose for early arthritis of the knee (4, 5, 8, 11). Little is known about the correlation of genua vara or valga with the frontal orientation of the ankle joint. Bony angles around the ankle like the mechanical Lateral Distal Tibia Angle (mLDTA) might not represent the functional orientation of the ankle joint line. It was the aim of this study to characterize the frontal orientation of the ankle joint line in varus, valgus, and neutral knees.

MATERIAL AND METHODS

All Long-leg standing radiographs of patients presenting between 2011 and 2020 for knee complaints because of any reason were chosen from our database. Cases with fractures or history of bony realignment surgeries were excluded (Fig. 1).

With the aim to ensure a standardized radiography, long-leg weight-bearing radiographs were obtained in accordance with Paley using a 1.3 m cassette (Global Imaging Baltimore, MD). Long leg antero-posterior standing radiographs were obtained with the patient

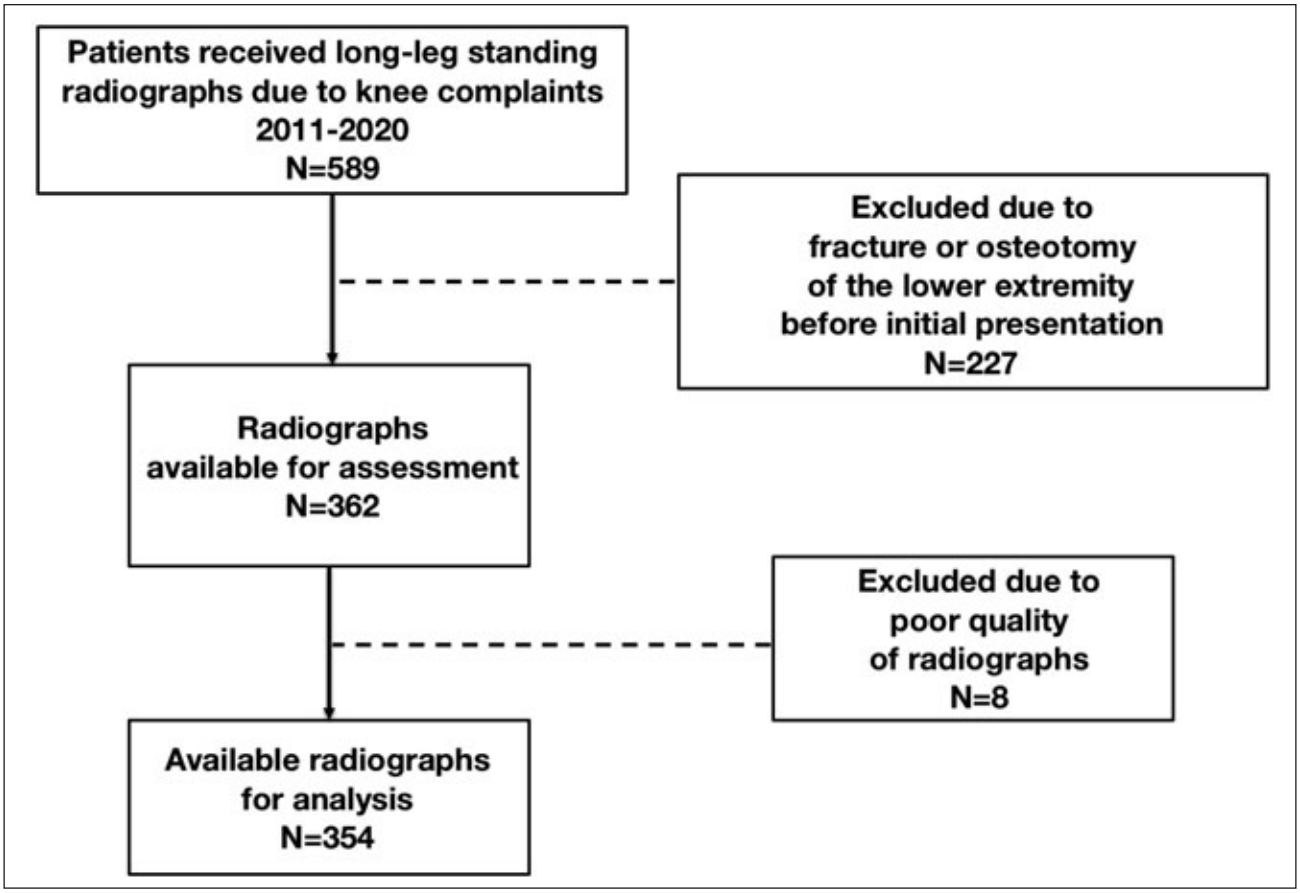

Fig. 1. Flowchart demonstrating inclusion.

standing in a bipedal stance in front of the long film cassette. Radiologic technical assistants were instructed to position both legs with the patella centered between the femoral condyles. The radiography tube was positioned in a distance of 305 cm. The selected film cassette was of sufficient length to include the hips, knees, and ankles. The magnification with this setup was approximately 5%. A calibration device (25 mm steel ball) was used to calibrate the radiographs. The X-ray beam was centered on the level of the knee joints.

The Hip-Knee-Ankle angle (HKA), the mechanical Lateral Distal Tibia Angle (mLDTA), and the Tibia Plafond Horizontal Orientation angle (TPHA) were measured (Fig. 2 and 3). Digital measurements were independently performed by two orthopaedic surgeons, who repeated their measurements after six weeks to determine intra- and interrater reliabilities.

For this study, neutral frontal alignment of the lower extremities was defined as HKA between -3.0° and +4.0°. HKA-values < -3.0° were defined as genua valga and values > 4.0° were defined as genua vara. According to these cutoffs, data was categorized into the following three patient groups: genua vara (n=157), genua norma (n=106), genua valga (n=91).

For each group, the ankle alignment in the frontal plane was compared to the HKA. Finally, the three groups were compared to each other analyzing the overall coronal leg alignment (HKA) and the angles around the ankle (mLDTA and TPHA).

Statistical analysis

Continuous variables were presented as mean, range, and standard deviation. Comparison between means was performed using the ANOVA test. A p value of <0.05 was considered statistically significant. SPSS version 24 (IBM, Armonk, NY, USA) was used. To analyze the intra- and interobserver reliability, the correlation coefficients (ICCs) were calculated.

RESULTS

In the varus-group, we found a HKA of 6.9°±2.4°, a TPHA of 4.7°±3.5°, a mLDTA of 87.4°±4.8°. In the neutral-group, we found a HKA of 1.8°±2.0°, a TPHA of 2.5°±2.9°, a mLDTA of 87.2°±4.6°. In the valgus-group, we found a HKA of -6.0°±2.7°, a TPHA of -0.2°±4.7°, a mLDTA of 85.0°±4.7°.

In patients with a valgus alignment of the long-leg axis, the TPHA demonstrated significantly less valgus alignment than in patients with a varus alignment of the long-leg axis ($p<0.001$). The mLDTA did not differ significantly between the three groups (Table 1).

The intra- and interrater reliabilities both were excellent, demonstrating ICCs of 0.931 and 0.918 respectively.

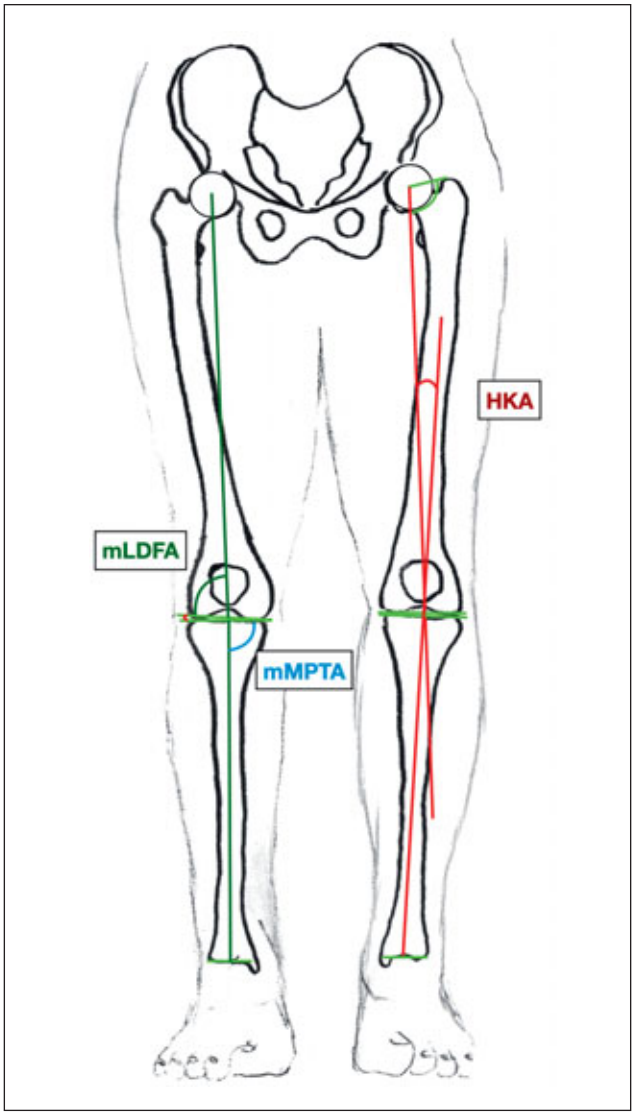

Fig. 2. Illustration of the radiographic measurement of the Hip-Knee-Ankle angle on a long-leg standing X-ray with the knees pointing forward [from Konrads et al. (9)].
HKA – Hip Knee Ankle angle, mLDFA – mechanical Lateral Distal Femoral Angle, mMPTA – mechanical Medial Proximal Tibial Angle.

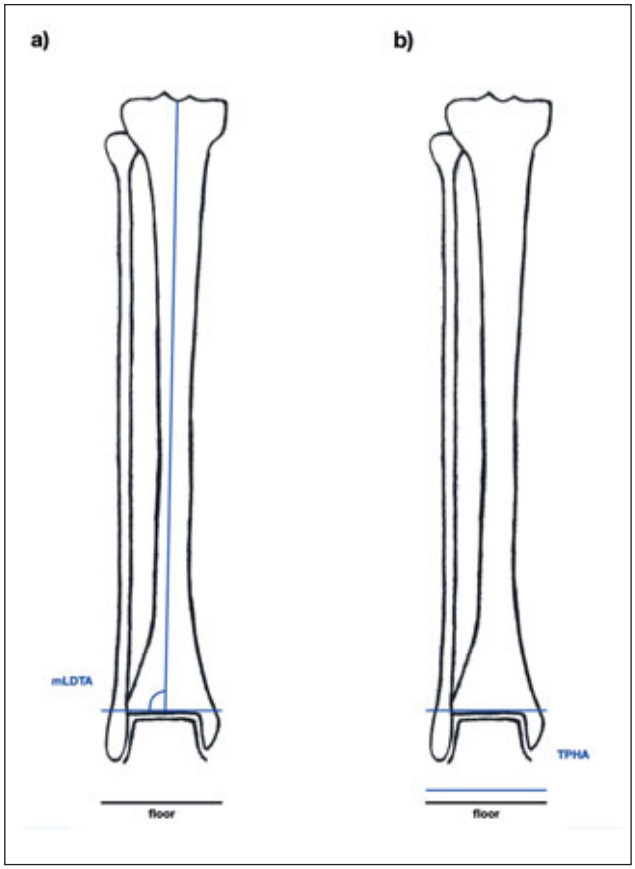

Fig. 3. Illustration of the radiographic parameters measured on a long-leg standing X-ray with the knees pointing forward. Measures around the ankle; a – mLDTA: angle between tibia-plafond and mechanical tibia axis; b – TPHA: angle between tibiaplafond and floor (0° = neutral; angle opening medial = positive values = valgus; angle opening lateral = negative values = varus) [modified from Konrads et al. (9)].
mLDTA – mechanical Lateral Distal Tibia Anglel, TPHA – Tibia Plafond Horizontal Orientation Angle.

DISCUSSION

The most important finding of this study is that in native valgus aligned knees the orientation of the ankle joint line is more varus in comparison with varus aligned knees where it is more valgus. This was demonstrated measuring the HKA and the TPHA. The mLDTA was very similar in all groups without significant differences. However, there was a tendency for a smaller mLDTA (more varus) in the group of genua valga than in genua vara and norma (Table 1).

The Mikulicz weight-bearing line from the center of the hip joint to the center of the ankle joint is used to estimate the long-leg axis and the load distribution in the knee. As the most distal point of the Mikulicz-line is

Table 1. Radiographic measurements of the long-leg axis and angles around the ankle

Radiographic measure	Genua vara (n = 157)	Genua norma (n = 106)	Genua valga (n = 91)	p-value
HKA [°]	6.9 (4.1 – 17.4; SD 2.4)	1.8 (–2.8 – 4.0; SD 2.0)	–6.0 (–11.5 – -3.2; SD 2.7)	< 0.001
TPHA [°]	4.7 (0.0 – 14.8; SD 3.5)	2.5 (0.0 – 8.3; SD 2.9)	–0.2 (–17.7 – 6.9; SD 4.7)	< 0.001
mLDTA [°]	87.4 (78.8 – 99.5; SD 4.8)	87.2 (76.5 – 92.5; SD 4.6)	85.0 (75.1 – 93.2; SD 4.7)	n. s.

HKA – Hip-Knee-Ankle angle
mLDTA – mechanical Lateral Distal Tibia Angle
TPHA – Tibia Plafond Horizontal Orientation Angle

Fig. 4. Anterior-posterior radiographs of a 60-year-old woman; a – the long-leg standing radiograph shows valgus alignment of both lower extremities; b – this photograph from the long-leg standing radiograph demonstrates that an isolated view of the ankles would not provide sufficient information regarding frontal alignment of the patient's anatomy.

defined to be at the center of the ankle, this line is not useful to estimate load distribution at the tibio-talar joint.

In valgus knees, the subtalar joint has to compensate for the valgus by inversion in order to enable even foot sole contact with the floor. In varus knees, the subtalar joint is more in eversion to compensate for the varus alignment of the leg. This has been demonstrated not only for native legs (2, 10, 15, 16), but also as an effect of osteotomies around the knee (9), and as a result of knee arthroplasty correcting the long-leg axis (3, 6).

For a sufficient workup of a patient's symptoms around the ankle, after taking history and conducting a comprehensive clinical examination, standard radiographs of the ankle are not sufficient to assess the mechanical alignment radiologically. Long-leg standing weight-bearing radiographs are needed to assess the long-leg axis in the frontal plane (Fig. 4). For evaluation of the inframalleolar hindfoot alignment, an additional Saltzman-view is recommended (1, 12).

For an even more complete assessment of lower extremity frontal alignment, a weight-bearing line from the hip to the contact-point of the calcaneus with the floor might be useful (7, 13). This would generally show a medialized weight bearing at the ankle in valgus knees and a lateralized loading of the ankle in varus knees. This theory could explain the Takakura classification of medial ankle arthritis (14).

A high number of standardized radiographs of native legs have been available for this study. The main limitation of the present study could be seen in the fact that a 3-dimensional reality has been simplified using 2-dimensional radiography. This problem would require complex imaging in a functional standing position. Given that the aim of this study was to prove the concept in a feasible standard clinical setting, the authors agreed on the sufficiency of the design chosen in this study. However, because of possible confounders to the postoperative alignment evaluated with 2-D X-ray in a standard clinical setting, the results of this study should be confirmed in future studies using 3-D analysis.

CONCLUSIONS

The frontal alignment of the ankle joint line depends on the overall frontal alignment of the leg. The TPHA correlates with varus or valgus alignment of the knee, but the mLDTA does not. In patients with a valgus alignment of the long-leg axis, the TPHA demonstrated less valgus alignment of the ankle than in patients with varus alignment of the long-leg axis. This knowledge is especially useful when planning osteotomies for correction of lower extremity malalignment. The TPHA should be appreciated during the planning process of osteotomies around the knee because the TPHA correlates with the constitutional knee alignment.

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