Increased ankle pain after total knee arthroplasty is associated with a preoperative lateralized gait and talar tilt but not with ankle laxity or the range of motion of the subtalar joint

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Aims
Total knee arthroplasty (TKA) may provoke ankle symptoms. The aim of this study was to validate the impact of the preoperative mechanical tibiofemoral angle (mTFA), the talar tilt (TT) on ankle symptoms after TKA, and assess changes in the range of motion (ROM) of the subtalar joint, foot posture, and ankle laxity.

Methods
Patients who underwent TKA from September 2020 to September 2021 were prospectively included. Inclusion criteria were primary end-stage osteoarthritis (Kellgren-Lawrence stage IV) of the knee. Exclusion criteria were missed follow-up visit, post-traumatic pathologies of the foot, and neurological disorders. Radiological angles measured included the mTFA, hindfoot alignment view angle, and TT. The Foot Function Index (FFI) score was assessed. Gait analyses were conducted to measure mediolateral changes of the gait line and ankle laxity was tested using an ankle arthrometer. All parameters were acquired one week pre- and three months postoperatively.

Results
A total of 69 patients (varus n = 45; valgus n = 24) underwent TKA and completed the postoperative follow-up visit. Of these, 16 patients (23.2%) reported the onset or progression of ankle symptoms. Varus patients with increased ankle symptoms after TKA had a significantly higher pre- and postoperative TT. Valgus patients with ankle symptoms after TKA showed a pathologically lateralized gait line which could not be corrected through TKA. Patients who reported increased ankle pain neither had a decreased ROM of the subtalar joint nor increased ankle laxity following TKA. The preoperative mTFA did not correlate with the postoperative FFI ($r = 0.037$; $p = 0.759$).

Conclusion
Approximately one-quarter of the patients developed ankle pain after TKA. If patients complain about ankle symptoms after TKA, standing radiographs of the ankle and a gait analysis could help in detecting a malaligned TT or a pathological gait.

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Introduction
Recent publications have claimed that patients may develop ankle symptoms following total knee arthroplasty (TKA).[1-4] The observation that the degree of preoperative mechanical tibiofemoral angle (mTFA) directly correlated with postoperative ankle pain provided a first possible biomechanical explanation for this clinical phenomenon.[2,5,6] In these studies, TKA was performed using the measured-resection technique, which aims to correct the mechanical leg axis to a neutral position and to adapt the

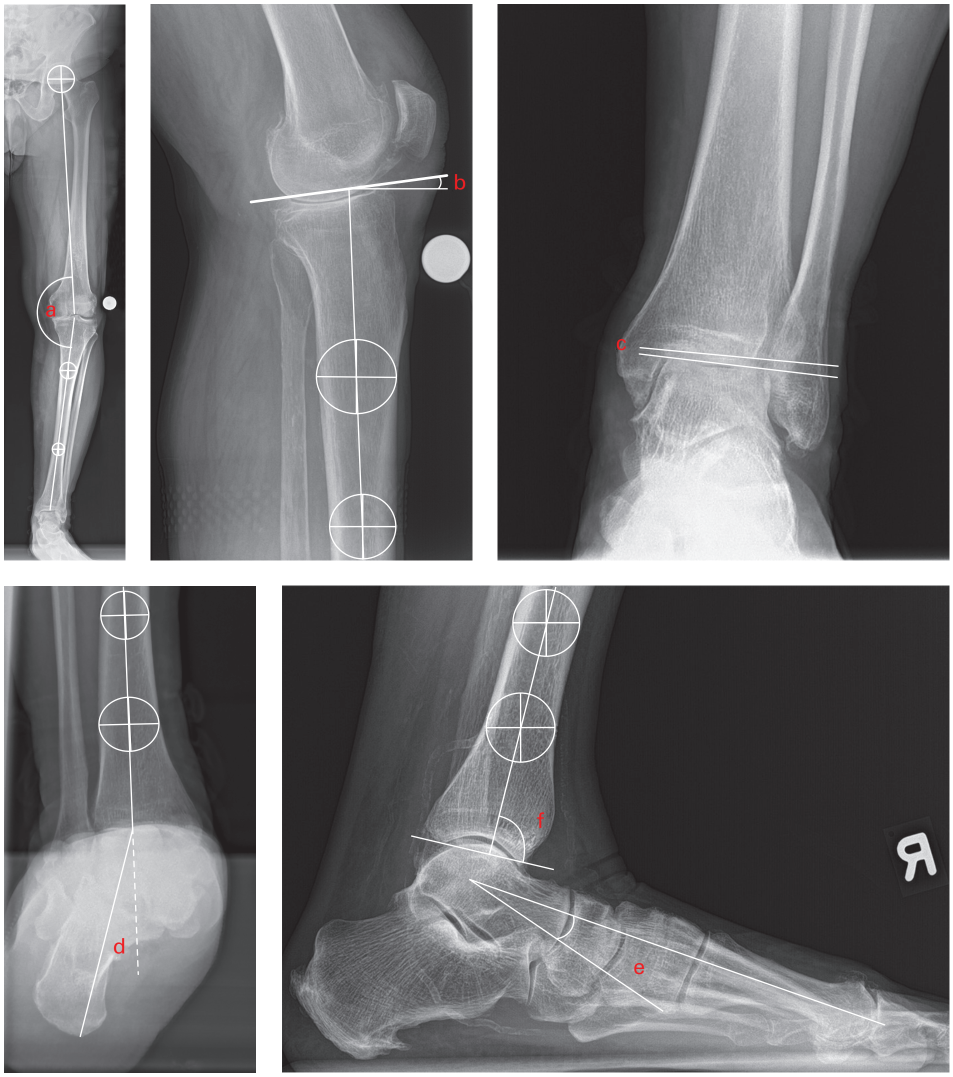

Fig. 1

Radiographs depicting the measurements which were conducted (see main text for full descriptions). a) The mechanical tibiofemoral angle (mTFA). b) The slope at the knee joint. c) The talar tilt. d) The hindfoot alignment view angle on a Saltzmann. e) The Meary's angle. f) The angle between the mechanical tibial axis and a tangent to the tibial plafond on standing lateral radiographs was defined as the anterior distal tibia angle.

soft-tissue to the implant position.[7] It has been reported that there is a high variety of knee phenotypes in both physiological and osteoarthritic knees.[8,9] Latterly, increasing numbers of TKAs are being implanted using the gap-balancing technique, which aligns the implant position kinematically to the tension of the surrounding soft-tissue, taking the patient's individual anatomy into account.[10] When analyzing the influence of TKA on the ankle joint, it is important to evaluate how these different alignment strategies in TKA may influence clinical and radiological parameters differently, and how this affects ankle pain and function.

Evidence of previous publications on ankle symptoms after TKA is limited because these studies were conducted retrospectively, primarily analyzed patients with varus knee osteoarthritis, or merely analyzed radiological changes.[1,2,5] However, studies could prove that radiological changes, specifically at the hindfoot, may be misleading if clinical features are ignored.[11] It is also important to differentiate between patients with varus and valgus osteoarthritis of the knee, since both malalignments induce different compensational mechanisms at the hindfoot, which in turn can lead to different pathologies at the foot and ankle (e.g. pes planovalgus or cavovarus depending on the hindfoot alignment).[12-15]

Additionally, it has been suggested that ankle pain following TKA could be the consequence of a reduced range of motion (ROM) of the subtalar joint and ligamentous instability of the ankle.[5,6] The aim of this study was to validate the clinical phenomenon of ankle pain after TKA and analyze the causes. In particular, the influence of ROM of the subtalar joint or ankle instability, and differences between varus and valgus malalignment in knee osteoarthritis, on symptoms at the ankle joint, were explored.

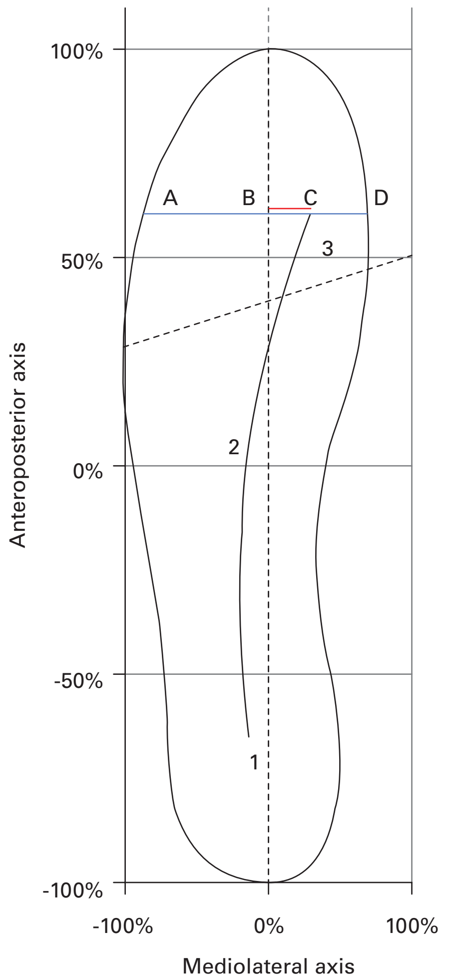

Fig. 2

The mediolateral excursion index (MLEI) was calculated by dividing the distance from the gait line at the specific point (B) to the mediolateral bisection of the sole (anterior-posterior axis) (point C) (distance BC = red line) and the width of the sole at that position (distance AD = blue line) multiplied by 100 (MLEI = BC/AD × 100).

A variety of clinical tests are available to measure the ROM of the subtalar joint and the ligamentous stability of the ankle joint.[16] These tests are, however, observer-dependent and often only provide qualitative results.[17] To perform quantitative data analyses, the ROM of the subtalar joint and ligamentous stability of the ankle joint have to be assessed using an ankle arthrometer to measure the exact inversion and eversion capacity.[18,19] By measuring the hindfoot alignment view angle (HAVA), it can additionally be evaluated, if the compensated position of the hindfoot returns to normal after restoration of the mechanical leg axis by TKA. Similarly, to measure qualitative changes of the foot posture while walking, gait analyses using digital pressure-sensitive insoles have to be performed. Here, evaluating mediolateral changes of the gait line could be indicative of developing ankle pain after TKA based on pathological gait lines displaying more pronated (flat) or supinated (hollow) feet. Additionally, the TT is an important radiological measure, which should be assessed to evaluate frontal malalignments of the ankle joint, which might be a consequence of frontal knee malalignments.[20,21]

The main hypothesis of this study was that the preoperative mTFA correlated with ankle symptoms, assessed by the Foot Function Index (FFI),[22] after the operation. Secondary hypotheses were that patients who experienced increased ankle symptoms after TKA demonstrated: a significantly increased TT; decreased ROM of the subtalar joint; increased ligamentous laxity of the ankle; and a pathological gait line.

Methods

The institutional ethics review board approved this study (number: AS 116(bB)/2019). All patients gave their written informed consent to participate. The study was registered at the German Clinical Trials Register (DRKS-ID: DRKS00017400) and conducted at a German university hospital with a board-certified joint arthroplasty centre. The STROBE checklist was followed for this observational clinical prospective study.[23]

Patient selection. Patients who were planned to undergo TKA using the measured-resection technique from September 2020 to September 2021 were asked to participate in this study. Inclusion criteria were: willingness to participate; primary end-stage osteoarthritis (Kellgren-Lawrence stage IV)[24] of the knee, and age > 18 years.[24] Exclusion criteria were: patients who did not attend the follow-up visit; rheumatoid arthritis; previous hindfoot operations or joint fusions of the foot and ankle; post-traumatic pathologies/osteoarthritis of the foot and ankle joint; neurological disorders or polyneuropathy affecting gait and postural control (e.g. Parkinson's disease); progressed diabetes; Charcot foot; and patients with unicompartimental osteoarthritis who were undergoing unicondylar knee arthroplasty. Pre-existing ankle symptoms were not an exclusion criterion.

Preoperatively, 87 patients were deemed eligible for study inclusion and were willing to participate. One patient was excluded because they had already undergone fusion procedures of the foot. Four patients were excluded after the operation as the surgeon had elected to implant a unicondylar knee arthroplasty intraoperatively. A total of 82 patients (varus n = 52; valgus n = 30) were included in this study and analyzed preoperatively, as recently published.[11,25]

Three months after the operation, 69 patients attended the follow-up visit and contributed to the final analysis (varus n = 45; valgus n = 24). This was represented in a follow-up rate of 84.1%, with 13 patients lost to follow-up. Five patients could not attend due to a medical condition unrelated to the TKA, four patients did not attend without stating a reason, three patients were unable to attend because they lived abroad, and one patient had died from COVID-19.

To detect variables which were associated with the onset or progression of ankle symptoms, patients were subdivided into two groups: patients who reported an equal or decreased (improved) FFI sum score postoperatively (FFI Sum better/equal), and patients who reported an increased (worse) FFI sum score after TKA (FFI Sum worse).

Clinical examination. Patients were clinically examined both pre- and postoperatively by assessing the ROM of the knee and ankle joint using a goniometer. All measurements were conducted by a single observer (MR). The ROM of the ankle joint was

Table I. Comparison between the preoperative and postoperative results, stratified into varus and valgus patients.

Variable	Varus			Valgus		
	Preoperative	Postoperative	p-value*	Preoperative	Postoperative	p-value*
n	45	45		24	24	
Median FFI (IQR)						
Pain	0.00 (0.00 to 19.40)	0.00 (0.00 to 22.20)	0.893	0.00 (0.00 to 28.28)	0.00 (0.00 to 29.20)	0.824
Function	0.00 (0.00 to 33.30)	0.00 (0.00 to 22.20)	0.958	0.00 (0.00 to 39.65)	0.00 (0.00 to 33.65)	0.813
Sum	0.00 (0.00 to 65.00)	0.00 (0.00 to 44.40)	0.958	0.00 (0.00 to 69.58)	0.00 (0.00 to 63.20)	0.726
Median KOOS (IQR)						
Pain	41.70 (30.60 to 52.00)	75.00 (61.10 to 86.10)	< 0.001	41.70 (35.40 to 47.90)	73.60 (66.70 to 89.60)	< 0.001
Symptoms	46.40 (39.30 to 60.70)	67.90 (60.70 to 78.60)	< 0.001	33.90 (21.40 to 47.30)	73.20 (63.40 to 79.47)	< 0.001
ADL	41.20 (32.40 to 50.00)	73.50 (64.70 to 82.40)	< 0.001	38.20 (29.40 to 45.98)	72.80 (64.70 to 82.75)	< 0.001
Sport	10.00 (5.00 to 15.00)	40.00 (30.00 to 55.00)	< 0.001	2.50 (0.00 to 10.00)	40.00 (25.00 to 50.00)	< 0.001
QOL	25.00 (6.30 to 31.25)	56.30 (43.80 to 68.80)	< 0.001	18.77 (6.30 to 30.31)	50.02 (37.50 to 62.50)	< 0.001
Median ROM, ° (IQR)						
Ankle dorsiflexion	5.00 (0.00 to 10.00)	10.00 (0.00 to 10.00)	0.451	5.00 (2.25 to 10.00)	10.00 (5.00 to 10.00)	0.749
Ankle plantarflexion	35.00 (30.00 to 40.00)	35.00 (30.00 to 40.00)	0.642	37.50 (30.00 to 40.00)	35.00 (30.00 to 36.25)	0.680
Knee extension	-5.00 (-10.00 to 0.00)	0.00 (-5.00 to 0.00)	0.097	-10.00 (-11.25 to 0.00)	0.00 (-10.00 to 0.00)	0.025
Knee flexion	115.00 (100.00 to 120.00)	110.00 (100.00 to 120.00)	0.079	110.00 (87.50 to 116.25)	115.00 (108.75 to 120.00)	0.100
Median ankle arthrometer measurements (IQR)						
Inversion rotation, °	35.77 (29.58 to 41.15)	34.36 (28.74 to 39.43)	0.629	40.85 (32.30 to 45.39)	35.68 (32.21 to 40.17)	0.266
Eversion rotation, °	20.84 (17.75 to 24.93)	16.39 (13.26 to 20.11)	0.004	19.85 (15.37 to 26.48)	20.41 (15.14 to 24.69)	0.635
Anterior displacement, mm	11.20 (9.69 to 16.91)	11.66 (8.50 to 14.34)	0.344	13.21 (9.96 to 15.71)	10.23 (8.09 to 11.88)	0.035
Posterior displacement, mm	5.60 (4.16 to 7.96)	5.84 (4.60 to 7.10)	0.717	7.22 (4.98 to 8.52)	6.81 (5.90 to 8.44)	0.983
Median MLEI (IQR)						
1	-12.54 (-14.76 to -9.88)	-9.28 (-11.44 to -7.11)	0.001	-10.02 (-13.91 to -6.32)	-8.96 (-12.25 to -6.73)	0.682
2	-15.11 (-19.71 to -11.39)	-10.70 (-15.71 to -8.01)	0.008	-10.73 (-14.50 to -6.43)	-11.55 (-15.65 to -8.78)	0.467
3	-1.59 (-5.08 to 1.49)	-0.35 (-2.64 to 2.89)	0.064	-0.36 (-6.28 to 3.93)	-1.05 (-5.05 to 1.40)	0.733
Median radiological measurements (IQR)						
mTFA, °	9.25 (5.04 to 12.60)	1.39 (-0.09 to 3.62)	< 0.001	-9.00 (-13.10 to -6.31)	-0.53 (-2.25 to 0.30)	< 0.001
HAVA, °	-3.92 (-6.53 to -2.10)	-1.82 (-3.28 to 1.57)	0.001	3.75 (2.41 to 5.77)	-2.37 (-4.79 to -1.60)	< 0.001
TT, °	0.40 (-0.55 to 0.92)	-0.16 (-0.99 to 0.47)	0.022	-0.72 (-1.60 to 0.10)	-0.45 (-1.33 to 0.19)	0.774
Meary, °	7.42 (2.24 to 12.00)	7.25 (4.48 to 12.86)	0.878	7.54 (3.16 to 14.02)	6.63 (2.32 to 14.23)	0.772
Slope, °	6.90 (5.26 to 9.35)	5.84 (4.37 to 7.12)	0.020	6.96 (5.22 to 10.31)	5.88 (3.70 to 6.40)	0.012
ADTA, °	83.74 (81.20 to 85.44)	83.30 (80.64 to 85.20)	0.744	83.39 (81.35 to 86.10)	84.00 (82.18 to 85.99)	0.343

*Wilcoxon signed-rank test.
ADL, activities of daily living; ADTA, anterior distal tibia angle; FFI, Foot Function Index; HAVA, hindfoot alignment view angle; IQR, interquartile range; KOOS, Knee injury and Osteoarthritis Outcome Score; MLEI, mediolateral excursion index; mTFA, mechanical tibiofemoral angle; ROM, range of motion; TT, talar tilt.

measured with the knee in 90° flexion. For statistical analysis, a motion deficit of e.g. 5° extension deficit of the knee (extension/flexion 0° to 5° to 90°) was documented as extension -5°. Subjective patient satisfaction was assessed using standardized and approved patient-reported outcome measures (PROMs).[26] Concerning the ankle joint, the widely accepted Foot Function Index (FFI) was used. The FFI is a two-part score including a pain and function scale. The two scales are reported separately and as the sum of both (FFI Sum) and higher points correlate to worse outcomes.[22,27] For the knee joint, the Knee injury and Osteoarthritis Outcome Score (KOOS) was documented. The KOOS consists of five separately reported parts (pain, symptoms, activities of daily living, sports, knee-related quality of life) and each part can score a maximum of 100 points with higher points correlating to better outcomes.[28]

Radiological analysis. Radiographs of the leg, knee, and ankle were acquired pre- and postoperatively. Anterior-posterior standing full weightbearing radiographs of the entire leg were acquired with the leg in neutral rotation and the patella facing anteriorly. If patients had a preoperative varus or valgus deformity ≥ 5°, additional radiographs of the foot and ankle with full weightbearing were acquired: a mortise view of the ankle, a lateral view of the entire foot and ankle, and a hindfoot view (Saltzman view).[29] All radiographs were calibrated using calibration markers.

All radiological measurements were conducted by two physicians with a minimum of five years experience of musculoskeletal imaging using the clinic's PACS and imaging software (MERLIN Diagnostic Workcenter, PHÖNIX PACS, Germany). Inter- and intraobserver reliabilities of these measurements

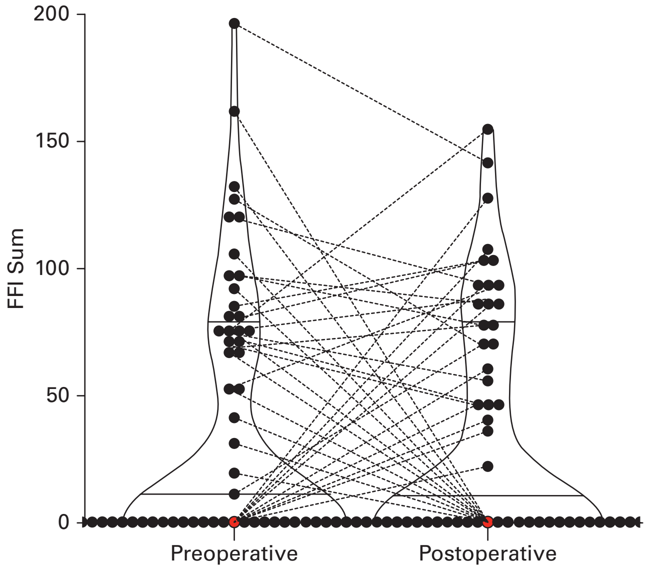

Fig. 3

Violin plot depicting the distribution of the pre- and postoperative Foot Function Index (FFI) sum score of the entire study cohort. The red dot represents the median FFI sum score value. The dashed lines show paired data of the same patients to visualize the proportion of patients who reported improved, equal, or worse ankle symptoms.

have recently been published.[25] Measurements of mechanical parameters on radiographs included the mTFA, which is the angle between the mechanical axis of the femur and the mechanical axis of the tibia. The centre of the femoral head was manually determined through the centre of a congruent sphere projected on the head. The mechanical axis of the femur was then measured from the centre of the femoral head to the centre of the femoral notch. The mechanical axis of the tibia was defined by a line crossing the centre of two circles which were manually overlayed on the proximal and distal tibial shaft to mark the medial and lateral borders of the tibia (Figure 1a). The TT was the angle between a tangent to the subchondral tibial plafond and a tangent to the talus dome.[20] The HAVA was measured on hindfoot radiographs and is the angle between the mechanical tibial axis and a line connecting the most distal part of the calcaneus and the centre of the ankle joint.[29,30] The mechanical tibial axis was defined as a line crossing the centre of two circles, which marked the medial and lateral borders of the mid-shaft and distal tibia. The centre of the ankle joint was defined as the intersection between the mechanical tibial axis and a tangent to the subchondral tibial plafond (Figure 1d).[30] The slope at the knee joint was measured using the method by Dejour and Bonnin,[31] which defines the mechanical axis of the tibia independent of the tibial tuberosity by placing the first measurement point below the tuberosity and the second one 10 cm further distally.[32] Positive values were noted for angles measured in varus, and negative values for valgus. The anterior distal tibial angle (ADTA) was measured between the mechanical tibial axis and a tangent to the subchondral tibial plafond on lateral standing radiographs of the foot and ankle. Measurement of pes planus or cavus deformities was done using the Meary's angle. The Meary's angle is the intersection between the anatomical longitudinal angle of the first metatarsal and a line bisecting the talus in standing lateral views of the foot and ankle.[33] Positive values were noted for pes planus deformities, negative values for cavus deformities (Figure 1).

Gait analysis. Gait analysis was conducted using pressure-sensitive insoles (Insole Model 3; Moticon ReGo, Germany). Measurements were recorded with a 100 Hz sampling rate while patients were walking a 20 m long straight line on even ground. Prior to each measurement, patients wore the sensor insoles for six minutes and were asked to walk 20 steps to allow for acclimatization and warm-up of the sensor insoles.[34] No measurements were taken during the warm-up phase. Gait parameters and 3D visualization of the pressure distributions were analyzed using the OpenGo software (Moticon ReGo). The vertical ground reaction force was normalized by division by the body weight in kg and the gravity.[35] The gait lines were calculated by the OpenGo software based on centre of pressure values. To analyze if gait lines between patients differed in the mediolateral direction, the mediolateral excursion index (MLEI) was calculated, representing an adjusted version of the centre pressure excursion index.[36] The MLEI is calculated for three positions. First, the beginning of the gait line corresponding to the heel strike/initial contact phase. The second MLEI position (midstance phase) was calculated at the intersection between the gait line and a line bisecting the sole from medial to lateral at the 0% position of the anterior-posterior axis, the mediolateral axis (Figure 2). The position for the third MLEI was at the end of the gait line corresponding to the toe-off phase. Each MLEI was calculated by dividing the distance from the gait line to the longitudinal bisection of the insole (anterior-posterior axis) and the width of the insole at that position (Figure 2). Lower MLEI values correspond to more lateral, higher MLEI values to more medial gait line excursions.

Ankle arthrometer. Ankle laxity was tested using an established and validated ankle arthrometer (AA) (Hollis Ankle Arthrometer; Blue Bay Research, USA).[19,37] Patients were lying on a couch with the leg placed on the calf support and the tibia strapped to the table. A hard pad was put underneath the calf support to minimize inaccuracies due to the soft padding of the stretcher. Before the actual measurement, a priming test (inversion-eversion and anterior-posterior) was performed to let patients accomodate to the procedure. The measurements were performed according to the manufacturer's instructions to test for the maximum anterior and posterior displacement and the maximum inversion and eversion of the ankle. A maximum force of 125 N was applied for the anterior-posterior measurement and a maximum torque of 4 Nm for the inversion-eversion testing. All measurements were performed by one examiner (MR) to ensure reproducibility. Inter- and intraobserver reliabilities have recently been published.[19]

Statistical analysis. Statistical analysis was performed using RStudio (Posit Software, USA). Sample size calculation was performed using the pwr package to answer the main hypothesis of a correlation between the preoperative mTFA and the postoperative FFI. Since previous studies reported extraordinarily high correlation coefficients ($r > 0.9$), we assumed a medium effect size ($r = 0.33$) for this study and a power of 80%,

Table II. Numbers of patients (with percentages) who reported an improved, equal, or worse outcome of the ankle joint assessed by the Foot Function Index after total knee arthroplasty.

Variable	FFI Pain			FFI Function			FFI Sum		
	Better	Equal	Worse	Better	Equal	Worse	Better	Equal	Worse
Varus, n (%)	10 (22.2)	25 (55.5)	10 (22.2)	10 (22.2)	24 (53.3)	11 (24.4)	12 (26.6)	24 (53.3)	9 (20.0)
Valgus, n (%)	7 (29.2)	11 (45.8)	6 (25.0)	6 (25.0)	11 (25.8)	7 (29.2)	6 (25.0)	11 (45.8)	7 (29.2)
Entire cohort, n (%)	17 (24.6)	36 (52.2)	16 (23.2)	16 (23.2)	35 (50.7)	18 (26.1)	18 (26.1)	35 (50.7)	16 (23.2)

FFI, Foot Function Index.

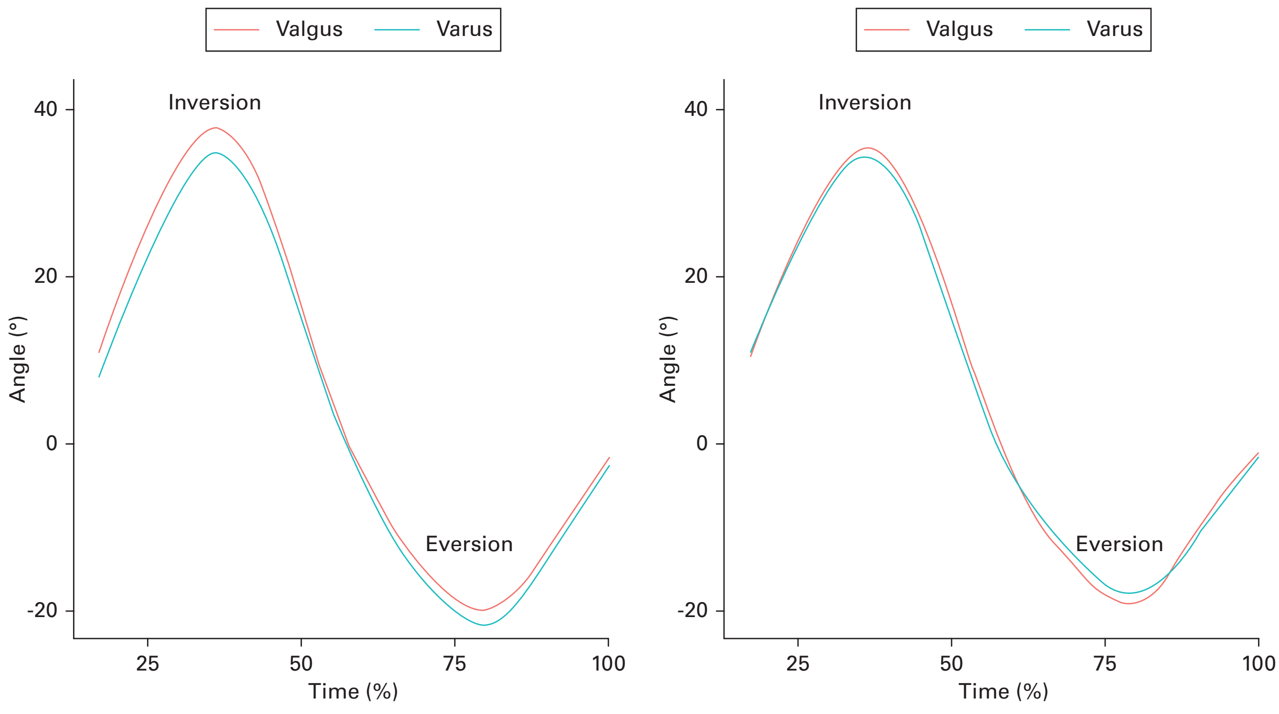

Fig. 4

Results of the ankle arthrometer a) preoperatively and b) postoperatively displaying the mean measurement curves. Overall, the maximum inversion and eversion in both groups decreased following total knee arthroplasty. The postoperative maximum eversion significantly decreased in the varus group (p = 0.004, Wilcoxon signed-rank test for paired data).

which showed that 69 patients were required for answering the main hypothesis.[5,6] Data were analyzed concerning normal/non-normal distribution using histograms, QQ-plots, mean/median, and skewness. Correlations were displayed with scatter plots and calculated using Pearson's correlation coefficient. Differences between two independent groups with non-normal distribution were calculated using two-sided Wilcoxon signed-rank tests and using paired Wilcoxon signed-rank test for paired data. Independent categorial variables were tested using the Fisher's exact test. The significance level was p-value < 0.05. Bonferroni correction was applied for multiple comparisons.

Results

Comparison between the pre- and postoperative PROMs demonstrated that all five scales of the KOOS significantly improved after TKA (Table I). The three FFI scales did not change significantly after the operation compared with the preoperative status in either the entire study cohort or in the varus or valgus group (Figure 3; Table I).

Of the entire study cohort, 18 patients (26.1%) reported an improved FFI sum score, 35 patients (50.7%) had no difference, and 16 patients (23.2%) noted a worse FFI sum score following TKA (Figure 3; Table II). The preoperative mTFA did not correlate with the postoperative FFI Sum score (entire study cohort: r = 0.037 (p = 0.759); varus: r = 0.029 (p = 0.847); valgus: r = 0.277 (p = 0.189)).

Results of the AA measurements demonstrated that the eversion significantly decreased following TKA in the varus group (p = 0.004). In both groups, the inversion decreased after the operation, although this was not statistically significant (Figure 4) (varus: p = 0.629; valgus: p = 0.266, Wilcoxon signed-rank test for paired data). In the valgus group, the decrease of the anterior displacement was significant (p = 0.035, Wilcoxon signed-rank test for paired data) (Table I).

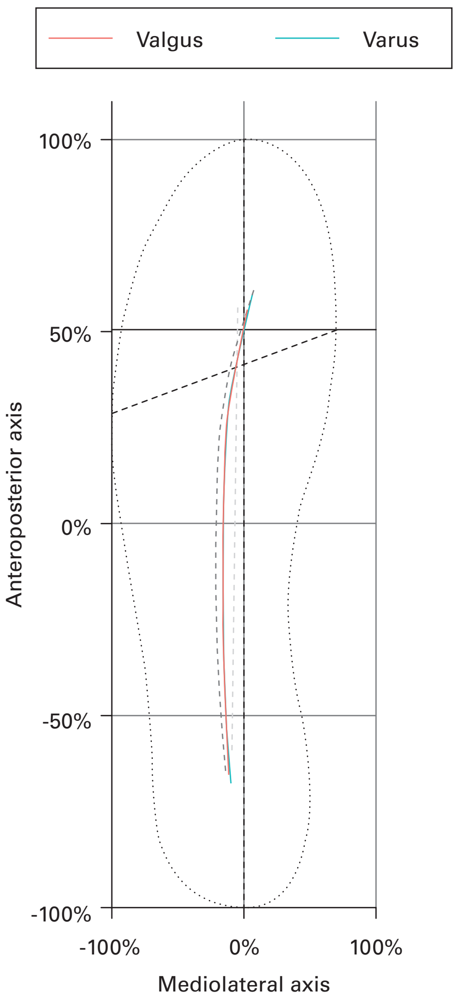

Fig. 5

The mean gait line of those patients with preoperative varus knee osteoarthritis were significantly medialized after total knee arthroplasty (MLEI 1: p = 0.001; MLEI 2: p = 0.008; MLEI 3: p = 0.064; Wilcoxon signed-rank test for paired data). In valgus patients, the mean gait line showed a tendency towards lateralization at the mid-stance and toe off phase, but these differences were statistically not significant (MLEI 1: p = 0.682; MLEI 2: p = 0.467; MLEI 3: p = 0.733, Wilcoxon signed-rank test for paired data). For visual comparison, the preoperaitve gait lines are also shown. The dark grey dashed line shows the preoperative mean gait line of the varus group and the light grey dashed line shows the preoperative mean gait line of the valgus group, as recently published.[11]

Gait analysis revealed that for patients with preoperative varus osteoarthritis, the mean gait line was significantly medialized following TKA (MLEI 1: p = 0.001; MLEI 2: p = 0.008; MLEI 3: p = 0.064; Wilcoxon signed-rank test for paired data). In patients with preoperative valgus knee osteoarthritis, the pre- and postoperative MLEI values did not differ statistically (MLEI 1: p = 0.682; MLEI 2: p = 0.467; MLEI 3: p = 0.733; Wilcoxon signed-rank test for paired data) (Table I; Figure 5).

Subgroup analysis between the two groups (FFI Sum better/equal versus FFI Sum worse) showed that a decreased inversion or eversion capacity of the ankle was not associated with the onset or progression of ankle symptoms after TKA (varus: preoperative inversion, p = 0.358, preoperative eversion, p = 0.988, postoperative inversion, p = 0.330, postoperative eversion, p = 0.503; valgus: preoperative inversion p = 0.546, preoperative eversion, p = 505, postoperative inversion, p = 0.975, postoperative, eversion p = 0.505, Wilcoxon signed-rank test). Similarly, the change of the hindfoot position, measured radiologically using the HAVA, showed no significant differences between those groups (varus: HAVA preoperative, p = 0.917, HAVA postoperative, p = 0.624; valgus: HAVA preoperative, p = 0.219, HAVA postoperative, p = 0.409, Wilcoxon signed-rank test). The full details are shown in Supplemenary Table i. Varus patients with a worse postoperative FFI Sum score had a significantly higher pre- and postoperative TT (preoperative, p = 0.040, postoperative, p = 0.009, Wilcoxon signed-rank test). Patients with preoperative valgus knee osteoarthritis and increased postoperative ankle symptoms demonstrated a significantly more lateral gait line both pre- and postoperatively (MLEI 1 preoperative, p = 0.010; MLEI 1 postoperative, p = 0,008; MLEI 2 postop, p = 0.020, Wilcoxon signed-rank test).

Discussion

Prior to this study it was unknown whether longstanding inversion of the hindfoot to compensate for valgus knee osteoarthritis, and similar eversion of the hindfoot to compensate for varus knee osteoarthritis, remained after correction by TKA, and ultimately provoked ankle pain.[25] We found that the hindfoot, radiologically measured using the HAVA, shifted into a physiological position in both varus and valgus patients after TKA. Therefore, the hypothesis of a stiff subtalar joint fixed in eversion or inversion due to chronic compensation of a varus/valgus knee deformity could not be confirmed.

Radiological analyses demonstrated that varus and valgus malalignments at the knee joint were associated with hindfoot valgization (eversion) and varization (inversion), respectively, particularly when osteoarthritis of the tibiotalar joint was present.[14,15] In this study, patients with preoperative varus knee osteoarthritis, who complained about increased postoperative ankle pain, were shown to have had a significantly increased varus-aligned TT preoperative compared to patients without postoperative ankle pain. After TKA, the TT in patients with ankle pain remained in a varus position. A varus-aligned ankle joint could be one reason for the increased ankle symptoms in these patients, as it is a sign for the collapse of the medial ankle joint space and therefore a sign for cartilage degeneration.[38] The TT could therefore serve as a variable in predicting whether patients develop ankle pain after TKA. There were nine varus patients with increased postoperative ankle symptoms in this study, and of those nine patients, seven had a TT > 0. Because of these small numbers, the TT as a predictor for postoperative ankle pain has to be regarded carefully. A full weightbearing anteroposterior radiograph of the ankle joint could help in identifying a malalignment of the ankle joint for future analyses.

In a recent study, gait analysis demonstrated using pressure-sensitive insoles that in varus patients, the gait line was more lateral despite radiological hindfoot eversion. In valgus patients, the gait line ran more medial, although the hindfoot shifted into inversion radiologically.[11] In the present study, valgus patients with increased postoperative ankle symptoms showed significantly more lateral gait lines than those valgus patients without the onset or progression of ankle pain. Valgus patients with ankle pain after TKA also demonstrated, a non-statistically significant tendency toward higher Meary's angle values, which can be interpreted as a sign of flat foot deformities. These observations are contradictory, since patients with flat foot deformities usually tend to show medialized gait lines as a sign of foot pronation.[39] Within the entire valgus group, the gait line shifted laterally after TKA, as one would expect after restoration of a neutral limb axis, but these results were statistically not significant. The resulting lateral gait line in valgus patients with increased postoperative ankle pain could therefore well be the result of a pathological gait.

Surprisingly, of those patients within the entire study cohort who reported ankle pain before the operation (n = 25), a substantial proportion (40%) did not suffer from any ankle pain after the operation (postoperative FFI Sum score = 0) (Figure 3). Accordingly, preoperative ankle pain does not seem to be predictive of postoperative ankle symptoms.

Another mechanism which has been thought to contribute to ankle pain after TKA is the correction of the leg axis, possibly revealing ligamentous instability at the ankle.[5,25] A recent study measured the medial and lateral laxity of ankle joints in patients with severe varus and valgus knee osteoarthritis and found that these patients showed a tendency toward increased eversion and inversion, respectively.[25] It was hypothesized that the abrupt change of the entire leg axis by TKA might lead to ankle instability. Our study demonstrated that the inversion and eversion did not increase, but decreased after TKA. Sub-group analysis showed that those patients who reported increased ankle symptoms after operation did not have a significantly different inversion or eversion capacity compared to those patients with no progression of ankle pain. Therefore, we could not support the hypothesis that TKA induces ankle instability as a reason for postoperative ankle pain.

It has recently been reported that the preoperative TT significantly correlated with the mTFA.[25] Consequently, in varus knees, the preoperative TT was aligned in varus; and in valgus knees, the preoperative TT was aligned in valgus. It was concluded that the hindfoot was unable to compensating for severe varus and valgus deformities in knee osteoarthritis and this affected the physiological ankle alignment. These assumptions were emphasized by the observation that gait analyses demonstrated a medial gait line in valgus knees and a lateral gait line in varus knees, despite hindfoot inversion and eversion, respectively.[11] The present study demonstrated that following TKA, the TT was corrected to a horizontal alignment in the entire study cohort. Following TKA, patients with preoperative varus osteoarthritis showed a valgization of the TT and patients with preoperative valgus osteoarthritis demonstrated a varization of the TT. In both the varus and valgus group, the postoperative TT was found to be in a slight valgus alignment. Moreoever, this study reported that the gait line was significantly medialized in varus knee patients after TKA. In valgus knee patients, the gait line showed a tendency toward lateralization after TKA, although this observation was not statistically significant.

Little is known about the interaction between the sagittal alignment of the knee and ankle joints. The slope of the distal tibia at the ankle joint, measured using the ADTA, is regarded as an important factor when analyzing malalignment.[40] A recent study found that the ADTA significantly correlated with the posterior displacement of the ankle joint, and when the distal tibial plafond was aligned more horizontally, the degree of posterior translation of the talus in relation to the distal tibia increased.[25] In this study, neither the slope nor the ADTA differed between patients with and without ankle pain after TKA. Similarly, the posterior translation of the talus measured using the AA did not differ between groups.

Taken together, our study could not confirm that the extent of mechanical axis correction by TKA correlated with the degree of postoperative ankle symptoms, as recently suggested.[5,6] Nevertheless, almost one-quarter of all patients in this study cohort complained about ankle symptoms after the operation. The only parameter found to be associated with postoperative increased ankle pain was a varus-aligned TT in patients with varus knee osteoarthritis and a pathologically lateralized gait line among patients with valgus knee osteoarthritis. After the operation, neither ligamentous instabilities of the ankle nor a reduced ROM of the subtalar joint could be detected.

One limitation of this study is that the postoperative examination was conducted only at three months. Therefore, it is unclear whether the ankle symptoms persist.

In summary, almost one-quarter of the study cohort developed ankle pain after TKA. Patients with varus knee osteoarthritis and a preoperative varus malalignment of the ankle joint are at risk of developing ankle pain following TKA. Patients with valgus knee osteoarthritis undergoing TKA should be screened for flat foot deformities and pathologically lateralized gait patterns because these patients can potentially develop ankle pain.

Take home message

- This study demonstrates that approximately one-quarter of patients develop ankle pain after total knee arthroplasty.
- Risk factors were a preoperative varus malalignment of the ankle joint in varus knee osteoarthritis and pathologically lateralized gait patterns in valgus knee osteoarthritis.

Supplementary material

Table showing a comparison of specific clinical and radiological variables between patients who reported the onset or progression of ankle pain and those who had equal or improved ankle symptoms.

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