Pedobarographic Analysis in Total Knee Arthroplasty

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Abstract

Pedobarographic gait analysis is a useful tool for the determination of loading distributions and alterations on the lower extremity and their reflection on the foot sole after many orthopaedic surgical applications. To date, there have been no studies evaluating the relationship between component alignment and changes of pedobarographic gait analysis in total knee arthroplasty (TKA). We aimed to investigate the effects of TKA and prosthetic alignment on the distribution of pedobarographic parameters. Quantitative gait patterns of 47 patients were prospectively evaluated by using pedobarography 1 week before surgery and at the seventh month, on average, postoperatively. Component positions were assessed, and all applications were divided into three groups according to tibial component position as varus, neutral, and valgus. Pedobarographic results were compared between pre- and postoperative values for all applications and compared among the groups. Mean postoperative tibiofemoral angle was 5.4 degrees in valgus, and preoperative knee scores were markedly improved postoperatively. The range of tibial component alignment changed between 1 and 4 degrees in the varus and valgus groups. Plantar loading parameters (force and pressure) were significantly decreased in all operated knees, especially in forefoot and midfoot. In varus tibial components, plantar loading values decreased in midfoot and hindfoot. However, in the neutral and valgus groups, similar alterations of plantar loadings were obtained, which included decreasing in forefoot and midfoot with significant increase in hindfoot. Plantar loading distribution changed statistically significantly after TKA despite good clinical and radiographic results. Tibial component alignment was also responsible for plantar loading distribution. Tibial components in varus position create different foot loading characteristics compared with neutral and valgus aligned components. Pedobarographic evaluation in TKA allows clinicians to obtain a proper understanding of abnormal gait caused by component malposition.

Keywords

- pedobarography
- gait analysis
- total knee arthroplasty
- foot loading
- component alignment

Total knee arthroplasty (TKA) is a widely used surgical procedure, which intends to relieve pain and improve lower extremity alignment in patients with knee osteoarthritis. Evaluation of the knee joint before and after TKA has been generally performed by static radiographic examination and clinical scoring systems.[1,2] However, these methods are not suitable for pre- and postoperative evaluations, especially in dynamic situations.[3] Subjective measurement methods have

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limited sensitivity and unrealistic effect sizes because they primarily reflect the reduction in pain after surgery and have limited value when determining the long-term effectiveness of treatment.[4] On the other hand, gait analysis has been used to objectively measure patient's function and evaluate the changes in gait, which are difficult to define by radiographic evaluation and subjective clinical assessment following TKA.[3–9] However, full gait analysis procedure is expensive and time-consuming, and has not been widely used for patients undergoing TKA.[3]

Load-bearing aspect of the feet during standing and walking can be measured by pressure platforms. Pedobarography analyzes the force across a defined surface by providing several parameters of interest and is an objective test for evaluation of foot functions.[10] It has been mainly used for the evaluation of foot deformities and for surgical decision-making in these pathologies to demonstrate postoperative results.[11] Pedobarography is a simple, rapid, and noninvasive technique, as well as a more useful and practical tool instead of full gait analysis. However, the number of studies on the use of pedobarography in clinical practice after TKA is very limited.[8,12]

The success of TKA depends on the balance of soft tissues, accurate positioning of femoral and tibial components, and correction of lower extremity alignment.[13] Limb alignment and component orientation in TKA are thought to be important factors that affect the wear and implant survival.[14,15] Many studies confirm that bone-cut errors should be within 3 degrees from the ideal position to prevent abnormal wear and mechanical loosening of the components.[16,17] The relationships between the changes in gait parameters and clinical symptoms or the axial alignment of the lower extremities have been evaluated before,[18,19] and some studies[14,15] have investigated the effect of prosthetic alignment on the loosening of the implants or on the functional results. Additionally, realignment of the knee after TKA has been suggested to change the foot alignment, which potentially alters the dynamic foot function.[20] However, to the best of our knowledge, there have been no studies in the literature, which investigate the relationship between the component alignment and changes of pedobarographic analysis in TKA.

We aimed to evaluate quantitatively the changes in static and dynamic loading patterns by using pedobarography before and after TKA. Primary hypothesis was that preoperative loading parameters can change after surgery. Secondary hypothesis was that postoperative tibial component alignment influence plantar loadings.

Materials and Methods

Patients operated by TKA due to knee osteoarthritis were prospectively evaluated between January 2013 and October 2013. Patients with a diagnosis of primary knee osteoarthritis and who were able to walk without using supports before the operation were included in the study. We excluded the patients who had foot and/or ankle deformities with and without pain, acute lower extremity trauma, history of ipsilateral or contralateral lower extremity surgery, leg length discrepancies greater than 2 cm, documented disorders of arterial or venous circulation in the lower extremities, presence of any kind of neurologic or metabolic disease that may cause balance disorder, and clinically obvious degenerative changes in more than one limb or in the spine. In some patients, more than one exclusion criteria were noted (►**Table 1**). According to these criteria, 25 patients were excluded, whereas 47 patients (7 males, 40 females) were included in the study. The mean age of the patients was 68 (range: 52–83) years. Left knee was operated in 22 (46.8%) patients, and right knee was operated in 25 (53.2%). None of the patients were operated simultaneously bilaterally. All patients were evaluated with clinical, radiographic, and pedobarographic analysis before and after TKA. The Human Studies Ethics Committee at the first author's institution provided ethical approval for the study. Written informed consent was obtained from all patients prior to data collection.

On the preoperative evaluations, weight (kg), height (cm), and body mass index (BMI, kg/m^2) were recorded for each patient. The mean BMI was 31.1 $\pm$ 4.3 (range: 20–41.4) kg/m^2. Radiographic assessment involved standard anteroposterior and lateral knee radiographs, as well as full-length weight-bearing anteroposterior radiographs of the lower extremities. The tibiofemoral alignment at the knee joint was evaluated by the tibiofemoral angle (TFA), which was defined as the angle between the anatomical axes of the femur and tibia. A varus-aligned knee joint was

Table 1 Exclusion criteria and number of patients

Causes of exclusion	No. of patients
Foot or ankle pain	4
Foot or ankle deformity	4
Acute lower extremity trauma	2
Presence of previous surgeries of lower extremity (ipsilateral or contralateral)	6
Leg length discrepancies (>2 cm)	1
Disorders of arterial or venous circulation in the lower extremities	5
Balance disorders (neurologic or metabolic)	2
Degenerative changes in more than one limb	4
Degenerative changes in the spine	4

described with an TFA less than 4 degrees valgus, whereas valgus-aligned knee joint was described with an angle greater than 10 degrees valgus.[14,21]

The severity of osteoarthritis was graded according to Ahlbäck's classification.[22] The degrees of osteoarthritis were grade 1 in 4 (8.5%), grade 2 in 11 (23.5%), grade 3 in 22 (46.8%), and grade 4 in 10 (21.2%) knees. Functional and objective knee scoring systems of the American Knee Society were used for the clinical evaluation.[23]

Pedobarographic analysis of each patient was performed by Tekscan pedobarography device (Tekscan Inc., South Boston, MA), which measured pedobarographic values in a static and dynamic manner. The system consisted of a 5-mm-thick floor mat (432 × 368 mm), which comprised 2,288 resistive sensors (1.4 sensors/cm^2) with sampling data at a frequency of 40 Hz. The gait analysis procedure was always performed with the patient barefoot. Before taking each measurement, the pressure-sensitive mat was calibrated for patient's body weight as recommended by the manufacturer.[24]

An independent examiner, who was blinded to the results of the clinical and radiographic evaluations, performed all pedobarographic measurements. For the static analysis, patients were asked to stand on the platform for 10 seconds while they were asked questions to prevent concentration to the foot and to prevent the wrong tended posture from causing overpressure on one side of the foot (►**Fig. 1A**). In the dynamic analysis, patients walked at the normal daily gait speed on the same platform, and the stance phase of walking was then analyzed for at least 60 seconds (►**Fig. 1B**). To be able to record the natural gait of the patients, they performed several practice walking trials with a self-selected speed to accommodate to the environment and refrain from looking down to avoid targeting of the force platform. Each patient performed at least six successful walking trials on the force platform. Patients were instructed to put the foot on the platform during their normal walking rhythm and were asked to retry in case of a fixed stride and wrong foot position on the platform. The first and final footfalls from the recordings of each foot were omitted to eliminate potential partial trials and measurement errors resulting from momentary loss of equilibrium at startup.[25]

The data, which were obtained during pedobarographic evaluations, were then analyzed by using F-Scan Mobile Research program. The footprint image of each foot was manually superimposed with 12 masks, which allowed calculating standardized pedobarographic values for each individual area of the foot.[26] The masks were recorded as a separate file for each patient and reused for postoperative evaluation of the same patient since it was rarely necessary to make more than minor adjustments to impose the existing masks on the new results. The sole of the foot was then divided into three main areas (forefoot, midfoot, and hindfoot) according to International Guidelines for Plantar Measurements (►**Fig. 2**).[26] Following parameters were evaluated during static measurement: total plantar force (TPF; N) of the whole foot, as well as plantar force (PF) percentages, contact area (CA) percentages, and peak pressure (PP; N/cm^2) values in the forefoot, midfoot, and hindfoot regions. During dynamic measurement, pressure-time integral (PTI; N/cm^2 × seconds), force-time integral (FTI; N × seconds), CA (cm^2), and PP values in the same regions were calculated. The mean and standard deviation were recorded for all parameters.

TKA was performed by conventional techniques, and a cruciate-retaining implant (Genesis II Total Knee System, Smith and Nephew, Memphis, TN) was placed in all knees by the same orthopaedic surgeon. Tibial components were placed by using extramedullary guide system, and the patella

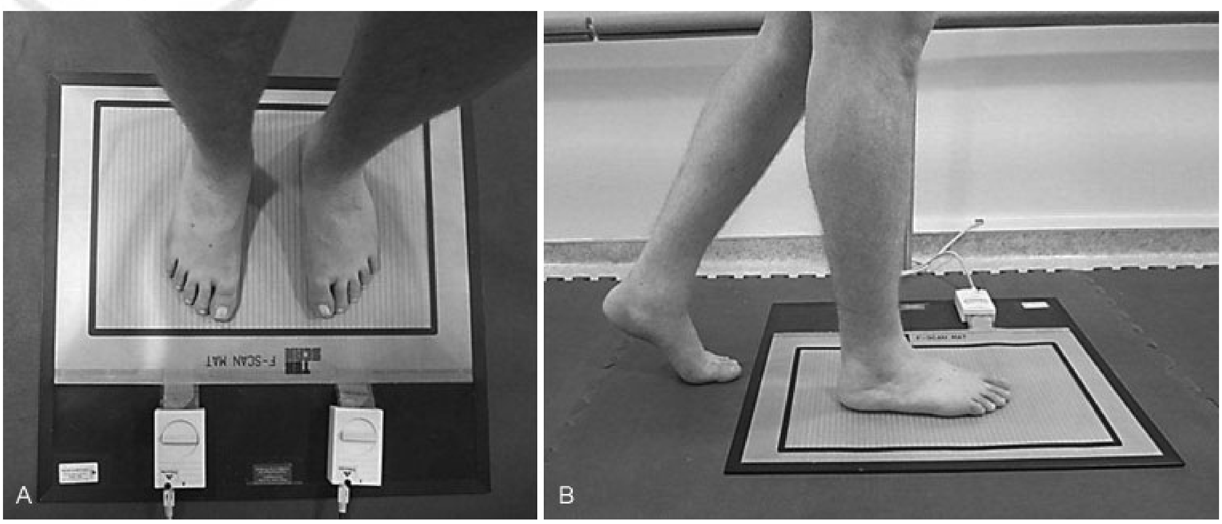

Fig. 1 **(A)** Static pedobarographic analysis refers to the collection and analysis of time series pedobarographic data for 10 seconds on standing position. Patients are asked to look at a constant point on the wall, which was 1.5 m away. While standing on the platform, the average distance between two feet is arranged to be 8 cm. **(B)** In the dynamic pedobarographic analysis, patients walk at the normal daily gait speed on the same platform for at least 60 seconds. To be able to record the natural gait of the patients, they perform several practice walking trials with a self-selected speed to accommodate to the environment and refrain from looking down to avoid targeting of the force platform. Then, patients are instructed to put the foot on the platform during their normal walking rhythm and were asked to retry in case of a fixed stride and wrong foot position on the platform.

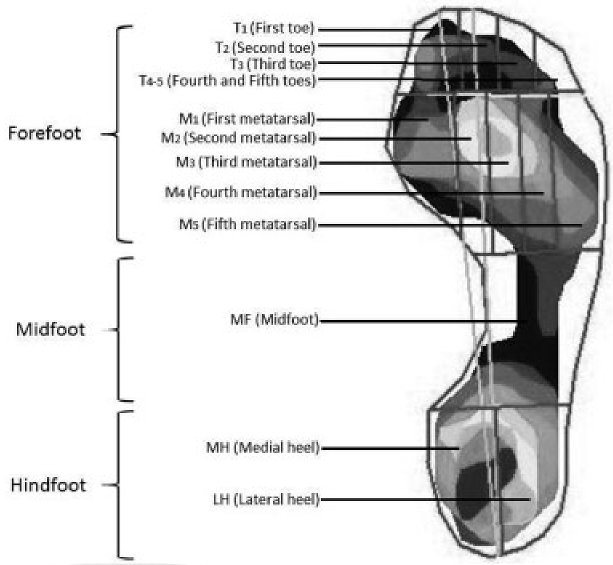

Fig. 2 Specific anatomical areas on the footprint image include the first (T1), second (T2), third (T3), fourth, and fifth (T4–T5) toes; the first (M1), second (M2), third (M3), fourth (M4), fifth (M5) metatarsals; midfoot (MF); medial heel (MH); and lateral heel (LH). The forefoot area is defined as the sum of the total area of the toes and metatarsals. The midfoot is defined in itself, and hindfoot is defined as the sum of medial and lateral heels.

was replaced in all knees. Full weight-bearing was started at the first day postoperatively, and active isometric and isotonic exercises for the foot, knee, and hip joints were encouraged. This protocol was continued until the patients were discharged from the hospital. They received a standard home-based rehabilitation program and were encouraged to give up the use of crutches or canes as soon as possible.

Pedobarographic, radiographic, and clinical evaluations were performed 1 week before the surgery and at the seventh month on average (range: sixth to eighth months) postoperatively, when patients were able to walk with full weight-bearing without pain or assistance. Femoral and tibial component positions in coronal and sagittal planes were also evaluated on radiographs by using the American Knee Society Radiological Evaluation System (►**Fig. 3**).[27] According to this evaluation, only tibial component position showed difference in all implanted knees. Therefore, all applications were divided into three groups according to tibial component position as varus, neutral, and valgus (►**Table 2**).

Pedobarographic, radiographic, and clinical results were compared between the pre- and postoperative values for all knees and were compared among the groups created according to tibial component position. Statistical analyses were performed using the NCSS 2007 program (NCSS Statistical Software, Kaysville, UT). Descriptive statistics (mean and standard deviation) were computed. Paired *t*-test was used

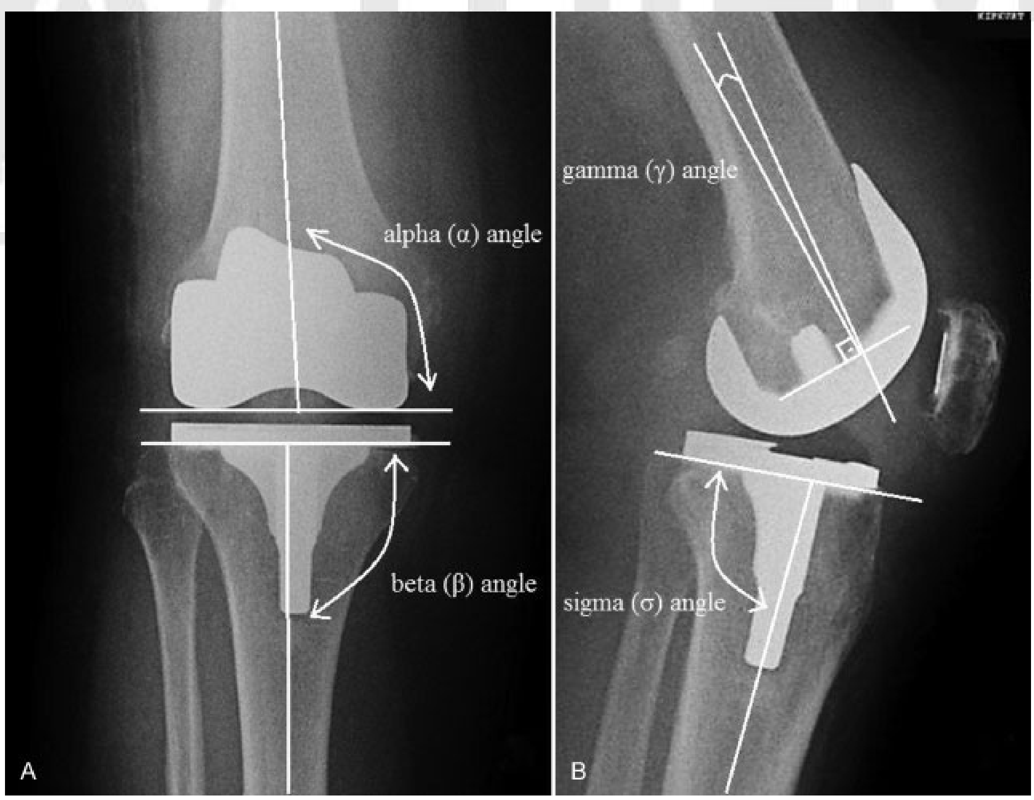

Fig. 3 **(A)** Alpha (α) angle between the distal surface of the femoral component and anatomic axis of the femur, and Beta (β) angle between tibial baseplate and anatomic axis of the tibia are measured on coronal images. **(B)** On sagittal images, gamma (γ) angle is determined by a line drawn perpendicular to the distal metal–cement interface of the femoral prosthesis and a line parallel to the femoral shaft axis. Sigma (σ) angle is calculated from a line drawn parallel to tibial baseplate and tibial shaft axis.

Table 2 Normal values of component alignment angles[15,27,31] and comparison of these angles among the groups created according to tibial component position in frontal plane

Component angles		Values accepted as normal[13,24,34]	Varus[a] (*n*: 18)	Neutral[a] (*n*: 12)	Valgus[a] (*n*: 17)	*p*-Value
Frontal plane	Alpha (α) angle	93–97 degrees (varus: <93 degrees, valgus: >97 degrees)	95.94 ± 1.86 degrees (93-99 degrees)	95 ± 3.44 degrees (93-98 degrees)	96.18 ± 1.88 degrees (93–97 degrees)	0.399
	Betα (β) angle	90 degrees (neutral) (varus: <90 degrees, valgus: >90 degrees)	87.84 ± 1.09 degrees (86–89 degrees varus)	90 degrees	91.94 ± 0.89 degrees (91–94 degrees valgus)	**0.0001**
Sagital plane	Gamma (γ) angle	Between 4 degrees flexion and 4 degrees extension	2.32 ± 0.78 degrees flexion (1.1–3.6 degrees)	2.73 ± 0.8 degrees flexion (2–4 degrees)	2.76 ± 0.96 degrees flexion (1–4 degrees)	0.262
	Sigma (σ) angle	85–90 degrees	85.5 ± 2.18 degrees (84–90 degrees)	86 ± 2.34 degrees (84–90 degrees)	87.2 ± 2.49 degrees (84–90 degrees)	0.701

Abbreviation: *n*, number of implanted knees.
[a]The values are given as the mean and standard deviation with the range in parentheses.

to compare pre- and postoperative parameters for all implanted knees. Repeated one-way analysis of variance was used to compare clinical and radiographic values among the groups. Tukey's honest significance test was used to compare the pedobarographic data among the groups. Qualitative data were compared by using the chi-squared test and Fisher's exact test. A *p*-value of <0.05 was considered to be statistically significant.

Prehoc power analysis was performed using the G-power 3.1 statistical software. To estimate the required sample size in each group, Cohen's effect size d_z (0.8), α (0.05), and 1-β (0.8) error probability values were used for the analysis. The minimum required sample size was calculated as 12.

Results

The mean preoperative TFA was 4.2 ± 2.8 degrees in varus (range: 0–10 degrees). TFA showed statistically significant improvement in valgus position (5.4 ± 2 degrees; range: 1–11 degrees) postoperatively ($p = 0.0001$). The preoperative functional and objective knee scores were 34.4 ± 9.7 (range: 20–55) and 45.7 ± 9.1 (range: 30–73), respectively. The postoperative functional (69 ± 11.9; range: 40–85) and objective (77.1 ± 9.5; range: 55–93) knee scores were greater than that measured preoperatively ($p = 0.0001$).

Comparison of pre- and postoperative pedobarographic parameters for all implanted knees is presented in ►**Table 3**.

On static pedobarographic evaluation, TPF decreased significantly ($p = 0.005$) in the postoperative period. Additionally, pressure ($p = 0.0001$) and force ($p = 0.003$) values decreased in midfoot, and CA decreased in forefoot ($p = 0.002$) and midfoot ($p = 0.0001$) postoperatively. On dynamic pedobarographic evaluation, PTI, FTI, and CA values decreased in the forefoot and midfoot regions postoperatively ($p = 0.0001$). PP decreased significantly only in midfoot ($p = 0.0001$). No significant changes were found in the hindfoot region for both static and dynamic evaluations.

No statistically significant differences were found among the study groups created according to tibial component position in terms of age, BMI, Ahlbäck's classification, pre- and postoperative TFA, and objective knee scores. Only postoperative functional knee score in the valgus group was greater than that in the varus and neutral groups ($p = 0.038$). Therefore, study groups were accepted as comparable by the pedobarographic data.

Comparison of Pedobarographic Parameters among the Study Groups

On static evaluation, postoperative TPF in the varus and valgus groups decreased significantly, whereas no statistically significant change was found in the neutral group. In knees with varus tibial component, PF, PP, and CA generally decreased in the midfoot and hindfoot regions. In knees with neutral tibial component, PF and PP decreased in forefoot; however, the same data increased in hindfoot. CA decreased in the forefoot and midfoot regions. In knees with valgus tibial component, PF, PP, and CA values decreased in the forefoot and midfoot regions; however, the same data increased in hindfoot postoperatively (►**Table 4**).

On dynamic evaluation, all pedobarographic parameters generally decreased in the midfoot and hindfoot regions postoperatively in knees with varus tibial component. However, in the neutral and valgus groups, all dynamic parameters showed statistically significant decrease in the forefoot and midfoot regions with significant increase in hindfoot postoperatively (►**Table 5**).

Discussion

The main finding of this study is that TPF decreased on postoperative period in all implanted knees. Additionally, all static and dynamic pedobarographic parameters showed significant decrease in the forefoot and midfoot regions postoperatively. These obtained results support our primary hypothesis, which is also compatible with the previous studies.[8,12] TKA affects the knee biomechanics as well as lower extremity loadings. Thus, pain relief might be a reflection of decreased postoperative lower extremity loadings.

Table 3 Comparison of preoperative and postoperative pedobarographic values for all implanted knees

		Preoperative	Postoperative	*p*-Value
Static evaluation[a]				
Total PF (N)		506.6 ± 151.13	463.52 ± 157.75	**0.005**
PF (%)	Forefoot	16.77 ± 7.72	17.36 ± 7.83	0.454
	Midfoot	11.12 ± 6.67	9.62 ± 7.55	**0.003**
	Hindfoot	21.4 ± 8.44	22.42 ± 8.79	0.274
CA (%)	Forefoot	26.26 ± 9.33	23.3 ± 8.22	**0.002**
	Midfoot	16.13 ± 8.12	12.04 ± 6.35	**0.0001**
	Hindfoot	16.81 ± 5.48	15.77 ± 3.48	0.123
PP (N/cm^2)	Forefoot	37.13 ± 16.27	34.98 ± 15.2	0.155
	Midfoot	7.19 ± 3.1	6.45 ± 3.1	**0.0001**
	Hindfoot	20.64 ± 6.73	21.09 ± 8.05	0.654
Dynamic evaluation[a]				
PTI ($N/cm^2 \times$ seconds)	Forefoot	50.76 ± 17.72	45.08 ± 12.2	**0.008**
	Midfoot	6.29 ± 2.81	4.41 ± 2.21	**0.0001**
	Hindfoot	13.32 ± 4.08	13.05 ± 4.51	0.526
FTI (N × seconds)	Forefoot	44.56 ± 11.13	37.71 ± 9.61	**0.0001**
	Midfoot	18 ± 10.3	13.2 ± 9.8	**0.0001**
	Hindfoot	20.24 ± 7.4	21.2 ± 7.41	0.156
CA (cm^2)	Forefoot	63.28 ± 10.17	58.58 ± 9.48	**0.0001**
	Midfoot	30.06 ± 10.72	24.9 ± 10.88	**0.0001**
	Hindfoot	28.92 ± 5.22	27.74 ± 4.79	0.121
PP (N/cm^2)	Forefoot	150.32 ± 30.98	146.32 ± 31.82	0.125
	Midfoot	16.91 ± 7.56	12.91 ± 7.24	**0.0001**
	Hindfoot	40.06 ± 11.96	41.79 ± 11.61	0.075

Abbreviations: CA, contact area; FTI, force-time integral; PF, plantar force; PP, peak pressure; PTI, pressure-time integral.
[a]The values are given as the mean and standard deviation.

If the evaluation was taken into consideration to tibial component positions, our secondary hypothesis was also confirmed. All static and dynamic pedobarographic parameters generally decreased in the midfoot and hindfoot regions postoperatively in knees with varus tibial component. However, in the neutral and valgus groups, the same parameters showed similar changes, which included decreased values in the forefoot and midfoot regions with significant increased values in hindfoot postoperatively. To the best of our knowledge, this study is the first one to evaluate the tibial component alignment with the pedobarographic gait analysis. This study represents that tibial component malalignment, even if in small degrees, can alter lower extremity loadings.

Alterations in lower limb alignment are likely to cause some differences in respective joint loading.[28] Additionally, it has been shown that patients with medial and lateral knee osteoarthritis have different mechanics at the knee and ankle, especially in the hindfoot region.[29] Generally, orthopaedic surgeons will look at radiographs to assess alignment of the implant and will use some clinical scoring systems to check pain and function of the joint replacement. However, it was stated that these evaluation methods are not enough to explain knee behavior precisely.[30] Relatively small surgical errors, which lead to slight implant malalignment, may not be detectable using standard follow-up tools and can still lead to considerable differences in foot loading parameters and pressure distribution.[31]

Accuracy of prosthetic alignment is an important factor in achieving successful TKA, and it is essential to provide long-term implant survival.[13,21,32] It was reported that knees with varus malalignment had an increased rate of long-term failure with an increased wear of polyethylene inserts, especially for knees aligned in 5 degrees or more varus.[13,32] Therefore, it is generally accepted that the tibial component should be placed perpendicular to the anatomical axis of the tibia to distribute load evenly across the implant and to prevent varus malalignment.[14,33] In this study, tibial components were placed in all knees by using extramedullary guide system. The rates of varus- and valgus-aligned tibial components were 38.2% ($n = 18$) and 36.1% ($n = 17$), respectively. Malalignment of tibial components in the varus and

Table 4 Comparison of static pedobarographic data among the groups created according to tibial component position

	Varus			Neutral			Valgus		
	Preoperative[a]	Postoperative[a]	*p*-Value	Preoperative[a]	Postoperative[a]	*p*-Value	Preoperative[a]	Postoperative[a]	*p*-Value
Total PF (N)	511.16 ± 119.03	433.74 ± 148.2	**0.003**	462.96 ± 219.82	483.99 ± 218.56	0.457	532.58 ± 123.38	480.61 ± 117.25	**0.037**
Forefoot PF (%)	15.49 ± 6.44	18.31 ± 7.31	0.126	16.32 ± 10.62	13.62 ± 9.19	**0.012**	19.07 ± 6.82	18.44 ± 6.68	0.190
Midfoot PF (%)	11.12 ± 6.99	9.07 ± 7.47	**0.013**	10.28 ± 6.23	11.48 ± 8.23	0.274	11.72 ± 6.94	8.88 ± 7.38	**0.0001**
Hindfoot PF (%)	23.07 ± 8.82	19.58 ± 8.31	**0.032**	20.13 ± 8.6	24.49 ± 7.52	**0.0001**	20.52 ± 8.13	23.95 ± 9.74	**0.019**
Forefoot CA (%)	26.18 ± 5.64	23.22 ± 3.26	**0.047**	28.44 ± 9.08	19.35 ± 7.06	**0.0001**	26.16 ± 11.32	24.81 ± 12.42	**0.017**
Midfoot CA (%)	15.49 ± 7.44	11.77 ± 4.33	**0.028**	17.42 ± 9.32	12.08 ± 6.15	**0.046**	15.91 ± 8.33	12.29 ± 8.37	**0.0001**
Hindfoot CA (%)	17.57 ± 5.53	15.12 ± 2.76	**0.032**	18.87 ± 6.53	15.66 ± 3.11	0.06	14.55 ± 3.88	16.54 ± 4.36	**0.0001**
Forefoot PP (N/cm^2)	33.61 ± 14.77	35.67 ± 16.72	0.502	36.08 ± 17.26	30.33 ± 13.67	**0.007**	41.59 ± 16.98	37.53 ± 14.66	0.06
Midfoot PP (N/cm^2)	7.17 ± 2.98	5.78 ± 2.82	**0.0001**	7.58 ± 3.85	7.5 ± 3.9	0.339	6.94 ± 2.82	6.41 ± 2.72	0.083
Hindfoot PP (N/cm^2)	21.67 ± 7.18	16.94 ± 7.63	**0.002**	18.04 ± 7.06	23.58 ± 7.33	**0.005**	21.35 ± 5.88	23.71 ± 7.49	0.08

Abbreviations: CA, contact area; PF, plantar force; PP, peak pressure.
[a]The values are given as the mean and standard deviation.

Table 5 Comparison of dynamic pedobarographic data among the groups created according to tibial component position

	Varus			Neutral			Valgus		
	Preoperative[a]	Postoperative[a]	*p*-Value	Preoperative[a]	Postoperative[a]	*p*-Value	Preoperative[a]	Postoperative[a]	*p*-Value
Forefoot PTI (N/cm^2 × second)	39.28 ± 14.17	42.21 ± 12.61	0.105	67.03 ± 17.99	45.21 ± 13.09	**0.001**	51.43 ± 10.95	48.04 ± 11.06	**0.029**
Midfoot PTI (N/cm^2 × seconds)	6.13 ± 2.6	4.32 ± 2.53	**0.0001**	8.45 ± 3.01	4.94 ± 2.38	**0.0001**	4.92 ± 1.93	4.13 ± 1.72	**0.001**
Hindfoot PTI (N/cm^2 × seconds)	14.94 ± 3.29	12.8 ± 3.43	**0.0001**	13.22 ± 3.13	12.05 ± 3.98	0.152	11.67 ± 4.88	14.02 ± 5.78	**0.0001**
Forefoot FTI (N × seconds)	36.81 ± 9.18	35.16 ± 9.53	0.233	49.54 ± 8.87	37.76 ± 9.92	**0.0001**	49.25 ± 10.15	40.39 ± 9.3	**0.0001**
Midfoot FTI (N × seconds)	18.61 ± 8.67	13.73 ± 9.46	**0.0001**	23.12 ± 11.53	15.54 ± 10.55	**0.0001**	13.76 ± 9.73	10.98 ± 9.75	**0.0001**
Hindfoot FTI (N × seconds)	23.18 ± 4.31	20.16 ± 4.59	**0.0001**	17.38 ± 6.83	20.01 ± 7.43	0.066	19.15 ± 9.4	23.14 ± 9.55	**0.0001**
Forefoot CA (cm^2)	66.54 ± 9.93	58.61 ± 10.53	**0.001**	62.77 ± 10.27	60.03 ± 9.07	0.128	60.19 ± 9.89	57.52 ± 9.01	**0.001**
Midfoot CA (cm^2)	32.29 ± 8.02	27.43 ± 7.5	**0.0001**	30.06 ± 11.77	25.94 ± 10.93	**0.002**	27.32 ± 12.36	21.48 ± 13.33	**0.0001**
Hindfoot CA (cm^2)	31.45 ± 5.37	27.2 ± 4.14	**0.006**	27.64 ± 5.53	29.7 ± 6.26	0.074	27.15 ± 3.87	26.92 ± 4.1	0.798
Forefoot PP (N/cm^2)	139.72 ± 28.01	137.28 ± 31.59	0.601	163.75 ± 40.16	157.83 ± 37.93	0.323	152.06 ± 23.49	147.76 ± 25.86	0.238
Midfoot PP (N/cm^2)	17 ± 8.18	12.78 ± 8.13	**0.0001**	19.33 ± 7.58	15.08 ± 6.08	**0.0001**	15.12 ± 6.75	11.53 ± 7.05	**0.0001**
Hindfoot PP (N/cm^2)	45.22 ± 14.04	42.22 ± 14.03	**0.038**	36.75 ± 10.35	40.67 ± 10.27	**0.018**	36.94 ± 8.91	42.12 ± 10.21	**0.001**

Abbreviations: CA, contact area; FTI, force-time integral; PP, peak pressure; PTI, pressure-time integral.
[a]The values are given as the mean and standard deviation.

valgus groups changed between 1 and 4 degrees. Although the postoperative TFA angles for these applications were not in varus position (5.1 ± 1.7 degrees valgus in the varus group; 6.2 ± 2.5 degrees valgus in the valgus group), we observed that the changes of tibial component angle in varus position up to 4 degrees created different foot loading characteristics compared with neutral and valgus-aligned tibial components.

One of the strengths' of our study was that all pedobarographic data were evaluated before and after knee replacement to act as a control. In addition, our study has good comparability in the baseline characteristics and demographic values among the groups that were considered to be comparable. The same orthopaedic surgeon and standard surgical approach, and the same TKA implant and postoperative rehabilitation program could also be accepted as the strength of our study.

However, our study has certain limitations. One of them is relatively short follow-up period (7 months on average). Gait mechanics are altered significantly for approximately 1 year after TKA, and generally patients could not be considered adequately rehabilitated before 6 months following surgery.[8] Therefore, longer term follow-up is required prior to reaching any decisive conclusions regarding pedobarographic data after TKA. On the other hand, postoperative follow-up period of 6 months is considered the minimum follow-up acceptable to describe the normal function of the replaced joint without the influence of healing.[3,34] We did not compare patient's gait speed between pre- and postoperative periods. Lower gait speed can reduce PF and pressure parameters and can limit the comparability of the pedobarographic parameters. However, it was also reported that greatest improvement in gait is expected within the first three postoperative months, and after 6 months, gait changes are considered negligible.[35] Another limitation is the use of pedobarography as the only assessment of gait. PF, pressure, and CA values are only one part of gait analysis, and further investigations would be required to fully appreciate the problems caused by component malposition in TKA. The walking pattern will probably be affected due to targeting of the subject's foot on the platform, especially when the platform has small dimensions like in this study. However, it was found that variability of ground reaction force is not significantly affected by targeting the force plate.[36] Platforms have a high methodological quality to measure the ground reaction force and are therefore frequently used as a gold standard against ambulatory devices or other systems.[36]

Pedobarography provides quantitative information and repeatable measurement option regarding foot functions. It can also be used as a clinical tool to evaluate the distribution of foot loading parameters after TKA. Despite the potential usefulness of gait analysis, variations in subject characteristics, prosthetic designs, and methodology of gait analysis make comparison of findings between studies difficult.[3] Therefore, we could not able to compare our results with other studies. Additional studies, which include subjective and functional outcome measures of the foot and ankle, both pre- and postoperatively, would be useful to determine if pedobarographic data influence the incidence of foot and ankle pain after TKA.

Conclusion

This study has identified postoperative loading changes in lower limbs during both static and dynamic pedobarographic evaluations despite patients reporting good clinical and radiographic outcomes. Component malalignment within small surgical errors can also influence loading parameters. Analyses of foot loading parameters before and after TKA by using pedobarography are useful for orthopaedic surgeons, as they allow clinicians to obtain a proper understanding of the abnormal gait caused by component malposition.

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