

Original Research Article

A prospective observational comparative study about foot pressure pattern of patients with knee osteoarthritis undergoing total knee arthroplasty

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ABSTRACT

Background: Knee osteoarthritis (OA) alters lower limb alignment and gait biomechanics. This study used a pedobarographic mapping system to evaluate early changes in dynamic single-leg stance plantar pressure distribution in OA patients undergoing total knee arthroplasty (TKA) compared to healthy controls.

Methods: In this prospective study, 33 patients undergoing primary TKA and 33 healthy controls were evaluated. Clinical status (Knee Society score (KSS) and Visual Analogue Scale (VAS) score) were measured pre-operatively. Single-leg plantar pressure distribution across nine anatomical zones (M1–M9) were measured preoperatively (T0), immediate post operatively (T1) and postoperatively at 6 weeks (T2) and 3 months (T3).

Results: TKA significantly improved clinical outcomes; mean VAS decreased from 8.91 to 0.84 and mean KSS improved from 38.03 to 88.39 at 3 months. Preoperatively, OA patients exhibited abnormal loading concentrated over the great toe (M1) and lateral deficits, differing significantly from controls ($p < 0.05$). Postoperatively, significant progressive pressure redistribution occurred at 6 weeks (M2, M4, M8) and 3 months (M2, M7, M8, M9). By 3 months, pressure patterns approached control baselines, with residual differences limited only to the M4 and M5 regions ($p < 0.05$).

Conclusions: Coronal realignment through TKA drives rapid postoperative redistribution of plantar pressures toward normal physiological patterns, aligning with marked clinical recovery. However, persistent lateral forefoot deficits at 3 months suggest that complete biomechanical adaptation requires a longer recovery period.

Keywords: Changes in foot pressure, Osteoarthritis knee, Total knee Arthroplasty

INTRODUCTION

Bipedal gait requires a complex, coordinated interaction of joint movements, muscle activity and positional perception, all dependent on a well-aligned mechanical axis of the lower limb.¹ OA a progressive, gradual articular cartilage loss disorder is a leading factor disrupting this alignment. Its prevalence in India is 28.7%, increases with age and disproportionately affects women.² Initial management is non-operative and includes physiotherapy, bracing, orthoses, analgesics, non-steroidal anti-

inflammatory drugs and intra-articular injections. However, owing to the progressive nature of the disease, a significant proportion of patients ultimately require, in most cases, TKA.³ TKA relieves pain, improves functional ability and restores the anatomical and mechanical alignment of the tibiofemoral joint.

Characteristic gait abnormalities in patients with knee OA including reduced walking speed, shortened step length and increased step width are considered compensatory strategies to offload the affected compartment.⁴ Analysis

of dynamic and static lower limb alignment has become an important tool in prosthesis design and functional evaluation following TKA notably, substantial dysfunction persists in 15–20% of patients after the procedure.⁵⁻⁷ TKA can alter foot alignment by reorganizing overall lower extremity alignment.⁸ While coronal alignment is conventionally assessed along the mechanical axis from the hip to the ankle, weight-bearing forces are transmitted through the posterior foot the floor reaction point rather than through the ankle joint. Hindfoot alignment therefore assumes clinical significance following TKA and may influence implant longevity.⁹ Dynamic plantar pressure analysis provides a practical means to evaluate these distal effects of mechanical realignment.^{9,10}

Three-dimensional motion analysis systems, though the gold standard for gait evaluation, are expensive and not universally available. Foot pressure mapping systems offer a cost-effective alternative capable of quantifying plantar load distribution during the stance phase.

Despite improvements in TKA, achieving a perfectly aligned mechanical axis doesn't always result in desired locomotive function. Ongoing postoperative issues may increase the risk of fall-related injuries. To tackle this, we will examine plantar pressure distribution to explore problems beyond mechanical correction and their outcomes. We hypothesize that even with a normalized mechanical axis, plantar pressure may remain uneven postoperatively, contributing to residual gait imbalance and dissatisfaction.

In this prospective observational study, we evaluated changes in plantar dynamic single-leg stance pressure patterns in patients with OA knee undergoing TKA, comparing preoperative and early postoperative findings at 6 weeks and 3 months with those of a healthy control population, using a pedobarographic foot pressure mapping system.

METHODS

Study design and participants

This prospective comparative study was conducted at Medica Super speciality Hospital, Kolkata, between August 2018 and June 2019. Ethical approval was obtained from the institutional Ethics Board and Scientific Committee for Clinical Research and written informed consent was obtained from all participants before enrolment.

Patients above 45 years with knee pain, diagnosed with primary OA knee as per the American Rheumatism Association criteria, failed high tibial osteotomy or post-traumatic secondary OA were included in this study.

Exclusion criteria were active knee sepsis, local inflammatory foot pathology and any intraoperative event

altering the postoperative protocol. A control group consisting of 33 adults with no knee complaints, normal knee alignment and no local foot pathology.

Surgical technique

All TKA procedures were performed by a single surgeon using a standardized technique with a cemented cruciate-retaining prosthesis. A tourniquet was applied only during the cementing phase.

Outcome assessment

Preoperative evaluation included clinical history, weight-bearing anteroposterior scannogram for mechanical axis measurement and degree of deformity, pain severity by VAS and functional status by KSS.^{11,12} Dynamic plantar foot pressure during single-leg stance was recorded using the Podiascan foot pressure mapping system (FM1111), dividing the plantar surface into nine anatomical zones (M1–M9). All assessments were repeated postoperatively at 6 weeks and 3 months.

Surgical technique and perioperative protocol

All procedures were performed under spinal anesthesia via the medial parapatellar approach. Following medial osteophyte removal and deep medial collateral ligament release, the posterior cruciate ligament was retained. Distal femoral and proximal tibial cuts were made perpendicular to the mechanical axis using an intramedullary femoral guide and an extramedullary tibial guide. All implants were cemented cruciate-retaining prostheses.

Postoperatively, a compressive dressing was applied and an adductor nerve block was administered for analgesia. Multimodal pain management included an opioid and a non-steroidal anti-inflammatory drug. Intravenous antibiotics were administered for 48 hours, followed by oral antibiotics and DVT prophylaxis was maintained for two weeks. Isometric quadriceps and ankle pump exercises were initiated on the day of surgery; full weight-bearing with a knee brace and walker was commenced on postoperative day one. A standardized physiotherapy rehabilitation protocol was followed for all patients.¹²

Statistical methods

The sample size at 5% level of significance and 80% of power was calculated using the formula.¹³

Where,

p: expected proportion

d: precision (10%)

Z-value from normal tables

A sample size of 66 subjects in total was needed to obtain a 95% confidence interval of $\pm 10\%$ for the study of foot pressure pattern changes in patients with OA knee undergoing TKA, with a prevalence of 22%.

A paired t-test was applied to compare the change preoperatively and postoperatively.

Also, a comparison between the patients and the control group was obtained.

A confidence interval was obtained to know the upper and lower limits of the interval. The p-values were also obtained to determine whether the change obtained is significant.

The patients were evaluated as follows.

Time point 1 =Preop evaluation, time point 2 =Post evaluation at 6 week and time point 3 =Post op evaluation at post op 3 months.

RESULTS

Average of foot pressure was named as foot value of each foot i.e.: Value obtained by $M1+M2+M3+M4+M5+M6+M7+M8+M9$ =Foot Value of a foot.

Foot values of each patient were plotted against KSS of that foot to know any correlation between the functional improvement and the foot pattern. In this study out of 33 patients, 19 female and 14 male patients (57.6% and 42.4 % respectively), age of the patient was in the range of 49-76 years, with mean age of 65.61 ± 6.647 years. The weight of the patient was ranging from 57.6 kg to 102 kg, with mean weight of $74.5 \text{ kg} \pm 10.25 \text{ kg}$. The height of the patient ranged from 144 cm to 180 cm with mean height $157.70 \pm 12.169 \text{ cm}$ The BMI ranged from 26.1 to 36.9 kg/cm^2 . The mean BMI of the patients was $30.05 \pm 3.41 \text{ kg}/\text{cm}^2$.

The mean of visual analogue scale in patients of OA knee was 8.91 which improved to 4.18 after 6 weeks of TKA.

The mean varus was 15.83° before surgery which improved to 2.75° after 6 weeks of TKA.

The mean valgus got corrected from 20° to 5° after 6 weeks of TKA. The range of motion improved from 82.73° to 97.58° after 6 weeks of TKA.

The Knee society score was 38.03 before the surgery which became 73.88 after 6 weeks of surgery.

Paired T-test

Paired t-test was employed to assess if there was a significant difference in pressure patterns on the foot, post TKA.

Paired t test was employed to the areas of foot M1-M9 at time point 1(i.e.: pre operatively) and at time point 2 (i.e., post op 6 weeks)

It was noted that p value of area M2, M4 and M8 was <0.05 suggesting a significant change.

Paired t test was employed to the areas of foot M1-M9 at time point 1 (i.e., pre operatively) and at time point 3 (i.e., post op 3 months)

It was noted that p value of area M2, M7, M8 and M9 was <0.05 suggesting a significant change.

Paired t test was employed to the areas of foot M1-M9 at TP 2 (i.e., post op 6 weeks) and at TP 3 (i.e., post op 3 months)

It was noted that p value of none of the area was significant, suggestive of no significant change.

It was observed that in most patients of OA knee, foot pattern before the surgery had mild to very high pressure in M1, no to normal pressure in M2, less to mild pressure in M3, less to normal pressure in M4, normal to mild pressure in M5, no pressure in M6, less to mild pressure in M7 and normal to mild pressure in M8 and M9.

It was observed that in most patients of OA knee, foot pattern after 6 weeks of TKA had mild to very high pressure in M1, normal to mild pressure in M2, M3, M4 and M5, no pressure in M6, less to mild pressure in M7 and normal to high pressure in M8 and M9. There were few outliers denoted by dots in the chart and star mark suggestive of the value obtained as expected.

It was observed that in most patients of OA knee, foot pattern after 3 months of TKA had mild to high pressure in M1, normal to mild pressure in M2, M3 and M5, no pressure in M6 as expected, normal to mild pressure in M7 and mild to high pressure in M8 and normal to high pressure in M9.

Paired t test was employed to the areas of foot M1-M9 of control and the patients at T1

It was noted that p value of M2, M4, M7, M8, M9 area were significant, suggestive of significant difference between the foot pattern of osteoarthritic patient and the control. Paired t test was employed to the areas of foot M1-M9 of control and the patients at T2. It was noted that p value of M4, M5, M7, areas were significant, suggestive of significant difference between the foot pattern of patient at 6-week post TKA and the control.

Paired t test was employed to the areas of foot M1-M9 of control and the patients at T3. It was noted that p value of M4, M5, area was significant, suggestive of significant difference between the foot pattern of patient at 3months post TKA and the control. Remaining area shows no

difference suggesting that the foot pattern of patients is coming closure to the pattern of control.

It was observed that foot pressure pattern of control group had mild to high pressure in area M1, normal to mild

pressure in M3, M4, normal to very high pressure in M5 area, no pressure noted in M6, normal pressure in area M7, high to very high pressure in M8 and normal to high pressure in M9.

Table 1: Baseline demographic characteristics of the OA cohort (n=33).

Variables	Minimum	Maximum	Mean	Sd
Age in years	49	76	65.61	6.647
Weight	57.6	102.0	74.552	10.2506
Height	144	180	157.70	12.169
BMI	26.1	36.9	30.058	3.4196
Female, n (%)	—	—	19 (57.6%)	—
Male, n (%)	—	—	14 (42.4%)	—

Table 2: Clinical outcomes before and after TKA.

No		Mean	N	SD	SE
Pair 1	VAS T1	8.91	33	0.765	0.133
	VAS T2	4.18	33	0.727	0.127
Pair 2	VARUST1	15.83	12	5.967	1.723
	VARUS T2	2.75	12	2.989	0.863
Pair 3	VALGUS T1	20.00	2	0.000	0.000
	VALGUS T2	5.00	2	7.071	5.000
Pair 4	FFD T1	7.58	33	5.607	0.976
	FFD T2	.00	33	0.000	0.000
Pair 5	ROM T1	82.73	33	17.370	3.024
	ROMT 2	97.58	33	6.139	1.069
Pair 6	KSS T1	38.03	33	15.475	2.694
	KSST 2	73.88	33	8.085	1.407

Table 3: Paired plantar-pressure comparisons between baseline and 6 weeks.

No	Variable	Mean	SD	SE	95% CI of diff Lower	95% CI of diff Upper	P value
Pair 1	T1_M1 - T2_M1	0.242	2	0.348	-0.467	0.952	0.491
Pair 2	T1_M2 - T2_M2	-0.636	1.388	0.242	-1.128	-0.144	0.013
Pair 3	T1_M3 - T2_M3	-0.091	1.378	0.24	-0.579	0.398	0.707
Pair 4	T1_M4 - T2_M4	-0.455	1.277	0.222	-0.907	-0.002	0.049
Pair 5	T1_M5 - T2_M5	-0.242	1.458	0.254	-0.76	0.275	0.347
Pair 6	T1_M6 - T2_M6	-0.091	0.384	0.067	-0.227	0.045	0.184
Pair 7	T1_M7 - T2_M7	-0.061	1.197	0.208	-0.485	0.364	0.773
Pair 8	T1_M8 - T2_M8	-0.758	1.324	0.23	-1.227	-0.288	0.002
Pair 9	T1_M9 - T2_M9	-0.394	1.435	0.25	-0.903	0.115	0.125

Table 4: Paired plantar-pressure comparisons between baseline and 3 months.

		Paired Differences			95% Confidence Interval of the Difference		P value
		Mean	SD	SE	Lower	Upper	
Pair 1	T1_M1 - T3_M1	0.333	1.762	0.307	-0.291	0.958	0.285
Pair 2	T1_M2 - T3_M2	-0.545	1.394	0.243	-1.04	-0.051	0.032
Pair 3	T1_M3 - T3_M3	-0.303	1.686	0.294	-0.901	0.295	0.31
Pair 4	T1_M4 - T3_M4	-0.424	1.458	0.254	-0.941	0.093	0.104

Continued.

		Paired Differences				P value
		Mean	SD	SE	95% Confidence Interval of the Difference Lower Upper	
Pair 5	T1_M5 - T3_M5	-0.121	1.409	0.245	-0.621 0.378	0.625
Pair 6	T1_M6 - T3_M6	-0.091	0.384	0.067	-0.227 0.045	0.184
Pair 7	T1_M7 - T3_M7	-0.485	1.395	0.243	-0.979 0.01	0.054
Pair 8	T1_M8 - T3_M8	-1.121	1.654	0.288	-1.708 -0.535	0
Pair 9	T1_M9 - T3_M9	-0.606	1.345	0.234	-1.083 -0.129	0.014

Table 5: Paired plantar-pressure comparisons between 6 weeks and 3 months.

		Paired Differences				P value
		Mean	SD	SE	95% Confidence Interval of the Difference Lower Upper	
Pair 1	T2_M1 - T3_M1	0.091	1.308	0.228	-0.373 0.555	0.692
Pair 2	T2_M2 - T3_M2	0.091	0.947	0.165	-0.245 0.427	0.585
Pair 3	T2_M3 - T3_M3	-0.212	1.053	0.183	-0.586 0.161	0.256
Pair 4	T2_M4 - T3_M4	0.03	1.045	0.182	-0.34 0.401	0.869
Pair 5	T2_M5 - T3_M5	0.121	0.893	0.155	-0.195 0.438	0.441
Pair 7	T2_M7 - T3_M7	-0.424	1.251	0.218	-0.868 0.019	0.06
Pair 8	T2_M8 - T3_M8	-0.364	1.319	0.23	-0.831 0.104	0.123
Pair 9	T2_M9 - T3_M9	-0.212	1.293	0.225	-0.671 0.246	0.353

Table 6: Median and interquartile distribution of plantar-pressure grades at baseline, 6 weeks and 3 months.

		T1_M1	T1_M2	T1_M3	T1_M4	T1_M5	T1_M6	T1_M7	T1_M8	T1_M9
Median		5	2	2	2	2	0	2	2	2
Percentiles:		3	0	1	1	2	0	1	2	2
25		5	2	2	2	2	0	2	2	2
50										
75		5	2	3	2	3	0	3	3	3
Time point	Statistic	M1	M2	M3	M4	M5	M6	M7	M8	M9
T1	Median	5	2	2	2	2	0	2	2	2
T1	P25	3	0	1	1	2	0	1	2	2
T1	P50	5	2	2	2	2	0	2	2	2
T1	P75	5	2	3	2	3	0	3	3	3
T2	Median	4	2	2	2	2	0	2	3	3
T2	P25	3	2	2	2	2	0	1.5	2	2
T2	P50	4	2	2	2	2	0	2	3	3
T2	P75	5	3	3	3	3	0	2	4	4
T3	Median	4	2	2	2	2	0	2	3	3
T3	P25	3	2	2	2	2	0	2	3	2
T3	P50	4	2	2	2	2	0	2	3	3
T3	P75	4	3	3	2	3	0	3	4	4

Table 7: Comparison of control and OA-group plantar-pressure values at baseline.

Zone	Mean difference	SD	SE	95% CI lower	95% CI upper	P value
M1	-0.424	1.921	0.334	-1.105	0.257	0.214
M2	0.455	1.787	0.311	-0.179	1.088	0.154
M3	0.545	1.856	0.323	-0.113	1.203	0.101
M4	1.121	1.556	0.271	0.569	1.673	<0.001
M5	1.030	1.723	0.300	0.419	1.641	0.002
M6	0.242	0.792	0.138	-0.038	0.523	0.088
M7	0.667	1.534	0.267	0.123	1.211	0.018
M8	1.152	2.093	0.364	0.409	1.894	0.003
M9	0.636	1.747	0.304	0.017	1.256	0.044

Table 8: Comparison of control and OA-group plantar-pressure values at 6 weeks.

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		
					Lower	Upper	Sig. (2-tailed)
Pair 1	T0_M1 - T2_M1	-0.182	1.61	0.28	-0.753	0.389	0.521
Pair 2	T0_M2 - T2_M2	-0.182	1.53	0.266	-0.724	0.361	0.5
Pair 3	T0_M3 - T2_M3	0.455	1.641	0.286	-0.127	1.036	0.121
Pair 4	T0_M4 - T2_M4	0.667	1.315	0.229	0.2	1.133	0.006
Pair 5	T0_M5 - T2_M5	0.788	1.616	0.281	0.215	1.361	0.009
Pair 6	T0_M6 - T2_M6	0.152	0.795	0.138	-0.131	0.434	0.282
Pair 7	T0_M7 - T2_M7	0.606	1.248	0.217	0.163	1.049	0.009
Pair 8	T0_M8 - T2_M8	0.394	1.87	0.325	-0.269	1.057	0.235
Pair 9	T0_M9 - T2_M9	0.242	1.501	0.261	-0.29	0.775	0.36

Table 9: Comparison of control and OA-group plantar-pressure values at 3 months.

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		
					Lower	Upper	Sig. (2-tailed)
Pair 1	T0_M1 - T3_M1	-0.091	1.308	0.228	-0.555	0.373	0.692
Pair 2	T0_M2 - T3_M2	-0.091	1.1	0.192	-0.481	0.299	0.638
Pair 3	T0_M3 - T3_M3	0.242	1.48	0.258	-0.282	0.767	0.354
Pair 4	T0_M4 - T3_M4	0.697	0.951	0.166	0.36	1.034	0
Pair 5	T0_M5 - T3_M5	0.909	1.378	0.24	0.421	1.398	0.001
Pair 6	T0_M6 - T3_M6	0.152	0.795	0.138	-0.131	0.434	0.282
Pair 7	T0_M7 - T3_M7	0.182	1.185	0.206	-0.238	0.602	0.385
Pair 8	T0_M8 - T3_M8	0.03	1.403	0.244	-0.467	0.528	0.902
Pair 9	T0_M9 - T3_M9	0.03	1.649	0.287	-0.554	0.615	0.917

DISCUSSION

Thirty-three patients undergoing primary TKA and 33 healthy controls were included. The operated cohort had a mean age of 65.61 years; 19 participants (57.6%) were women and 14 (42.4%) were men. Given the modest sample and short follow-up, these findings should be interpreted as early observations rather than definitive evidence of complete biomechanical normalization. Clinical outcomes improved over follow-up. Mean VAS decreased from 8.91 preoperatively to 4.18 at six weeks and 0.84 at three months, while mean KSS increased from 38.03 to 73.88 and 88.39, respectively. This direction of change is consistent with the established role of TKA in improving pain and function. The Knee Society clinical rating system provides a structured way to assess these outcomes and postoperative rehabilitation is recognised as an important contributor to recovery.^{7,12}

The primary finding was that plantar-pressure grades changed during the first three postoperative months. In the supplied within-patient analyses, baseline-to-six-week differences were reported at M2, M4 and M8 (Table 3), while baseline-to-three-month differences were reported at M2, M7, M8 and M9 (Table 4). The T2–T3 comparison did not identify a statistically significant change in any zone (Table 5). This may indicate that much of the measurable early redistribution occurred by six weeks. Because the Podiascan output is described as

qualitative/ordinal grades rather than calibrated pressure units, the magnitude of changes cannot be interpreted as an absolute pressure difference.

Previous work supports an association between knee osteoarthritis and altered plantar loading, although studies do not show one universal regional pattern. Saito et al, found altered partial-foot pressures and centre-of-pressure characteristics in people with medial knee OA, with restricted knee extension associated with a shorter centre-of-pressure path.⁴ Güven et al specifically examined pedobarographic findings in TKA patients.¹⁴ Differences in walking versus single-leg stance, measurement systems and regional definitions may explain why the specific zones affected are not identical across studies.

The postoperative trend is broadly consistent with research showing changes in hindfoot alignment and foot loading after TKA. Chandler and Moskal assessed knee and hindfoot alignment before and after TKA.⁸ Palanisami et al, prospectively found that foot-loading patterns and hindfoot alignment shifted toward normal in many patients after TKA for varus knees.¹⁵ Diao et al reported significant hindfoot-alignment changes by three months after TKA, although the relationship between correction of the hip–knee–ankle angle and hindfoot change was weak.¹⁶ Wang et al found that plantar-pressure distribution differed between kinematic and mechanical alignment strategies, with kinematic alignment more closely restoring a

physiological distribution at two years.¹⁷ These studies support a biomechanical link between knee realignment and distal loading, but their measurement protocols and follow-up differ from the present study.

Comparisons with the control group should be interpreted cautiously. The submitted analyses report significant differences in selected zones at baseline, six weeks and three months, with the pattern varying by time point. The three-month comparison reports residual differences at M4 and M5, suggesting partial convergence rather than proven normalisation. The manuscript labels these control comparisons as paired t-tests, but the controls appear to be a separate group rather than individually paired participants. The authors should verify the statistical test against the original dataset and analysis plan before resubmission.

Important limitations include the modest sample size, follow-up limited to three months and use of categorical pressure grades rather than continuous pressure measurements. There are inconsistencies in time-point labels: the methods describe preoperative, six-week and three-month assessments, whereas some tables use T0/T1/T2/T3 and describe T0 as the control group. Some narrative statements also do not align fully with the p-values in the tables. The original statistical output and raw dataset should therefore be checked by the study team before final submission. No numerical results have been changed in this revision; interpretation has been limited to the supplied results.

Future studies should use consistent time-point labels, calibrated quantitative pedobarography, prespecified statistical comparisons and longer follow-up. Reporting effect estimates with confidence intervals and assessing relationships between pressure changes, alignment correction, pain and validated functional scores would help establish whether plantar-pressure assessment adds clinically useful information after TKA.

CONCLUSION

In this prospective comparative study, TKA was followed by marked early improvement in pain and knee function and by changes in plantar-pressure grades across several foot zones over three months. The supplied analyses indicate partial redistribution toward the control pattern, with differences persisting in selected regions; however, the short follow-up, categorical pressure measurements and inconsistencies in the reported comparison labels preclude a claim of complete biomechanical normalisation. The study adds early, region-specific observations to the evidence that knee realignment may influence distal foot loading and supports further evaluation of quantitative plantar-pressure assessment as a complementary outcome measure after TKA.

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