



Original Article

## Assessment of Knee Skin Surface Temperature and Inflammatory Markers (TLC, ESR, and CRP) Following Primary Unilateral Total Knee Replacement: An Observational Study

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### ABSTRACT

**Introduction:** Although TKA yields excellent long-term outcomes—with modern studies reporting implant survival rates of 97.9% at 10 years and 97.6% at 15 years for any-cause revision(8–10) and national registries showing over 99.5% survival at 1 year and 95.6% at 10 years(11), patient satisfaction varies from 82% to 94%(8,9,12) Up to 20% of patients remain dissatisfied, often citing ongoing pain, stiffness, instability, neurogenic issues, and unmet expectations(8,11–15). Systematic reviews highlight persistent pain and functional limitations as the primary contributors(11,15). Postoperative physiological changes, including elevated knee skin surface temperature, are common and generally reflect normal healing from surgical trauma, increased local vascularity, tissue regeneration, and acute inflammation(7,16,17). Systematic reviews confirm transient SST elevation after TKA, typically peaking around postoperative day 2 and then gradually resolving. A meta-analysis of 318 patients reported a maximum  $\Delta$ ST of 2.8°C in the first 2 weeks, 1.4°C, at 3 months, and 0.6°C at 12 months(7,16,18–20). However, persistent hyperthermia may signal complications like infection, underscoring the importance of distinguishing normal from abnormal patterns to inform reassurance or intervention(7,16,18–20).

**Material And Methods:** Following the index procedure, all patients adhered to a standardized postoperative care protocol with longitudinal monitoring of inflammatory markers performed on postoperative days 1–2. Clinical examinations and SST measurements were systematically conducted at the initial dressing change and at defined follow-up intervals (POD 4–6, 14–16, 28–30, 6 weeks, and 3 months). To ensure thermometric precision and minimize environmental interference, a standardized equilibration protocol was implemented where both knees were exposed for a minimum of 3 minutes prior to recording to reach thermal equilibrium with the ambient room temperature.

**Results:** A total of 42 patients underwent total knee replacement (TKR) during the study period, including two cases of simultaneous bilateral procedures (44 knees). Four patients with prior contralateral TKR were excluded. Additionally, five patients were excluded due to underlying inflammatory conditions (rheumatoid arthritis, psoriasis vulgaris) or loss to follow-up. Thus, 31 patients undergoing primary unilateral TKR for osteoarthritis were included in the final analysis

**Conclusion:** In uncomplicated total knee replacement, operated knee skin temperature rises gradually post-surgery, peaks on postoperative day 7(34), and returns to baseline by three months(42). The inflammatory marker CRP peaks early on POD 2(22,33); ESR peaks around POD 3-5(22,24,33). Operated knee skin temperature, CRP, and ESR all normalize by three months(24,33,42). Knee temperature strongly correlates positively with CRP, mirroring inflammation(16). Larger multicenter studies with standardized protocols are needed. This pattern supports patient counseling, surgeon reassurance, and early detection of recovery deviations.

## INTRODUCTION

Knee osteoarthritis is a leading cause of pain, disability, and reduced quality of life among middle-aged and older adults worldwide(1). Its global prevalence stands at 16.1% in individuals aged 15 years and older, affecting approximately 654 million people aged 40 and above in 2020 (2,3). Recent Global Burden of Disease studies project a substantial increase, with over 595 million OA cases worldwide in 2020, 453 million older adults affected in 2021, and 16 million disability-adjusted life years attributed to the condition(1). In the United States, around 60 million adults have OA, with the knee being the most commonly involved joint(4). The disease arises from progressive articular cartilage degradation, subchondral bone remodeling, synovial inflammation, and other joint structural changes, leading to pain, stiffness, swelling, reduced mobility, and functional impairment(2,5). While conservative treatments—such as lifestyle modifications, physical therapy, analgesics, and intra-articular injections—provide symptomatic relief, they fail to halt disease progression in advanced stages. Consequently, total knee arthroplasty is the definitive intervention, as it restores joint alignment, relieves pain, improves function, and delivers favorable patient-reported outcomes in end-stage OA. Degenerative and post-traumatic OA are the main indications for TKA(6), and demand is expected to surge, potentially reaching 3.5 million procedures annually in the US by 2030 due to population aging(7).

Although TKA yields excellent long-term outcomes—with modern studies reporting implant survival rates of 97.9% at 10 years and 97.6% at 15 years for any-cause revision(8–10) and national registries showing over 99.5% survival at 1 year and 95.6% at 10 years(11), patient satisfaction varies from 82% to 94%(8,9,12). Up to 20% of patients remain dissatisfied, often citing ongoing pain, stiffness, instability, neurogenic issues, and unmet expectations(8,11–15). Systematic reviews highlight persistent pain and functional limitations as the primary contributors(11,15). Postoperative physiological changes, including elevated knee skin surface temperature, are common and generally reflect normal healing from surgical trauma, increased local vascularity, tissue regeneration, and acute inflammation(7,16,17). Systematic reviews confirm transient SST elevation after TKA, typically peaking around postoperative day 2 and then gradually resolving. A meta-analysis of 318 patients reported a maximum  $\Delta$ ST of 2.8°C in the first 2 weeks, 1.4°C, at 3 months, and 0.6°C at 12 months(7,16,18–20). However, persistent hyperthermia may signal complications like infection, underscoring the importance of distinguishing normal from abnormal patterns to inform reassurance or intervention(7,16,18–20).

Conventional postoperative monitoring depends on invasive serological markers, including total leukocyte count, erythrocyte sedimentation rate, and C-reactive protein(21,22). In uncomplicated recoveries, these follow predictable patterns: TLC peaks at 24-48 hours; ESR rises gradually and normalizes over 6-8 weeks; and CRP surges sharply by days 2-3 before returning to baseline within 2-6 weeks(22–27). Under enhanced recovery protocols, CRP typically peaks around day 3 and normalizes by 2 weeks(25). Comparable trends appear in Indian populations, where CRP peaks on day 2 and normalizes by 3-12 weeks, depending on procedural extent(22,24).

Despite these well-defined systemic inflammatory profiles, the link between non-invasive knee SST—which may reflect local inflammation and correlate with CRP, ESR, and white blood cell count beyond 2 weeks—remains underexplored(7,16,18,25). Evidence indicates that SST changes align with inflammatory markers and show heightened sensitivity to local inflammation, persisting up to 6 weeks post-TKA(16,18). Combining systemic markers with localized SST measurements could improve early detection of complications, minimize unnecessary interventions, and optimize patient care.

This prospective observational study evaluated knee skin surface temperature and inflammatory markers following primary unilateral total knee replacement for OA over three months postoperatively. The primary objectives were to characterize the temporal patterns of knee skin surface temperature and inflammatory markers. The secondary objective was to investigate correlations between skin surface temperature and these markers.

## MATERIAL AND METHODS

This prospective observational study was conducted within the Department of Orthopaedics at the All India Institute of Medical Sciences, Bhopal—an academic tertiary care hospital—to examine the association between postoperative knee skin surface temperature and systemic inflammatory markers among patients undergoing primary unilateral total knee replacement for osteoarthritis. Conducted over an 18-month period at this single center, the study enrolled participants who had undergone primary unilateral TKR for knee osteoarthritis, provided informed consent, and satisfied predefined inclusion and exclusion criteria.

Inclusion criteria comprised adults undergoing primary unilateral TKR for knee osteoarthritis who consented to participate in the study. Exclusion criteria included individuals undergoing revision TKR, bilateral procedures, or concurrent surgeries beyond primary arthroplasty; those declining informed consent; patients with inflammatory arthritis or autoimmune conditions; and those with prior TKR on the contralateral knee. Given the constrained study duration, convenience

sampling was employed to maximize recruitment of eligible patients from the Department of Orthopaedics at AIIMS Bhopal, targeting a minimum sample size of 30.

Preoperative assessments were conducted the evening prior to surgery to establish baseline reference values, utilizing standardized patient information sheets and formalized consent forms for systematic data acquisition. These assessments included the collection of venous blood samples for analysis within standardized laboratory facilities to quantify inflammatory biomarkers—specifically total leukocyte count, erythrocyte sedimentation rate, and C-reactive protein—while skin surface temperature of both the operated and contralateral (control) knees was quantified using high-precision handheld infrared thermometer (Model: COR T800, 3V DC powered), with a measurement range of 34°C to 42.9°C and an accuracy of  $\pm 0.3^\circ\text{C}$ .

Following the index procedure, all patients adhered to a standardized postoperative care protocol with longitudinal monitoring of inflammatory markers performed on postoperative days 1–2. Clinical examinations and SST measurements were systematically conducted at the initial dressing change and at defined follow-up intervals (POD 4–6, 14–16, 28–30, 6 weeks, and 3 months). To ensure thermometric precision and minimize environmental interference, a standardized equilibration protocol was implemented where both knees were exposed for a minimum of 3 minutes prior to recording to reach thermal equilibrium with the ambient room temperature.

All readings were obtained while the patient was at rest under consistent environmental conditions using a quadrant-based approach, with temperatures recorded from four distinct quadrants of each knee. For statistical analysis, the average of the two highest recorded values from each knee was utilized as the representative SST, and all data were managed via dedicated electronic spreadsheets to ensure accuracy and integrity.

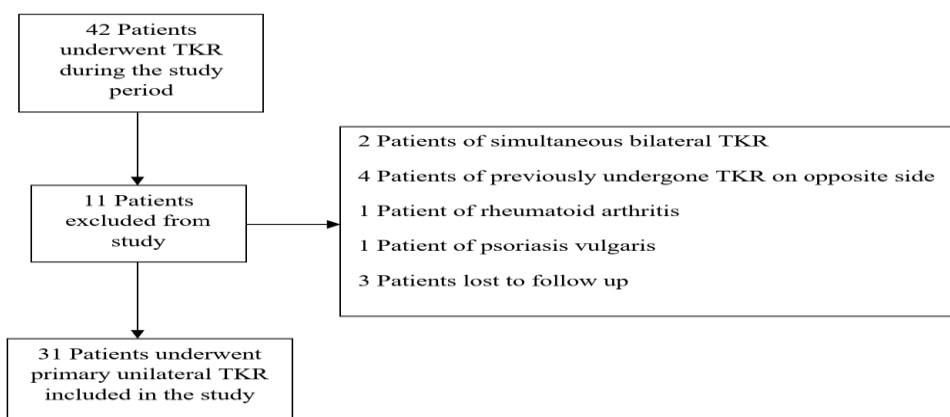
Comprehensive data—including patient demographics, thermometric measurements, and systemic inflammatory marker concentrations—were prospectively recorded and managed using a dedicated electronic spreadsheet (Microsoft Excel; Microsoft Corp., Redmond, WA, USA) to ensure data integrity. Statistical processing was performed using the Statistical Package for the Social Sciences (SPSS) software. Descriptive statistics were utilized to summarize the clinical data, with continuous variables expressed as mean  $\pm$  standard deviation and ranges.

Given that the data for skin surface temperature and inflammatory markers did not strictly follow a normal distribution, the Spearman rank correlation coefficient ( $r_s$ ) was employed to evaluate their association(28,29). This non-parametric approach is suited for identifying monotonic relationships without linear assumptions(30). Correlation strength was interpreted using established thresholds for  $r_s$ (28,29): very weak or negligible (0.00– $\pm 0.19$ ); weak ( $\pm 0.20$ – $\pm 0.39$ )(29,31); moderate ( $\pm 0.40$ – $\pm 0.59$ ); strong ( $\pm 0.60$ – $\pm 0.79$ )(29,32); very strong ( $\pm 0.80$ – $\pm 1.00$ )(31,32). Statistical significance was defined as a two-tailed  $p < 0.05$ .

The study adhered to ethical guidelines by obtaining informed consent from all participants, maintaining confidentiality, and minimizing risks. The design included measures to ensure participant comfort and safety during skin surface temperature assessments and blood sampling at follow-ups. Ethical approval was obtained from the Institutional Human Ethics Committee-Student Research of AIIMS Bhopal prior to commencement.

## RESULTS

A total of 42 patients underwent total knee replacement (TKR) during the study period, including two cases of simultaneous bilateral procedures (44 knees). Four patients with prior contralateral TKR were excluded. Additionally, five patients were excluded due to underlying inflammatory conditions (rheumatoid arthritis, psoriasis vulgaris) or loss to follow-up. Thus, 31 patients undergoing primary unilateral TKR for osteoarthritis were included in the final analysis .



**Figure 1: Flow diagram showing patient selection and exclusion process for the study**

The baseline characteristics of the study population are summarized in Table 1. The mean age of participants was  $63.05 \pm 7.73$  years (range: 48–82 years), with the majority in the 56–65 years age group (54.8%). Females constituted 61.3% of the study population. The distribution of operated side was nearly equal (left: 51.6%, right: 48.4%).

**Table 1: Baseline Characteristics of Study Participants (n = 31)**

Variable	Category	n (%)	Mean $\pm$ SD
Age (years)	48–55	4 (12.9)	
	56–65	17 (54.8)	
	66–75	8 (25.8)	
	>75	2 (6.5)	
	Overall		$63.05 \pm 7.73$
Gender	Male	12 (38.7)	
	Female	19 (61.3)	
Operated side	Right	15 (48.4)	
	Left	16 (51.6)	

Temporal changes in knee skin surface temperature are presented in Table 2. The operated knee temperature increased postoperatively, peaking on postoperative day (POD) 7 at  $97.32 \pm 0.53^\circ\text{F}$ , followed by a gradual decline, approaching baseline values by 3 months.

At the 3-month follow-up, 74.2% (23/31) of patients had operated knee temperatures within  $\pm 1^\circ\text{F}$  of their baseline (POD 0) values, while the remaining patients demonstrated mildly elevated temperatures, with no cases showing values below baseline. When compared to the contralateral knee at the same time point, 23 patients exhibited higher temperatures in the operated knee, whereas 8 patients had values within  $\pm 1^\circ\text{F}$ , and none showed lower temperatures. The non-operated knee temperature remained relatively stable throughout the study period, with only minimal variation. The interlimb temperature difference increased postoperatively, reaching a peak of  $3.28 \pm 0.89^\circ\text{F}$  on POD 7, followed by a gradual decline, approaching baseline levels by 3 months.

**Table 2: Temporal changes in mean knee skin temperature ( $^\circ\text{F}$ ) of operated and non-operated limbs, and interlimb temperature difference across postoperative follow-up periods**

Time point	Temperature $^\circ\text{F}$ [mean $\pm$ SD (range)]		
	Operated knee	Non-operated knee	Interlimb temperature difference
POD0	$94.54 \pm 1.06$ (92.30–96.20)	$94.33 \pm 0.88$ (92.30–96.20)	$0.21 \pm 0.74$ (–1.27–1.69)
POD2	$96.54 \pm 0.79$ (94.60–98.20)	$94.09 \pm 0.59$ (92.60–95.40)	$2.45 \pm 0.92$ (0.61–4.29)
POD7	$97.32 \pm 0.53$ (96.40–98.60)	$94.04 \pm 0.71$ (92.70–95.20)	$3.28 \pm 0.89$ (1.50–5.06)
POD 14-16	$96.55 \pm 0.85$ (94.30–98.30)	$93.58 \pm 0.59$ (92.20–94.80)	$2.97 \pm 1.00$ (0.97–4.97)
POD 28-30	$96.17 \pm 0.76$ (94.80–98.30)	$93.22 \pm 0.54$ (92.00–94.20)	$2.95 \pm 0.81$ (1.33–4.57)
POD 1.5 months	$95.64 \pm 0.58$ (94.00–96.80)	$93.87 \pm 0.90$ (92.60–96.80)	$1.77 \pm 0.99$ (–0.21–3.75)
POD 3 months	$95.05 \pm 0.87$ (93.60–97.20)	$93.67 \pm 0.87$ (92.20–96.80)	$1.38 \pm 0.58$ (0.22–2.54)

Temporal trends in inflammatory markers are presented in Table 3. The total leukocyte count (TLC) demonstrated an early postoperative rise, peaking on postoperative day (POD) 2 at  $9054.52 \pm 2052.65/\text{mm}^3$ , followed by stabilization and a gradual decline to near-baseline levels by 3 months. The erythrocyte sedimentation rate (ESR) showed a gradual increase,

reaching a peak at POD 14–16 ( $30.69 \pm 8.75$  mm/hr), and subsequently declined steadily toward baseline by 3 months. In contrast, C-reactive protein (CRP) exhibited a sharp early rise, peaking on POD 2 at  $110.72 \pm 32.74$  mg/L, followed by a rapid decline over subsequent follow-up periods, approaching near-baseline levels by 3 months.

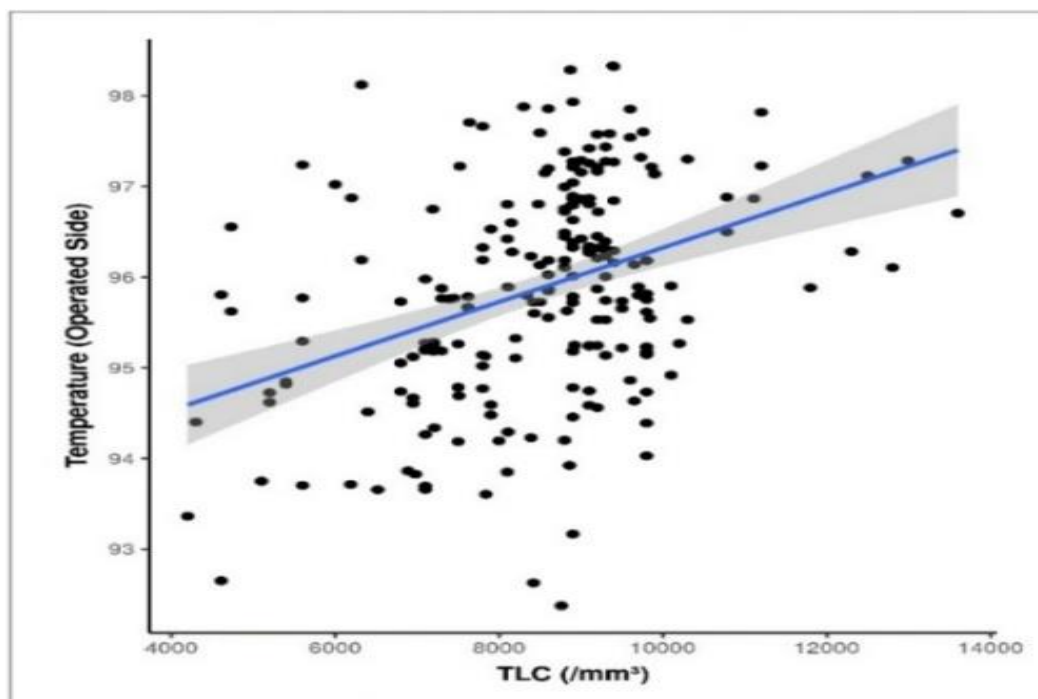
**Table 3: Temporal trends in inflammatory markers—total leukocyte count (TLC), erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP)—across postoperative follow-up periods**

Time point	Inflammatory Markers [mean $\pm$ SD (range)]		
	TLC (/mm <sup>3</sup> )	ESR (/mm)	CRP (mg/L)
POD0	7327.42 $\pm$ 1341.26(4610–9840)	11.11 $\pm$ 8.13(0.35–30.00)	13.23 $\pm$ 13.59 (0.35–54.30)
POD2	9054.52 $\pm$ 2052.65(4730–13600)	21.12 $\pm$ 11.05(5.64–49.00)	110.72 $\pm$ 32.74(26.37–165.20)
POD7	8965.81 $\pm$ 509.90(7800–9900)	24.37 $\pm$ 8.50(11.80–45.00)	67.53 $\pm$ 37.79(22.90–214.21)
POD 14-16	9010.97 $\pm$ 1697.88(4300–12500)	30.69 $\pm$ 8.7(12.00–45.20)	43.09 $\pm$ 41.86(7.56–233.88)
POD 28-30	8881.61 $\pm$ 757.71(5600–9800)	25.07 $\pm$ 6.27(14.70–43.00)	30.17 $\pm$ 44.72(3.10–178.20)
POD 1.5 months	8962.90 $\pm$ 1300.26(5100–11110)	18.76 $\pm$ 9.56(9.80–59.00)	22.42 $\pm$ 21.53(6.50–92.10)
POD 3 months	7440.97 $\pm$ 1431.85(4200–11200)	12.14 $\pm$ 3.43(4.20–18.10)	12.47 $\pm$ 13.32(2.10–45.00)

Correlation analysis between operated knee skin surface temperature and inflammatory markers is summarized in Tables 4 and shown in Figures 2-4. A weak positive correlation was observed between knee temperature and total leukocyte count (TLC) ( $\rho = 0.38$ , 95% CI: 0.25–0.50;  $p < 0.001$ ). The correlation with erythrocyte sedimentation rate (ESR) was very weak but statistically significant ( $\rho = 0.17$ , 95% CI: 0.03–0.31;  $p = 0.012$ ). In contrast, a strong positive correlation was found between knee temperature and C-reactive protein (CRP) ( $\rho = 0.60$ , 95% CI: 0.50–0.68;  $p < 0.001$ ).

**Table 4: Correlation Between Knee Temperature and Inflammatory Markers**

Correlation of knee skin surface temperature (operated side) with	Spearman correlation coefficient	p value
TLC	0.38 (95%CI: 0.25 to 0.5)	<0.001
ESR	0.17 (95%CI: 0.03 to 0.31)	0.012
CRP	0.6 (95%CI: 0.5 to 0.68)	<0.001



**Figure 2: Correlation between operated knee skin surface temperature and total leukocyte count (TLC) following total knee replacement**

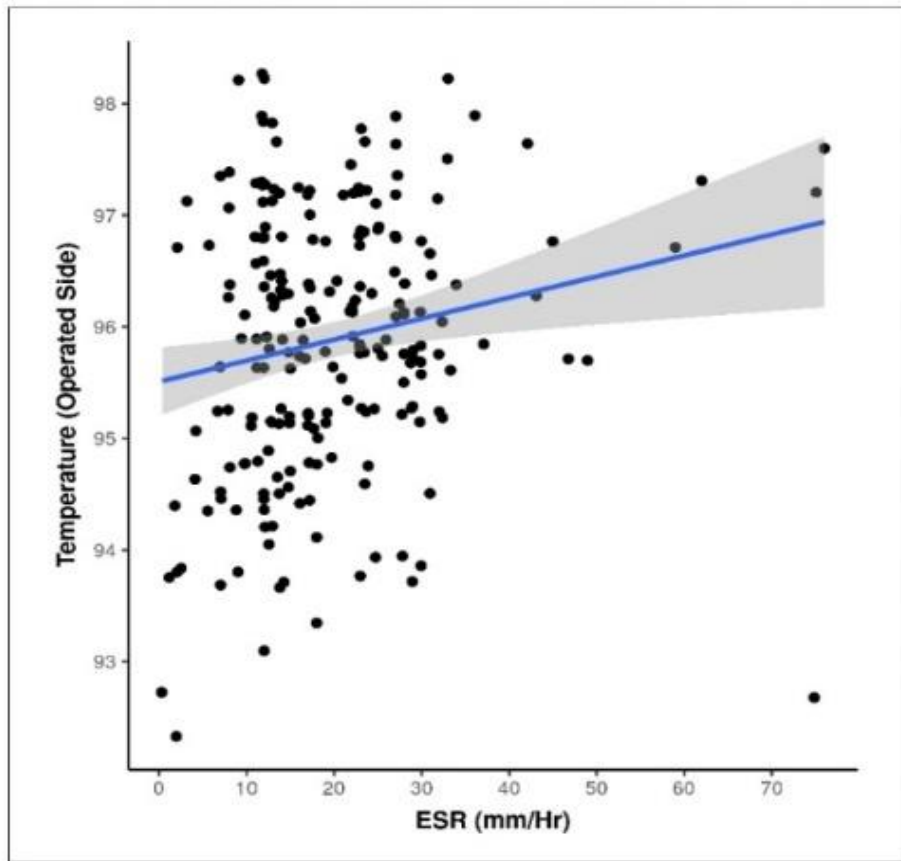


Figure 3: Correlation between operated knee skin surface temperature and erythrocyte sedimentation rate (ESR) following total knee replacement

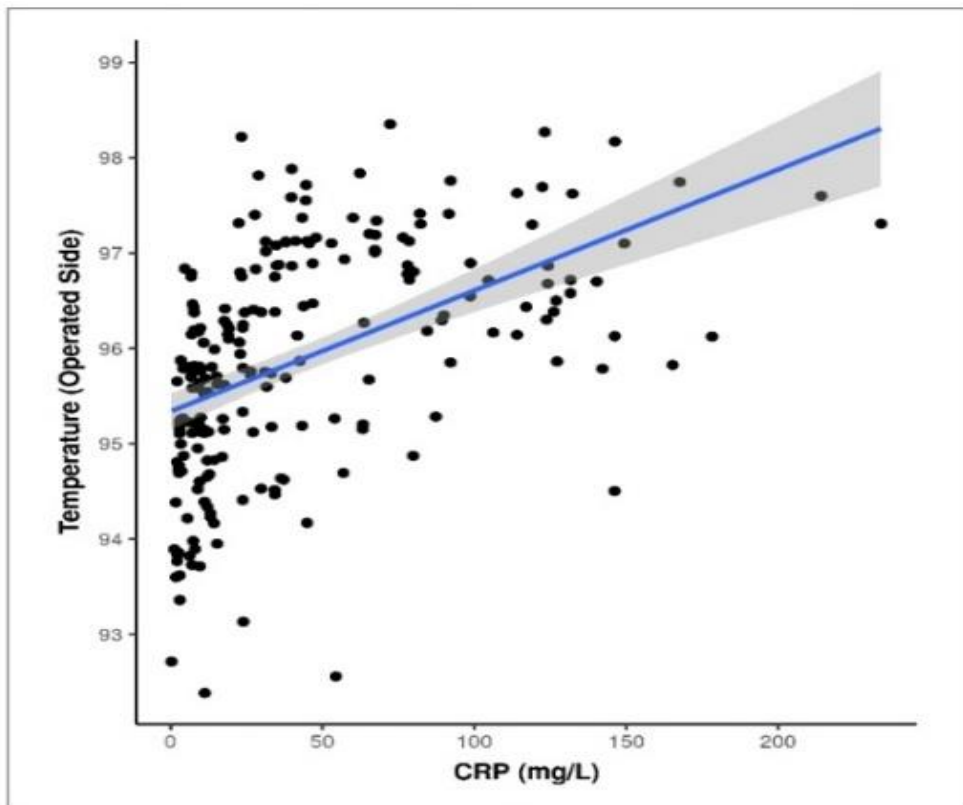


Figure 4: Correlation between operated knee skin surface temperature and C-reactive protein (CRP) following total knee replacement

### ***Postoperative Complications***

One patient developed a postoperative complication in the form of a patellar fracture, for which surgical management was planned. All remaining patients had an uneventful postoperative course, with no complications observed during the 3-month follow-up period.

### **DISCUSSION**

This observational study, entitled “Assessment of Knee Skin Surface Temperature and Inflammatory Markers Following Primary Unilateral Total Knee Replacement: An Observational Study,” was conducted at the Department of Orthopaedics, AIIMS Bhopal, between February 2024 and August 2025. It examined the trajectories of skin surface temperature on the operated knee and systemic inflammatory markers among patients undergoing primary unilateral total knee replacement for osteoarthritis.

Postoperatively, skin surface temperature of the operated knee increased progressively, peaking on postoperative day 7, prior to a steady decline toward baseline levels by three months(7). In parallel, total leukocyte count exhibited an early surge followed by reduction; erythrocyte sedimentation rate rose more gradually; and C-reactive protein demonstrated a marked elevation on POD 2, subsequently normalizing progressively (22,24,33). Various devices have been utilized for postoperative knee temperature assessment, including contact thermometers (e.g., Genius First Temp Monitor (23,34–38)), infrared thermometers (e.g., IT 540E (18,39,40)), and thermal imaging cameras (e.g., NEC-Avio Thermo Shot F30S (41), FLIR E60 (42), or specialized medical systems (43)). Contact thermometers are prone to operator variability and reduced accuracy, whereas infrared modalities provide superior reproducibility(44). The current investigation employed a handheld digital infrared thermometer, facilitating non-invasive, cost-effective, and accurate measurements amenable to both clinical and domiciliary settings (7,20).

The operated knee attained a peak temperature of 97.32°F on POD 7, consistent with observations from previous studies (34,35,39,40,45), which documented peaks between POD 5–7. These congruences likely reflect similarities in follow-up schedules, osteoarthritis cohorts, patient positioning (supine or seated), anterior knee measurement sites, and acclimatization procedures. Conversely, some studies (18,37,38,41) reported delayed peaks, attributable to disparities in device resolution, positioning, exposure durations, follow-up timing, arthritis etiology, and environmental conditions. Contact thermometers in (38) and (37) omitted methodological details; (18) utilized 0.2°C resolution without specifying posture or exposure; while thermal imaging in (41,43) delineated broader thermal distributions, necessitating extended acclimatization (16,18).

At three months postoperatively, 23 of 31 patients exhibited operated knee temperatures exceeding the contralateral knee by >1°F, with 23 displaying elevations above POD 0 baselines. Prolonged monitoring to six months revealed no infections, with temperatures spanning 92–98°F, affirming physiological increments due to augmented vascular perfusion, metabolic activity, and superficial inflammation—typically 5–8 °C less than the core temperature(46)—under controlled conditions, rather than pathological processes. The postoperative elevation in knee skin surface temperature is multifactorial, encompassing surgical trauma-induced acute inflammation with cytokine-mediated vasodilation, heightened local perfusion, reactive hyperemia, and tissue metabolism during soft tissue and osseous repair(16,47). Resolution of inflammation and reparative progression culminate in normalization over weeks to months (7,16).

In the present cohort, TLC peaked on POD 2 at  $9054.52 \pm 2052.65/\mu\text{L}$ , declining to near-baseline by three months. Analogous POD 2 peaks with normalization by 3–5 weeks were noted (36,37,42,43). This profile mirrors acute neutrophil mobilization driven by cytokines and stress hormones, maximal at 24–48 hours, preceding abatement with convalescence (22,33). ESR peaked around POD 14, returning to near-baseline by three months(24,33). Similar 2-week apices with normalization by 3–5 weeks were evident (18,36,37,42). The protracted ascent signifies incremental acute-phase protein production fostering erythrocyte rouleaux formation amid sustained inflammation (24,26). CRP peaked on POD 2 at  $110.72 \pm 32.74 \text{ mg/L}$ , normalizing by three months—mirroring patterns (18,23,36–39,41,42,45), with resolution by 3–5 weeks. Hepatic CRP synthesis, stimulated by cytokines, crests approximately 48 hours post-insult prior to decline (33,48).

Correlation analyses disclosed modest positive relationships between operated knee skin surface temperature and TLC or ESR, alongside a robust association with CRP(16). Moderate CRP-temperature correlations corroborated (37,41,42); attenuated TLC/ESR links aligned with previous studies (34,40). TLC's prompt, ephemeral surge contrasts protracted local hyperthermia; ESR's indolent, non-specific kinetics trail thermal changes; whereas CRP synchronizes with inflammation via interleukin-6 induction (7,16,18).

Strengths of this investigation encompass delineation of post-TKR baseline temperature dynamics, proposition of infrared thermometry as a non-invasive adjunct to laboratory assays, serial evaluations elucidating chronologic patterns, and correlations substantiating thermometric validity. Limitations comprise the modest single-institution sample, prospective environmental confounders, and three-month horizon potentially overlooking protracted alterations.

Prospective investigations ought to incorporate multicenter designs, extended surveillance, sophisticated imaging or artificial intelligence integration, revision/infection cohorts, methodological harmonization, economic evaluations, and applicability to diverse arthroplasties—fostering dependable self-monitoring paradigms.

## CONCLUSION

In uncomplicated total knee replacement, operated knee skin temperature rises gradually post-surgery, peaks on postoperative day 7(34), and returns to baseline by three months(42). The inflammatory marker CRP peaks early on POD 2(22,33); ESR peaks around POD 3-5(22,24,33). Operated knee skin temperature, CRP, and ESR all normalize by three months(24,33,42). Knee temperature strongly correlates positively with CRP, mirroring inflammation(16). Larger multicenter studies with standardized protocols are needed. This pattern supports patient counseling, surgeon reassurance, and early detection of recovery deviations.

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