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Case Report

Detection of Knee Implant Instability Using the Persona IQ Smart Implant System: A Case Report

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Abstract

Total Knee Arthroplasty (TKA) is performed in over 700,000 patients annually in the United States, providing significant pain relief and functional improvement for osteoarthritis and other degenerative conditions. However, complications such as periprosthetic fractures, loosening and instability remain challenges, especially post-trauma, with early detection often elusive using traditional methods. This report describes the first documented case of a proximal tibial stress fracture detected via vibrational profile shifts in the Persona IQ smart knee implant following a Motor Vehicle Accident (MVA) at 7 months post-TKA. Gait metric declines post-MVA, including a -18% change in step count (from 3140 to 2584 steps/day), -25% change in walking distance (km) and -8.8% change in walking speed (m/s) and vibrational analysis showing statistically significant variations in amplified wavelet power spectra (p=0.000329) aligned with medial-proximal tibial pathology on MRI, despite no radiographic loosening. Compared to three matched controls, the MVA patient's unique pre-/post-MVA shifts highlight the implant's sensitivity to trauma-induced changes, supporting its role in identifying instability before advanced imaging. This case demonstrates smart implants' potential for proactive monitoring to prevent failures and improve outcomes. Future directions include AI-driven predictive models fusing vibration and gait data for real-time alerts, multi-center trials to establish thresholds and expanded registries to generalize findings, ultimately reducing revision rates through patient-centered prevention.

Keywords: Total Knee Arthroplasty; Motor Vehicle Accident; AI-Driven Predictive Models

Introduction

Total Knee Arthroplasty (TKA) is performed in over 700,000 patients annually in the United States, with volumes projected to exceed 2.5 million by 2040, driven by aging populations and expectations for improved mobility [1]. While TKA offers substantial pain relief and functional restoration for Osteoarthritis (OA), up to 20% of patients experience suboptimal outcomes, including persistent pain, stiffness and functional limitations [2]. Periprosthetic tibial fractures, occur in 0.1-1.4% of primary TKAs and rises to 2.5-8% in revisions. These fractures often mimic loosening post-trauma, leading to prolonged edema, high complications rates (up to 40%) and a 1-year mortality higher than primary TKA and isolated distal femoral fractures at 18% [3-5]. Emerging biomechanical insights reveal that loads and alterations, such as elevated joint moments from midflexion laxity or pin-induced stresses, concentrate forces on the tibial component, predisposing to microfractures, wear or instability [6,7]. Pin placement and slope variations amplify these impacts by propagating alterations at the bone-implant interface, while compartmental imbalances during dynamic activities may exacerbate micromotion [8]. Notably, hindfoot deformities further compound these issues by deviating Ground Reactive Forces (GRF), with valgus hindfoot in medial OA initially compensating via GRF lateralization but failing with progressive deformity, distorting the mechanical axis and overloading medial compartments post-TKA [9,10]. Post-traumatic arthritis prior to primary TKA can heighten aseptic failure to 26% and complications to 57%, further underscoring the need for tools sensitive to these biomechanical vulnerabilities [11].

Conventional diagnostics rely on an algorithmic approach including history, physical exam, radiographs and labs to exclude infection or loosening. Current diagnostics often overlook early bone-implant interface changes and symptoms like load-bearing pain resulting from instability or gap imbalance [2]. CT and nuclear imaging face limitations from artifacts and non-specificity, remaining positive up to 2 years post-TKA [9]. Novel technologies, such as smart implants, are embedded with sensors for continuous gait and vibration monitoring, capable of capturing high-frequency heel-strike spectra to detect micromotion and load alterations indicative of instability [12-14]. By quantifying the biomechanical impacts that arise from instability, axis deviations, and/or compromised bone-implant interface, vibration analysis offers a path to feasible, non-invasive early warning in high-risk patients [15-17]. This enables proactive management that may mitigate risks before clinical escalation. This report describes the first documented use of a smart implant system to detect post-traumatic tibial component loosening, emphasizing its role in diagnosis and early interventions.

Methodology

The study utilized data from the Persona IQ smart implant, which provides objective kinematic data during a patient's TKA post-surgical care. The Persona IQ smart implant contains three-dimensional (3-D; x-, y- and z-axes) accelerometers and gyroscopes that collect data post-TKA using an autonomous algorithm. The 3-D accelerometer and gyroscope data is captured at a rate of 25 Hz when prompted by an internal triggering algorithm that is designed to identify walking. Additionally, the 3-D accelerometer captures a 3-second window of high-resolution data at a rate of 800 Hz following the initial medium-resolution data capture. While the medium-resolution data is processed to produce the standard Canary Medical Gait Parameters (CMGP) outputs, such as walking speed, cadence, etc., the high-resolution data can be further analyzed to assess implant stability. Data collections took place daily following implantation for the first year and then reduced to 36 consecutive daily measurements each quarter during the second year. Gait parameters were evaluated using rolling averages and linear regression in defined postoperative periods: 2-12 weeks, 12-26 weeks, 26-52 weeks and from Motor Vehicle Accident (MVA) to last available data. Percentile bands were derived from a normative TKA cohort for contextual comparison. Vibration analysis utilized scale-averaged wavelet power spectra, amplified by multiplying x-axis (medial-lateral) with y-axis (vertical/loading) to normalize for external variables. Statistical comparisons employed 2-sample t-tests for pre- versus post-MVA differences, with $p<0.05$ indicating significance. Three controls were matched for gender, BMI and data availability, with pre/post demarcations aligned to the MVA timing (~7 months post-implant). All procedures complied with institutional review board guidelines and informed consent was obtained for data use.

Case Presentation

This patient underwent primary cemented TKA with the Smart Implantable Device (SID) (Zimmer Biomet) in the left knee in July 2023 for osteoarthritis. The SID incorporates embedded sensors for daily gait metrics (step count, distance, speed, cadence, stride length, functional knee Range of Motion (ROM), tibia ROM) and high-frequency vibration data during ambulation.

Initial recovery was uneventful. The patient did well, progressed with therapy and was satisfied with no pain. She had returned to work and full activities. At the February 2024 follow-up (7 months post-op), the patient reported a MVA that day. Radiographs demonstrated a well-fixed implant and no acute fracture. She underwent a period of rest followed by physical therapy. She continued to complain and a Metal Artifact Reduction Sequence (MARS) protocol MRI was obtained and showed a stress reaction on the medial tibial cortex. At this point she was treated with limited weight bearing for 6 weeks followed by continued PT. She continued to have trouble and we initiated NSAID's and she was no longer progressing.

By June 2024 (11 months post-op), the patient presented with severe knee pain (7/10) and ambulation difficulty. SID data revealed an "alarming trend" of declining gait metric over the prior weeks. Subsequent visits (July-September 2024, January 2025) noted persistent pain (5-8/10) and edema. Repeat MARS MRI-confirmed a medial-proximal tibial stress fracture without dislocation. New radiographs taken in the September 2024 visit showed loosening of the tibial component. There was also a significant change in her SID data.

Results

Gait Metrics

Rolling averages and linear trends were analyzed in four periods: 2-12 weeks post-op, 12-26 weeks, 26-52 weeks and accident to last data point (~ February 2024 to January 2025). Gait metric trends for the MVA patient are described in Table 1. These declines were modest but noticeable post-MVA, contrasting with variability in three matched controls (age, gender, BMI, data availability) without clinical implications (Table 2, Fig.1-6).

Metric	Trend Description
Step Count	+167% (1024 to 2729 steps/day) in 2-12 weeks; +37% (2785 to 3811) in 12-26 weeks; -2% (3112 to 3058) in 26-52 weeks; -18% (3140 to 2584) post-accident
Stride Length	Declining 30-day trend post-accident, correlating with reduced distance and steps
Distance	Declining 30-day trend post-accident, correlating with reduced stride length and steps
Walking Speed	Declining 30-day trend post-accident
Cadence	Decline in 7-day trends post-accident
Functional Knee ROM	No notable pre- vs post-accident differences
Tibia ROM	Slow, minimal decline in 30-day trend post-accident

Table 1: Gait metric trends in MVA patient.

Step Count (steps/day)

MVA patient. Step count trends revealed an initial rapid recovery phase up to the 30-week post-op mark. At the 30-week post-op, coinciding with the MVA, an observed decline occurred, which suggested a gait stability disruption by week 52.

Control 1 (bilateral TKA, left knee first). Showed similar early gains comparative to the MVA patient. The left knee surgery was performed around the 30-week mark, showing a drastic decline between 26 and 52 weeks. After 52 weeks post-op, there was a positive rebound, which was stabilized in the mid-percentile bands. The right knee also showed similar gains comparative to the MVA patient and left knee pre-op, where there was an initial increase in step count up to week 26. Around the 30-week mark, the right knee surgery was performed, showing a drastic decrease up to week 52. Similarly to the left knee surgery, there was an increase in step count after the 52 week post-op mark, indicating stabilization above median bands.

Control 2 (unilateral right TKA). Presented a robust early recovery up to week 26. Around the 30-week mark, when the surgery was performed, there was a decline in step count by week 52. After week 52 post-op, there was an exponential increase by week 70, which exceeded the upper percentile bands mid-recovery.

Control 3 (unilateral left TKA). Showed an increase in step count up to week 52 post-op. Although there were no decreases observed in step count post-op, by week 52, the patient remained in lower percentile bands, underscoring limited functional improvement in lower-activity patients.

Distance (km)

MVA patient. Distance trends demonstrated an initial rapid recovery phase up to the 30-week post-op mark. At the 30-week post-op, aligned with the MVA, an observed decline occurred up to the 90 week post-op mark, highlighting gait disruption captured by the implant's distance metric.

Control 1 (bilateral TKA, left knee first). Showed similar early gains as the MVA patient. The left knee surgery was performed around the 30-week mark, which showed a drastic decline between 26 and 52 weeks. After 52 weeks post-op, there was a positive change in distance, which was stabilized in the lower-mid percentile bands. The right knee also showed similar gains comparative to the MVA patient and left knee pre-op, where there was an initial increase in step count up to week 26. Around the 30-week mark, the right knee surgery was performed, showing a less drastic decrease compared to the left knee, up to week 52. Overall, the bilateral TKA's capacity rebound above median bands.

Control 2 (unilateral right TKA). Demonstrated a vigorous recovery up to week 26. Around the 30-week mark when the surgery was performed, there was a decline in distance walked by the 52 week post-op mark. After week 52, distances surpassed the upper percentile bands mid-recovery.

Control 3 (unilateral left TKA). Demonstrated limited advances, with an increase in distance up to week 26. Around the 30-week mark when surgery was performed, there was a slight decrease in distance in comparison to control 2 and a positive increase by week 52, illustrating improvement in less active individuals.

Walking Speed (m/s)

MVA patient. Walking speed trends indicated a robust recovery, with an observed decrease by week 36. Around week 30, coinciding with the MVA, an observed decline continued, which placed the trajectory below median percentile bands.

Control 1 (bilateral TKA, left knee first). Showed early gains up to week 12. At week 12, there was a decline in walking speed, followed by a continued decline post 30 weeks after surgery. Post- op week 52, a slight increase in walking speed was observed, with stabilization in lower percentile bands. The right knee showed different gains compared to the left knee, with increase in walking speed up to the 26 week mark. After surgery was performed around week 30, there was a slight decrease observed up by week 70, which illustrated bilateral TKA's tendency for gradual speed plateaus without severe long-term loss.

Control 2 (unilateral right TKA). Presented with an increase in walking speed up to week 26, with a decline in walking speed present by week 52, due to surgery performed around the 30 week mark. By week 70 and increase in walking speed was observed, with speeds that approached upper percentile bands mid-recovery.

Control 3 (unilateral left TKA). Showed an increase in step count up to week 52. Although there were no decreases observed in walking speed by week 52, the patient remained below median bands throughout the 50-week follow-up, which highlighted subdued improvement in lower-activity profiles.

Cadence (steps/min)

MVA patient. Cadence trends showed an initial rapid recovery phase up to the 12-week mark. At week 26, a decline in cadence was observed. Post-MVA, a continued decline was present up to the 52 week mark, with trajectory remaining near median percentile bands suggesting disrupted gain rhythm.

Control 1 (bilateral TKA, left knee first). Displayed comparable early progress to the MVA patient, but presented a decrease in cadence beginning at week 26. The left knee surgery was performed around the 30-week mark and an increase was observed beginning week 52, stabilizing above median bands. The right knee presented an initial increase in cadence up to week 26. Around the 30-week mark, the right knee surgery was performed, showing a drastic decrease up to week 52. Similarly to the left knee surgery, there was an increase in cadence after the 52 week mark.

Control 2 (unilateral right TKA). Presented with an increase in cadence up to week 12, but a decrease was observed by week 26. Around the 30-week mark, when the surgery was performed, the decrease continued.

Control 3 (unilateral left TKA). Showed an increase in cadence up to week 26. Decreases began by week 52, which persisted in lower percentile bands over the 52-week period.

Stride Length (m)

MVA patient. Stride length trends revealed an initial decline phase up to the 90 week mark. The post-accident dip positioned the patient's trajectory below the median percentile bands, suggesting a disruption in gait stability detected through the implant's monitoring of stride metrics.

Control 1 (bilateral TKA, left knee first). Exhibited early declines with a decline continuing up to week 52, with trajectory stabilizing in lower percentile bands. The right knee presented an initial increase in stride length up to week 12. By week 26, there was a decrease in stride length observed, which continued decreasing by week 52, which highlights bilateral TKA's potential for interim setbacks, but eventually stabilization near median bands.

Control 2 (unilateral right TKA). Demonstrated a consistent decline up to week 52. The patients stride lengths remained within mid-percentile bands throughout recovery.

Control 3 (unilateral left TKA). Demonstrated an initial increase in stride length by week 12, but by week 52, a slight decrease was observed, remaining in lower percentile bands over the 52-week follow-up.

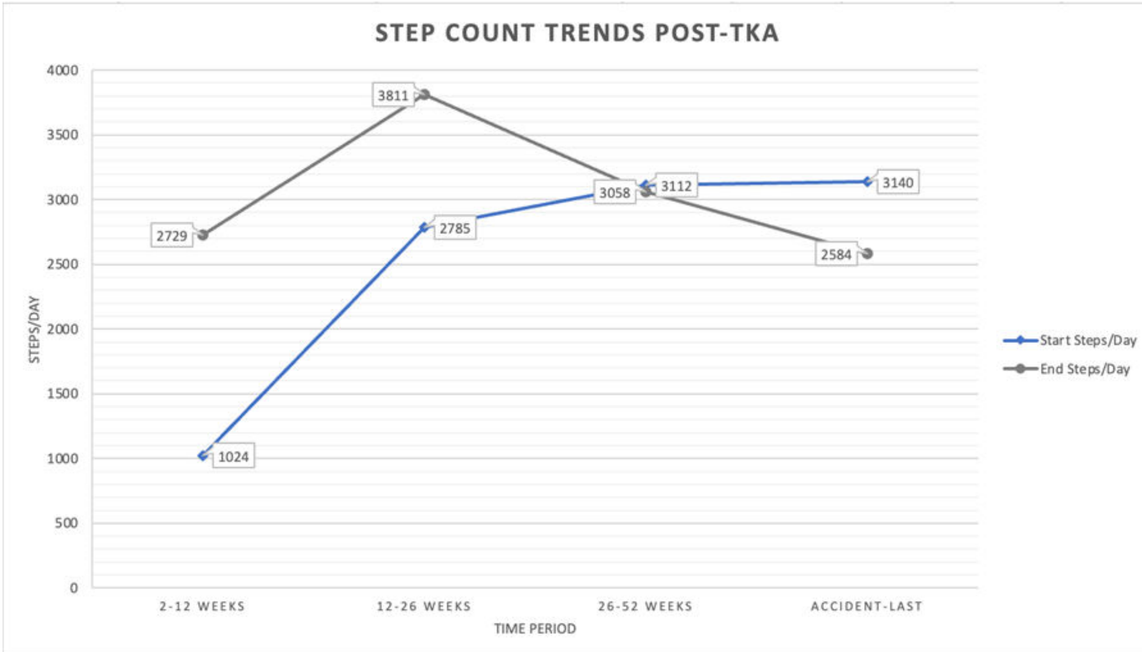

Figure 1: Longitudinal trends in daily step count for the MVA patient, divided into postoperative periods. Note the plateau pre-MVA and sharp -18% decline post-accident, indicating potential instability.

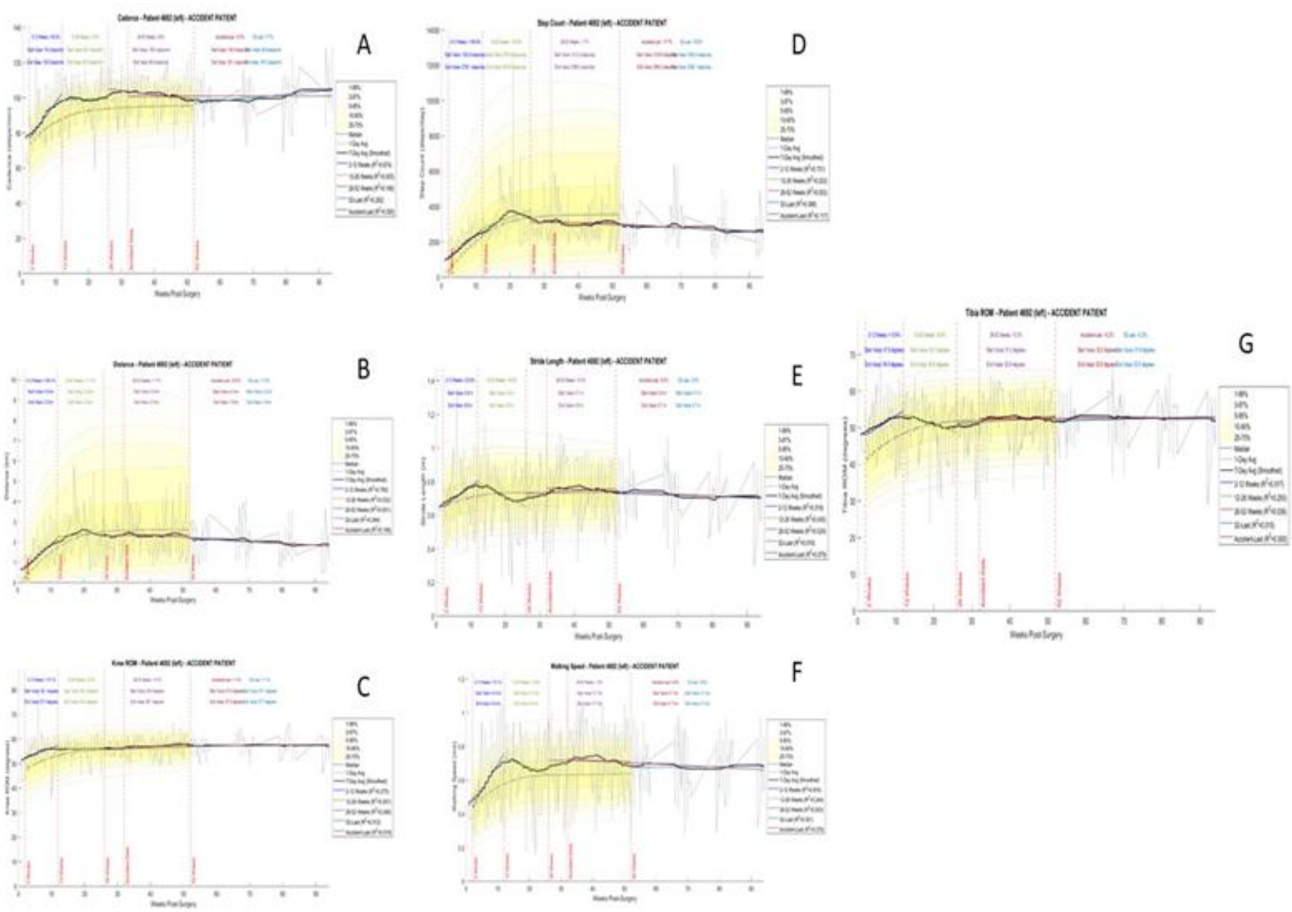

Figure 2: 30-day rolling trends in selected gait metrics post-TKA for the MVA patient. Declines in stride length (E), distance (B) and speed post-accident (F) correlate with reported pain and ambulation difficulty, while cadence (A) and functional knee ROM (C) remains stable.

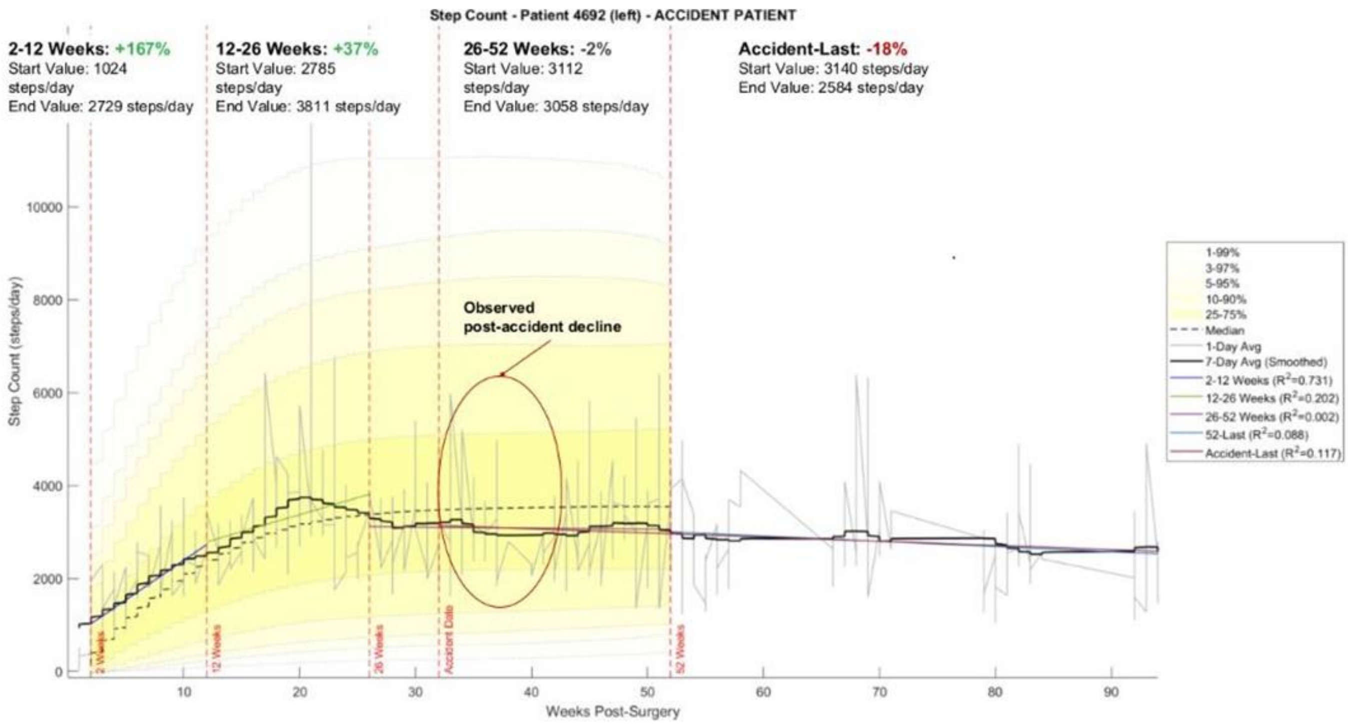

Figure 3: MVA Patient Step Count Trends showing an observed post-accident decline around the 30 week mark.

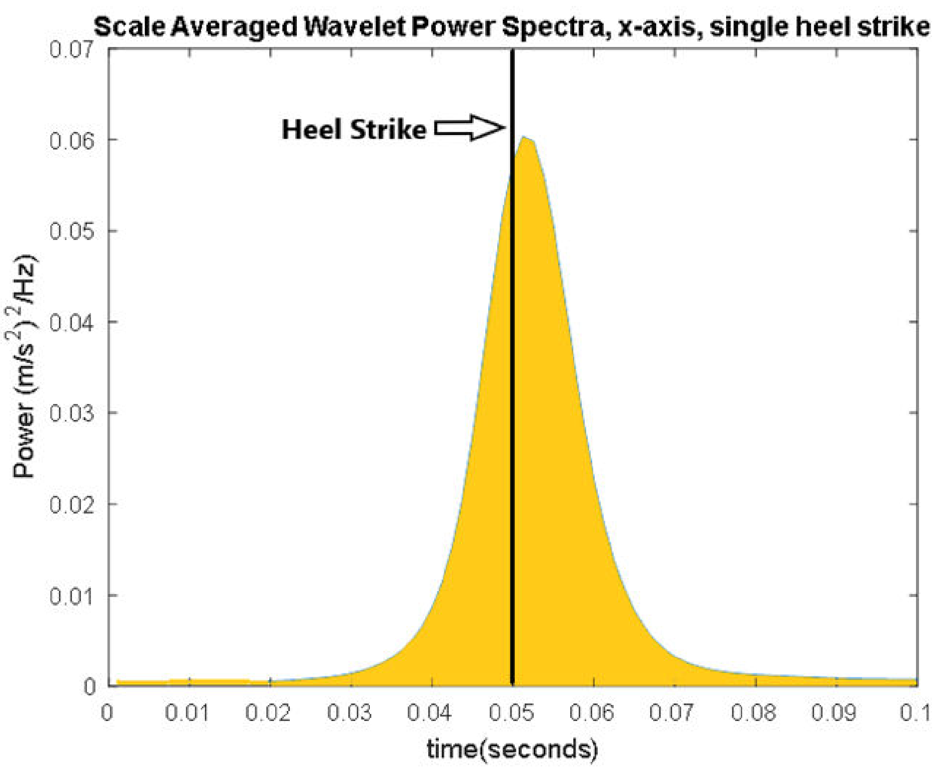

Figure 4: The scale averaged wavelet power spectra from a single heel strike are plotted with the area used to compute the Area Under the Curve (AUC) shown in yellow.

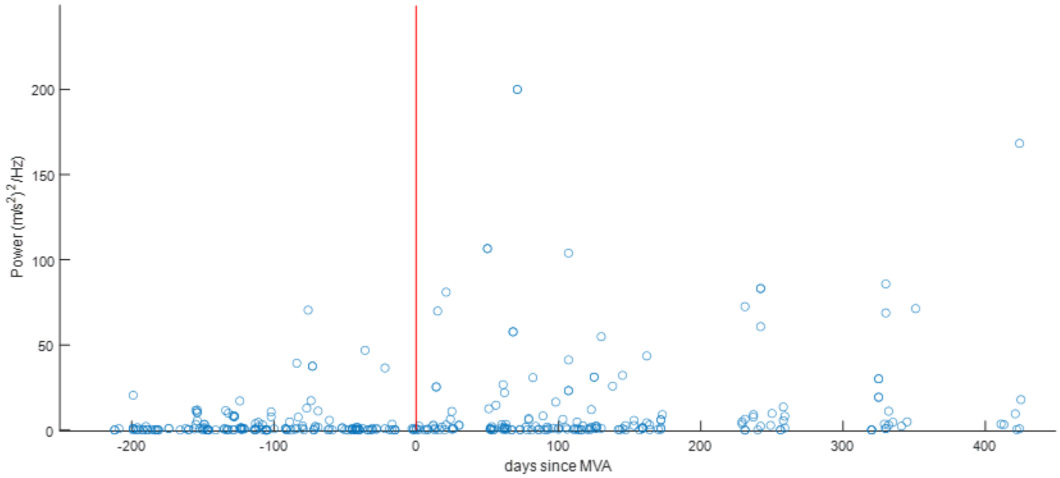

Figure 5: Scale-averaged wavelet power spectra (x*y-axis) pre- and post-MVA (MVA marked by the red line) in the medial-lateral direction. Increased post-MVA power (AUC inset) aligns with medial-proximal tibial edema and stress fracture p=0.000329).

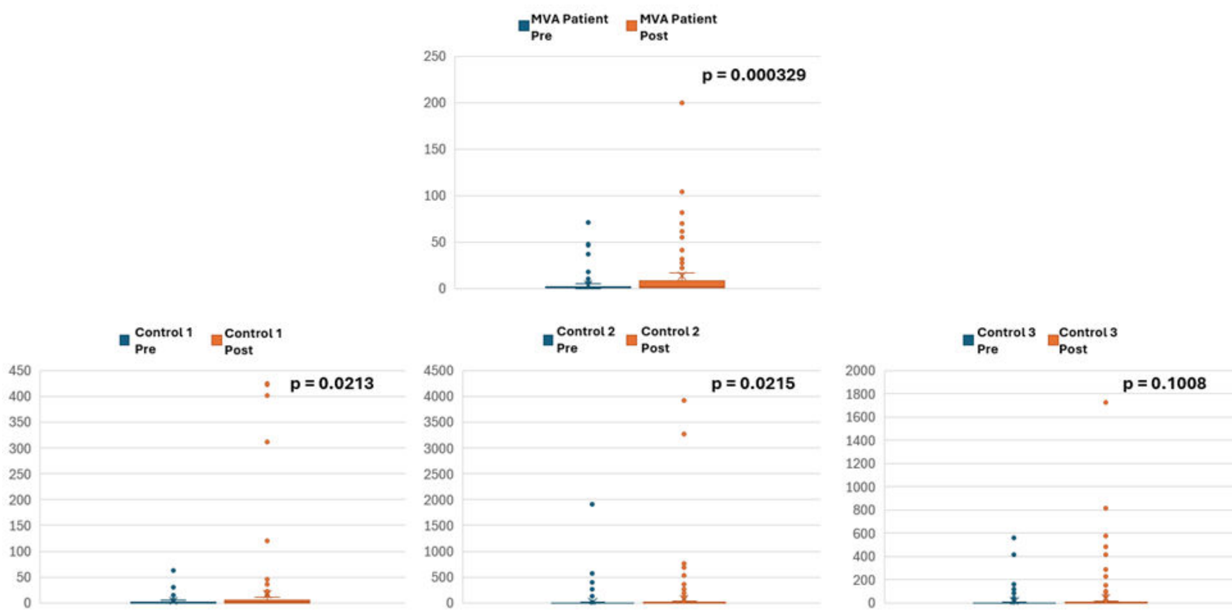

Figure 6: Distribution of vibration power (x*y-axis) before and after MVA for the patient and matched controls. Post-MVA increases contrasts with control stability, suggesting vibration as a marker for instability.

Patient	Metric	Time Frame (Weeks)	Start Value	End Value	% Change	R^2
MVA	Steps/day	2 to 12	1023.8	2729.1	166.60%	0.731
		12 to 26	2784.8	3810.6	36.80%	0.202
		26 to 52	3112.2	3058	-1.70%	0.002
		30 to 90	3139.8	2584.2	-17.70%	0.088
		52+ (Post MVA)	3,002	2528.1	15.80%	0.117

	Distance (km)	2 to 12	0.6	2.2	239.10%	0.785
		12 to 26	2.2	2.5	11.70%	0.032
		26 to 52	2.3	2.3	1.70%	0.001
		30 to 90	2.4	1.8	-25.50%	0.094
		52+ (Post MVA)	2.2	1.8	-17.20%	0.189
	Walking Speed (m/s)	2 to 12	0.4	0.8	72.10%	0.816
		12 to 26	0.7	0.6	-13.80%	0.244
		26 to 52	0.7	0.7	-1.60%	0.003
		30 to 90	0.7	0.7	-8.80%	0.001
		52+ (Post MVA)	0.7	0.7	0.80%	0.076
	Cadence (steps/min)	2 to 12	76.3	102.5	34.30%	0.674
		12 to 26	98.7	99.5	0.90%	0.005
		26 to 52	105	98.9	-5.80%	0.186
		30 to 90	100.8	101.1	0.30%	0.282
		52+ (Post MVA)	96.8	104.3	7.70%	0
	Stride Length (m)	2 to 12	0.6	0.8	23.60%	0.519
		12 to 26	0.8	0.6	-18.50%	0.43
		26 to 52	0.7	0.8	4.00%	0.024
		30 to 90	0.8	0.7	-8.00%	0.016
		52+ (Post MVA)	0.7	0.7	-3.30%	0.079
Control 1 (Bilateral TKA, Left Knee First)	Steps/day	2 to 12	0	3898.4	100.00%	0.863
		12 to 26	3332	5041.6	51.30%	0.623
		26 to 52	4937.6	749.1	-84.80%	0.645
		52+ (Post MVA)	2905.5	3990.9	37.40%	0.171
	Distance (km)	2 to 12	0	2.3	100.00%	0.883
		12 to 26	1.9	2.8	46.80%	0.41

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		26 to 52	2.7	0.4	-84.60%	0.617
		52+ (Post MVA)	1.5	2.3	48.70%	0.177
	Walking Speed (m/s)	2 to 12	0.4	0.6	43.20%	0.432
		12 to 26	0.6	0.5	13.50%	0.163
		26 to 52	0.5	0.4	-26.10%	0.164
		52+ (Post MVA)	0.5	0.5	8.40%	0.065
	Cadence (steps/min)	2 to 12	68.5	97.1	41.80%	0.737
		12 to 26	91.1	94.7	4.00%	0.076
		26 to 52	98.6	81.8	-17.10%	0.205
		52+ (Post MVA)	95.5	99.8	4.40%	0.084
	Stride Length (m)	2 to 12	0.6	0.6	-8.10%	0.028
		12 to 26	0.6	0.6	-0.30%	0
		26 to 52	0.5	0.5	-15.60%	0.107
		52+ (Post MVA)	0.5	0.6	6.40%	0.042
Control 1 (Bilateral TKA - Right Knee Second)	Steps/day	2 to 12	0	4022.1	100.00%	0.832
		12 to 26	2199.5	4938.3	124.50%	0.675
		26 to 52	5808.2	3416.9	-41.20%	0.523
		52 to 70	3703.9	5021.2	35.60%	0.437
	Distance (km)	2 to 12	0	2.5	100.00%	0.837
		12 to 26	1.2	3	144.50%	0.538
		26 to 52	3.6	1.8	48.90%	0.537
		52 to 70	2.2	2.9	34.00%	0.38
	Walking Speed (m/s)	2 to 12	0.3	0.6	105.20%	0.818
		12 to 26	0.5	0.5	8.60%	0.067
		26 to 52	0.6	0.5	-7.80%	0.05
		52 to 70	0.5	0.5	-1.50%	0.00

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	Cadence (steps/min)	2 to 12	65.8	102.5	55.70%	0.879
		12 to 26	94.3	95.4	1.20%	0.008
		26 to 52	95	98.1	3.30%	0.034
		52+ (Post MVA)	98.7	98.9	0.20%	0
	Stride Length (m)	2 to 12	0.5	0.6	36.90%	0.65
		12 to 26	0.6	0.6	6.00%	0.042
		26 to 52	0.6	0.6	-11.30%	0.143
		52+ (Post MVA)	0.6	0.6	-1.70%	0.005
Control 2 (Unilateral Right TKA	Steps/day	2 to 12	695	4594.1	561.00%	0.981
		12 to 26	4036.5	5249.4	30.00%	0.389
		26 to 52	7341.6	4541.7	-38.10%	0.418
		52 to 70	1876.1	5230.9	178.80%	0.326
	Distance (km)	2 to 12	0.4	3.6	721.60%	0.91
		12 to 26	3.1	3.8	23.70%	0.164
		26 to 52	5.8	3	48.20%	0.429
		52 to 70	1.2	3.7	208.30%	0.385
	Walking Speed (m/s)	2 to 12	0.4	0.7	60.40%	0.732
		12 to 26	0.6	0.6	2.10%	0.003
		26 to 52	0.7	0.5	-21.60%	0.221
		52 to 70	0.4	0.7	59.70%	0.402
	Cadence (steps/min)	2 to 12	69.8	94.4	35.30%	0.859
		12 to 26	87.2	95.1	9.10%	0.227
		26 to 52	95.8	88	-8.20%	0.242
		52+ (Post MVA)	78.5	100.2	27.70%	0.358
	Stride Length (m)	2 to 12	0.7	0.8	20.50%	0.266
		12 to 26	0.8	0.7	-8.30%	0.09

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		26 to 52	0.8	0.7	-14.60%	0.15
		52+ (Post MVA)	0.6	0.7	21.60%	0.23
Control 3 (Unilateral - Left TKA)	Steps/day	2 to 12	36.1	908.9	2419.20%	0.948
		12 to 26	725.9	820.8	13.10%	0.033
		26 to 52	854.4	933.6	9.30%	0.002
	Distance (km)	2 to 12	0	0.6	100.00%	0.876
		12 to 26	0.4	0.6	32.40%	0.105
		26 to 52	0.5	0.5	-6.70%	0.001
	Walking Speed (m/s)	2 to 12	0.4	0.6	45.40%	0.802
		12 to 26	0.5	0.6	13.40%	0.142
		26 to 52	0.5	0.6	9.20%	0.006
	Cadence (steps/min)	2 to 12	70.6	88.7	25.60%	0.673
		12 to 26	84.3	94.1	11.60%	0.552
		26 to 52	87.2	68.5	-21.50%	0.151
	Stride Length (m)	2 to 12	0.5	0.6	26.10%	0.487
		12 to 26	0.6	0.6	16.00%	0.158
		26 to 52	0.6	0.6	3.10%	0.001

Table 2: Gait Metric Values obtained for MVA patient, Control 1, Control 2 and Control 3, including R^2 Values.

Vibration Analysis

Vibrational data from the smart implant, analyzed via amplified high-frequency wavelet power spectra (x-axis medial-lateral multiplied by y-axis vertical/loading), demonstrated a statistically significant difference in the vibration profile pre- versus post-MVA. Clinical notes confirmed no loosening appreciated on radiographic imaging but identified a stress fracture and edema in the medial-proximal tibia on subsequent MRI. The vibrational analysis feasibly detected the stress fracture and edema, interpreted as instability in this single case (n=1). The strongest difference occurred in the medial-lateral direction, aligning with the location of pathology. Capturing data at 800 Hz across 0-400 Hz during heel strikes, the analysis amplified signal power through force representation to normalize for loading variability influenced by footwear, surface stiffness (e.g., carpet vs. tile) and ambulation forcefulness. Pre-MVA scale-averaged wavelet power spectra in the x-axis exhibited a prominent peak at heel strike (±50 milliseconds), reaching up to 0.5 m/s^2/Hz across multiple scales, reflecting normal high-frequency vibrational energy during impact. A 2-sample t-test on pre- versus post-MVA amplified x*y AUC rejected the null hypothesis (p=0.000329). P-values for pre-post differences highlighted statistical significance in the MVA patient (3.29E-04) versus controls (0.0213, 0.0215 and 0.1008, respectively), suggesting the method's ability to detect isolated trauma-induced signals.

Discussion

This case marks the inaugural detection of proximal tibial stress fracture and tibial loosening via SID, predating imaging confirmation. The patient's post-MVA trajectory aligns with literature on post-traumatic TKA complications [3,11]. Periprosthetic tibial stress fractures, as seen here, often result from trauma in well-fixed implants and can mimic loosening with pain and swelling in 84% and 76% of complicated TKAs, respectively [19]. Vibration shifts in the medial-lateral axis match the fracture anatomy demonstrated on MRI, suggesting micromotion at the bone-implant interface before detection with radiographs or advanced imaging. The medial-proximal location, edema and vibrational shifts support the biomechanical stress concentration [20].

This vibrational analysis supports smart implant utility for early detection of complications like stress fractures prior to radiographic confirmation, with the amplified x*y metric enhancing sensitivity in the medial-lateral direction. While controls' higher power signals warrant further investigation into unmatched factors, the distinct post-MVA variability in the case demonstrates potential for non-invasive monitoring, though limited by small sample size and axis-specific data. Nonetheless, vibrational differences ($p<0.001$) provide novel evidence for instability detection. While knee-specific literature is sparse, analogous shoulder studies use vibration to simulate/detect loosening, with power spectra indicating micromotion [21]. The medial-lateral emphasis aligns with fracture anatomy, suggesting vibration captures bone-implant interface disruptions before radiographic loosening.

Comparative analysis of step count data across the index case and controls illustrates the utility of smart implant monitoring in detecting post-TKA instability. The index patient's abrupt -18% post-MVA decline at ~30 weeks mirrored disruptions in bilateral Control 1 (-85% post-second surgery) but differed from the milder, non-event-related declines in unilateral Controls 2 (-38%) and 3 (+9%), where recoveries were more consistent or plateaued without sharp drops. In the MVA patient, the step count deviation below expected percentile bands preceded radiographic confirmation of instability, enabling early intervention [22]. This pattern supports the role of continuous gait metric tracking via smart implants to identify trauma-induced complications, as the MVA patient's sustained lower plateau (2,584 steps/day at week 90) contrasted with controls' higher long-term averages (3,900-5,230 steps/day), highlighting MVA's lasting impact on recovery trajectories.

Comparative analysis of cadence data illustrates smart implant utility in detecting post-TKA disruptions, with the MVA patient's post-accident decline mirroring event-related drops in bilateral Control 1 but differing from gradual or stable patterns in unilateral Controls 2 and 3. The MVA patient's plateau near 90-100 steps/min post-accident contrasted with controls' averages (80-100 steps/min), highlighting MVA's impact on rhythm. Gait declines post-MVA (-18% steps, reduced speed/stride) mirrors studies where gait metrics predict TKA complications (e.g., slower speed and shorter stride associated with instability or poor outcomes [9]). Controls' variability without declines underscores the specificity to trauma-induced changes.

Limitation include n=1 (with controls n=3), requiring larger cohorts for predictive models. Nonetheless, this supports early trends as intervention indicators, potentially reducing revisions. Canary's cementless programs could expand vibratory monitoring during osteointegration (0-12 weeks post-op).

Conclusion

The smart implant enabled unprecedented early detection of post-traumatic knee implant instability through gait and vibration analytics, correlating with clinical stress fracture and edema. This case underscores smart implants' transformative potential in orthopedic monitoring, warranting prospective studies to validate predictive thresholds and impact on revision rates. By integrating biomechanical data with traditional assessments, such systems could redefine TKA surveillance, improving long-term outcomes in high-risk patients.

Conflict of Interests

The authors declare that there is no conflict of interest related to this study.

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