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ORIGINAL ARTICLE

Unicompartmental knee arthroplasty results in a better gait pattern than total knee arthroplasty: Gait analysis with a smartphone application

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ABSTRACT

Objectives: The aim of this study was to compare the smartphone-based gait analysis data of patients who underwent total knee arthroplasty (TKA) and unicompartmental knee arthroplasty (UKA).

Patients and methods: Between January 2016 and April 2019, a total of 51 patients (3 males, 48 females; mean age: 60.92 years; range, 51 to 70 years) who were operated with UKA or TKA in our clinic were retrospectively analyzed. The patients were divided into two groups according to the type of procedure as the UKA group (n=17) and unilateral TKA group (n=34). Gait analysis was made via a smartphone application (Gait Analyzer software version 0.9.95.0) with data acquired from the accelerometer of the smartphone. This analysis was performed using data collected from the Acceleration Sensor LSM6DSO into the Samsung Galaxy Note 10 Plus phone. Gait velocity, step time, step length, cadence, step time symmetry, step length symmetry, and vertical COM (vert-COM) parameters were measured.

Results: There were no statistically significant differences between the groups in respect of age, sex, body mass index, operated side, and follow-up duration. Compared to the TKA group, the UKA patients showed a better gait pattern in gait velocity (p=0.03), step time symmetry (p=0.005), and step length symmetry (p=0.024). No significant difference was detected in step time (p=0.807), step length (p=0.302), cadence (p=0.727) and vert-COM parameters (p=0.608).

Conclusion: The gait of UKA patients is closer to the physiological pattern with a better gait velocity, step time symmetry, and step length symmetry than TKA patients. The surgical treatment option of UKA for knee medial compartment osteoarthritis leads to a better gait pattern than TKA.

Keywords: Gait analysis, knee arthroplasty, smartphone, unicompartmental.

There is an ongoing debate on whether unicompartmental knee arthroplasty (UKA) or total knee arthroplasty (TKA) for end-stage medial osteoarthritis (OA) provides better functional outcomes.[1] The main findings of a recent meta-analysis showed a shorter survival time for UKA, but better clinical and functional performance scores, compared to TKA.[2] However, other reviews have reported no statistically significant difference in the postoperative knee scores.[3] The gait pattern of patients changes dramatically after knee arthroplasty, and a physiological gait pattern after TKA has been shown to lead to better patient-related outcome measures (PROMs), than a non-physiological gait pattern.[4,5] Gait pattern is an important predictor of functional abilities and PROMs after knee arthroplasty and smartphone-based gait analysis has been shown to be a valid, reliable, cost-effective, and easily applicable method for the assessment of gait pattern.[6,7]

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To the best of our knowledge, there is no study available comparing the gait patterns of fixed bearing UKA and TKA using a smartphone application in the literature. In the present study, we hypothesized that UKA would be associated with a better gait pattern after arthroplasty surgery than TKA. We, therefore, aimed to compare the pre- and postoperative smartphone-based gait analysis data of patients who underwent TKA and UKA.

PATIENTS AND METHODS

This retrospective study on a single-surgeon series of TKA patients was conducted at Ankara Numune Training and Research Hospital, Department of Orthopedics and Traumatology and Aksaray University Training and Research Hospital, Department of Orthopedics and Traumatology. Hospital records of the patients aged between 55 and 80 years with a previous history of unilateral UKA for Kellgren-Lawrence (K-L) Grade 3-4 medial compartment OA, and having a well-functioning lower extremity were reviewed between January 2016 and April 2019. A total of 51 patients (3 males, 48 females; mean age: 60.92 years; range, 51 to 70 years) who were operated with UKA or TKA were included. The patients were divided into two groups according to the type of procedure as the UKA group (n=17) and age-matched unilateral TKA group (n=34) which a double number of patients to account for the higher number of TKA procedures, compared to UKA. The prospectively collected data of the patients were retrospectively analyzed. Exclusion criteria were as follows: >10° fixed varus deformity, rheumatological joint diseases, previous knee surgery, neuromuscular diseases, bilateral OA, or insufficiency of collateral ligaments. A written informed consent was obtained from each patient. The study protocol was approved by the Aksaray University Ethics Committee (Date/No: 31.08.2020/08-31). The study was conducted in accordance with the principles of the Declaration of Helsinki.

All surgeries were performed by the senior surgeon. For K-L Grade 3-4 medial compartment OA, the decision of senior surgeon for choosing TKA over UKA was based on the presence of anterior cruciate ligament (ACL) insufficiency, anterior knee pain, and lateral compartment pain, despite no evident lateral OA. A medial parapatellar approach was used and patellar resurfacing was not performed in any of the cases. After the administration of spinal anesthesia, a tourniquet was inflated to pressure of 300 mmHg. A straight, longitudinal midline skin incision and medial parapatellar arthrotomy were performed in both UKA and TKA surgeries. The Zimmer® Unicompartmental High Flex Knee system (Zimmer Biomet Inc., IN, USA) and posterior cruciate ligament retaining total knee replacements of the Vanguard® Complete Knee System prosthesis (Zimmer Biomet Inc., IN, USA) were used in all surgeries. Both femoral and tibial prostheses were implanted with pressured bone cement. The patients were mobilized one day after surgery under the supervision of the physiotherapist. All patients underwent the same rehabilitation procedure during the outpatient period. The Knee Society Score (KSS) of each patient was recorded preoperatively, postoperatively, and at one-year follow-up visit.

Gait analysis of the patients was performed during the final follow-up examination. The patients, who were able to walk continuously without the assistance of another person or a walking aid, walked barefoot along a 25-m walkway at a self-selected walking speed with a smartphone attached by a belt to the body above the third lumbar vertebrae in a horizontal orientation.[6] Gait analysis was made using the Gait Analyzer version 0.9.95.0 (Control One LLC, NM, USA) smartphone application running on Samsung Galaxy Note 10 Plus smartphone (143.3×71.1×6.3 mm; 141 g), as described in a previous study.[6] The data collected by the Acceleration Sensor LSM6DSO (STMicroelectronics, Geneva, Switzerland) were low-pass filtered before further analysis (fourth-order zero-lag Butterworth filter at 20 Hz). In the new graphic, the heel strike time points were determined using the relevant mathematical formulas. The gait velocity, step time (ST), step length (SL), cadence, step length symmetry, step time symmetry, and vertical COM (vert-COM) parameters were measured in all patients (Figure 1, 2).[8]

Statistical analysis

Statistical analysis was performed using the IBM SPSS for Windows version 22.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were presented in mean ± standard deviation (SD), median (min-max) or number and frequency, where applicable. The fitness of variables to normal distribution was tested using the Shapiro-Wilk test. As all variables were normally distributed, the Student's t-test was used to analyze gait analysis data. A p value of <0.05 was considered statistically significant.

RESULTS

The demographic and operative data of the patients are shown in Table I. There was no statistically

Gait Analyzer

Height: 1,65 m
Weight: 85,00 kg

Gender: Female
Race: White
Education level: Middle school
DOB: 17-Jun-1968
Study: TKA&UKA
Diagnoses: Knee Osteoarthritis

GAİT RESULTS

Spatiotemporal Measures

Date	Condition	Gait Velocity (m/s)	Step Length (m)	Step Time (sec)	Cadence (steps/min)
6-Sept-2020		0.64	0.48	0.75	81.62

Symmetry and Balance

Date	Condition	SL Symmetry (%)	ST Symmetry (%)	Vert COM (cm)
6-Sept-2020		20.73	11.36	1.11

FIGURE 1. Output from the application for a unicompartmental knee arthroplasty patient at 26 months after surgery.

Gait Analyzer

Height: 1,52 m
Weight: 84,00 kg

Gender: Female
Race: White
Education level: Elementary School
DOB: 16-Jul-1966
Study: TKA&UKA
Diagnoses: knee osteoarthritis

GAİT RESULTS

Spatiotemporal Measures

Date	Condition	Gait Velocity (m/s)	Step Length (m)	Step Time (sec)	Cadence (steps/min)
16-Sept-2020		0.86	0.58	0.70	86.25

Symmetry and Balance

Date	Condition	SL Symmetry (%)	ST Symmetry (%)	Vert COM (cm)
16-Sept-2020		29.34	48.55	2.62

FIGURE 2. Output from the application for a total knee arthroplasty patient at 19 months after surgery.

TABLE I
Demographic and operative data of patients

	UKA group (n=17)		TKA group (n=34)		
	n	Mean±SD	n	Mean±SD	*p*
Age (year)		59.4±5.3		61.7±3.8	0.075
Sex					1.000
Female	16		32		
Male	1		2		
Body mass index (kg/m^2)		27.9±2.0		29.1±2.1	0.067
Operation side					0.366
Right	5		16		
Left	12		18		
Follow-up (month)		31.7±10.0		26.4±10.6	0.094

UKA: Unicompartmental knee arthroplasty; TKA: Total knee arthroplasty; SD: Standard deviation.

significant difference in the anthropometric and demographic data between the groups (p>0.05). Complications of superficial infection in one patient in the TKA group and symptomatic deep vein thrombosis in another patient in the UKA group were successfully treated medically.

There were no statistically significant differences between the preoperative and one-year postoperative KSS-knee and KSS-function scores (p>0.05) (Table II). Both groups showed statistically significant improvements in the KSS-knee and KSS-function scores postoperatively (p<0.05) (Table II). Gait analysis at one year postoperatively showed similar cadence (p=0.727), ST (p=0.807) mean SL (p=0.302), and vert-COM (p=0.609) values for both groups. A statistically significant difference was observed between the groups in terms of gait velocity (p=0.003), step time symmetry (p=0.005), and step length symmetry (p=0.024) values (Table III).

DISCUSSION

In the present study, we demonstrated that UKA patients had a gait closer to the physiological norm with a better gait velocity, step time, and step length symmetry than TKA patients at one year postoperatively, although both groups experienced similar improvements in the KSS. The debates in the literature continue about the effects of different knee arthroplasty designs on postoperative results, such as mobile-bearing versus fixed bearing,[9] posterior cruciate ligament retaining versus stabilized,[10] and UKA versus TKA.[2,3,11] Gait analysis is one of the main aspects in the comparisons of these designs. However, despite the increasing number of studies utilizing gait analysis in patients with UKA and TKA, there remains a need for more data due to the low number of patients included in the published studies.[12,13]

As gait analysis is an expensive test which requires laboratory conditions and trained personnel,[14] there has been a search for less costly methods that can be used by a single clinician without the need for specific conditions. Since the invention of accelerometer sensors to measure acceleration, researchers have used them to measure human movements, and they have become suitable instruments for gait analysis with recent technological developments.[15,16] However, as these devices are expensive and not comfortable, researchers have evaluated the capability of smartphone accelerometers in measuring gait

TABLE II
Pre- and postoperative patient-reported outcomes

	Preoperative			Postoperative		
	UKA	TKA		UKA	TKA	
	Mean±SD	Mean±SD	*p*	Mean±SD	Mean±SD	*p*
Knee Society Score-knee	56.5±11.5	54.6±12.7	0.706	90.8±4.0	89.4±4.7	0.327
Knee Society Score-function	55.6±12.7	53.9±13.9	0.662	87.1±8.6	82.8±7.4	0.073

UKA: Unicompartmental knee arthroplasty; TKA: Total knee arthroplasty; SD: Standard deviation.

TABLE III
Gait analysis results

	Patients	Mean±SD	*p*
Gait velocity	UKA	1.2735±0.09034	0.003
	TKA	1.1621±0.13200	
Cadence	UKA	102.0588±10.99131	0.727
	TKA	103.2218±11.24077	
Step time	UKA	592.0000±47.09830	0.807
	TKA	594.7429±32.14472	
Step length	UKA	60.0000±6.08335	0.302
	TKA	61.6062±4.69228	
Step time symmetry	UKA	13.5453±8.68827	0.005
	TKA	20.0606±6.76177	
Step length symmetry	UKA	16.3041±8.33020	0.024
	TKA	21.6932±7.47925	
Vertical COM	UKA	1.0529±0.43606	0.609
	TKA	1.1176±0.41635	

UKA: Unicompartmental knee arthroplasty; TKA: Total knee arthroplasty; SD: Standard deviation.

parameters, and contemporary studies have shown smartphone-based gait analysis to be a reliable and valid alternative.[6,14,17] Nevertheless, certain mathematical operations requiring engineering knowledge are still necessary to interpret the raw data from the accelerometer. Software is now available which enables clinicians without engineering knowledge to perform gait analysis using data from accelerometer sensors.[18] This software runs on computer platforms, and additional applications are required to obtain and transfer the raw data from the smartphone. Currently, a smartphone application that can measure the accelerometer-based spatiotemporal gait parameters in a valid and safe manner is available, which eliminates the need for a computer, engineering knowledge, or additional applications.[7,19] The Gait Analyzer application measures the spatiotemporal gait parameters in a simple way, by connecting the mobile phone to various parts of the body.

Gait symmetry is one of the main parameters evaluating gait. As gait symmetry improves, energy consumption decreases, thereby increasing the walking speed.[20,21] It has been shown that life expectancy can increase with the increased walking speed.[22] It has been also reported that gait symmetry and associated parameters are more determinant in terms of physiological gait than other factors in patients undergoing unilateral knee arthroplasty.[23] In the current study, the parameters related to symmetry and walking speed were found to be significantly improved in patients who underwent unilateral UKA compared to those with unilateral TKA.[24] This finding is consistent with the results of previous studies which evaluated the gait symmetry parameters of unilateral UKA patients.[12,25,26] The better results in the UKA patients compared to TKA patients could be attributed to the fact that the ACL is sacrificed in TKA operations, but not in UKA operations. Patients with ACL deficits show significantly less isokinetic quadriceps muscle strength than normal patients, leading to the development of a pathological femoral rollback mechanism.[27] These patients walk by decreasing knee flexion to reduce the load on the quadriceps in the stance phase of walking, thereby shortening SL, and a gait style called quadriceps avoidance gait is formed.[12] These differences were not reflected in the KSS-knee and function scores, suggesting that gait velocity and symmetry may not be directly correlated with the patient satisfaction and activity level. However, it is important to note that a pronounced impact on clinical and functional outcome of altered gait can be still expected in a long-term follow-up study or in a study with a younger population with a more demanding lifestyle.[28]

Nonetheless, there are some limitations to this study. First, it has a retrospective design. Second, only primary knee OA patients were included in this study and those with knee OA secondary to other disorders such as rheumatological disorders were excluded. Third, fixed insert designs of UKA and TKA were compared in the current study and, therefore, these findings cannot be applied to the mobile insert designs of TKA and UKA. Finally, this study evaluated the results of TKA and UKA using the inserts of only one company and only one design. Insert designs of other companies should be evaluated to reach more generalizable results.

In conclusion, compared to TKA, UKA seems to provide a better and more physiological gait pattern. In patients with end-stage medial compartmental knee OA, UKA can be recommended rather than TKA for a better gait pattern.

Declaration of conflicting interests

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