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Simultaneous bilateral unicompartmental knee replacement improves gait parameters in patients with bilateral knee osteoarthritis

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ABSTRACT

Background: Unicompartmental knee replacement (UKR) can provide reliable clinical and functional outcomes when performed simultaneously in both knees for treating bilateral osteoarthritis (OA). No studies to date have evaluated gait pattern after simultaneous bilateral UKR. The aim of this study was to evaluate changes in gait variables after bilateral single-stage UKR (B-UKR) and to compare them with the outcomes after unilateral UKR in two other groups of patients: one with bilateral knee OA (P-UKR) and one with the contralateral knee unaffected (H-UKR).

Methods: Three-dimensional motion cohort data were prospectively collected before and six months after surgery; 37 were allocated to the B-UKR (n = 13), P-UKR (n = 12) or H-UKR (n = 12) group. Spatiotemporal variables (stride length, gait speed, gait cadence, stance phase, swing phase, and double support phase) and kinematic parameters (knee flexion and extension peak values, knee range of motion (ROM), and hip abduction peak value) were analyzed using mixed analysis of variance (ANOVA). The magnitude of effect for significant outcomes (ES) was determined using Cohen's *d*.

Results: Postoperative improvement in gait cadence ($P < 0.01$; ES = 1.20), walking speed ($P < 0.05$; ES = 0.58), stride length ($P < 0.05$; ES = 0.67), knee ROM ($P < 0.05$; ES = 0.89), knee flexion ($P < 0.05$; ES = 0.94), and hip abduction ($P < 0.001$; ES = 1.16) was noted for the B-UKR group, whereas only stride length improved ($P < 0.05$; ES = 0.48) for the H-UKR group, and no changes in any gait parameter were seen for the P-UKR group.

Conclusions: Postoperative improvement in gait parameters was observed in the B-UKR patients with bilateral OA. Whenever possible, simultaneous bilateral UKR should be considered in such patients.

1. Introduction

Total knee replacement (TKR) is one of the most successful procedures in orthopedic surgery. It relieves pain and restores function in patients with end-stage knee osteoarthritis (OA), with reliable and long-lasting results in over 85% of cases [1]. Patients' expectations are not always satisfied, however [1]. TKR sacrifices healthy compartments of the knee and one or both of the cruciate ligaments, altering normal knee kinematics and proprioception [2].

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Knee OA affects the joint in a non-uniform manner, often affecting only a single compartment. The medial tibiofemoral compartment is affected nine times more often than the lateral compartment [3,4]. When only a single compartment of the knee is affected and the ligaments are intact, unicompartmental knee replacement (UKR) is a valid option. Because UKR replaces only the affected compartment, preserving the other knee joint structures, it can ensure better knee kinematics and proprioception than TKR [5–8]. Moreover, UKR is less invasive than TKR, with faster recovery times, less bone loss, less blood loss and lower risk of complications in the perioperative period [8–11]. Bilateral knee OA affects at least 20% of patients undergoing a primary knee arthroplasty; consequently, they are destined to undergo a second contralateral surgery within a few years after the initial operation [12,13].

While much has been published about bilateral TKR, few studies have evaluated bilateral UKR. Romagnoli et al. compared simultaneous bilateral UKR (n = 220 patients) and unilateral UKR (n = 347 patients) and found no differences in complications, revision rates, and length of hospital stay between the two groups [11]. Only hemoglobin was decreased, with consequent need for blood transfusion; this was higher in the simultaneous bilateral group. Other studies reported shorter operative time and shorter length of hospital stay after simultaneous bilateral UKR, higher postoperative clinical and functional score and no differences in complication rates compared to two-stage bilateral UKR [6,14,15]. In contrast, Chan et al. reported more major complications, particularly deep venous thromboembolism, after bilateral compared with after unilateral UKR [16]; importantly, however, no thromboembolic prophylaxis had been administered in his series.

Despite the excellent clinical results of simultaneous bilateral UKR in the absence of increased complication rates as compared with unilateral UKR, no studies to date have evaluated gait after simultaneous bilateral UKR. Motion analysis is fundamental for the quantification of human motion during daily activities. Three-dimensional kinematic gait analysis is a valid, reliable, and reproducible tool for supporting clinical decisions and to conduct clinical research in a variety of settings, such as assessment of response to therapeutic interventions (e.g., surgery, physiotherapy, or orthotics) [17].

The primary aim of the present study was to evaluate possible changes in gait analysis variables, including spatiotemporal parameters and kinematic data, after bilateral single-stage UKR (B-UKR). The secondary aim was to compare the gait data of the B-UKR group with the data from two other groups of patients that underwent unilateral UKR: one with bilateral knee OA (pathological + UKR: P-UKR) and one with the contralateral knee unaffected (healthy + UKR: H-UKR). We hypothesized greater improvement in gait parameters in the B-UKR group as compared with the P-UKR group and similar postoperative results for the B-UKR and H-UKR groups.

2. Materials and methods

2.1. Materials and study design

The study was approved by the Ethical Committee of our Institution (registration number 95/INT/2017) and written informed consent was obtained from all patients. Three-dimensional motion cohort data were prospectively collected between 2014 and 2016 from 184 consecutive patients who underwent knee replacement (partial or total, unilateral or bilateral) in a single institution. Indications for UKR, both unilateral and bilateral, were: grade III–IV OA according to the Kellgren–Lawrence classification in the medial tibiofemoral compartment with OA grade lower than II in the other compartments, range of motion (ROM) greater than 90°, flexion contracture lower than five degrees, a clinically stable knee in the coronal and sagittal planes, and no inflammatory disease [18]. Inclusion criteria were: age 55–75 years, no previous bone surgery in the lower limbs, absence of unilateral or contralateral hip or ankle OA, and American Society of Anesthesiologists (ASA) score equal to or lower than II [19]. Exclusion criteria were: UKR due to pathologies other than primary knee OA (osteonecrosis, post-traumatic sequelae), hip or ankle OA, hip or ankle replacement, previous bone surgery in the lower extremities, neurological or skeletal diseases affecting gait, any postoperative complications, loss to follow-up, and ASA score greater than III.

In total, 37 patients met the inclusion criteria and three groups were formed: (1) bilateral-unicompartmental knee replacement group (B-UKR; n = 13): patients who underwent bilateral single-stage UKR; (2) healthy-unicompartmental knee replacement group (H-UKR; n = 12): patients who underwent unilateral UKR with healthy contralateral knee; and (3) pathological-unicompartmental knee replacement group (P-UKR; n = 12): patients who underwent unilateral UKR with stage III–IV OA in the contralateral knee.

Patients in the P-UKR group underwent unilateral UKR even if affected by bilateral OA because the opposite osteoarthritic knee was not symptomatic at the time of surgery. Patients were matched for age, body mass index (BMI, weight in kg divided by height in meters squared) and preoperative hip–knee–ankle (HKA) angle. Table 1 presents the mean and standard deviation (SD) of patients' baseline characteristics (age, weight, height, and BMI).

2.2. Gait analysis

Patients underwent clinical examination and routine gait analysis before (PRE) and six months after (POST) surgery in the Motion Analysis Laboratory of our Institute. For the gait analysis, a Helen Hayes marker set of 22 retro-reflective passive markers was used and a Davis biomechanical model was utilized during data acquisition and processing [20]. For gait analysis before and after the intervention, patients were asked to walk as best as they could at a self-selected speed without walking aids along a 13-meter walkway at least six times. An optoelectronic system (SMART-D, BTS Bioengineering, Milan, Italy) with eight infrared cameras (sampling rate 100 Hz) was used for spatiotemporal and kinematic data acquisition during each walking section. Marker trajectories were recorded, reconstructed, and processed by SMART-D Analyzer software (BTS Bioengineering). The gait parameters included in the statistical analysis were as follows: (1) spatiotemporal variables — stride length (m), gait speed (m/s), gait cadence (steps/min), stance phase, swing phase, and double support phase; stance, swing, and double support phases were normalized as a percentage of the gait cycle and (2) kinematic parameters (in degrees, °): knee flexion and extension peak values, knee ROM, and hip abduction peak value.

2.3. Surgery and postoperative care

The senior author performed all surgeries. The patient lay supine under spinal anesthesia; no tourniquet was applied. A mini-midvastus approach was performed in all cases. After joint exposure, bone cuts were performed to achieve kinematical alignment with under-correction of the deformity. The orientation and level of the joint line were anatomically restored. The two types of unicompartmental knee arthroplasty (UKA) systems were: the Allegretto system (Zimmer Biomet, Warsaw, IL, USA) and the combine Accuris femoral component–Journey tibial component (Smith and Nephew, Memphis, TN, USA). Both UKAs were cemented and had a resurfacing philosophy. Before suturing, local infiltration analgesia was given. A drain was maintained for the first six postoperative hours. Postoperative passive mobilization was started four hours after surgery and walking with full weight-bearing six hours after surgery. The day after surgery, patients walked on level ground and started active flexion exercises. On postoperative day 2, patients performed stair climbing and continued active flexion–extension exercises; they were discharged on the same day from the Orthopedic Department.

2.4. Statistical analysis

The normality of the distribution of the anthropometric (weight, height, and BMI) and background (age) variables for B-UKR, H-UKR, and P-UKR was checked using the Shapiro–Wilk test. All parameters were normally distributed, except for age in the H-UKR group. One-way analysis of variance (ANOVA) and the non-parametric Friedman test for the age variable were applied to test the differences between groups. A P-value ≤0.05 was considered statistically significant. The data are expressed as mean ± SD (Table 1).

Gait parameters were acquired at two timepoints, PRE and POST surgery, for each group (B-UKR, H-UKR, and P-UKR). Kinematic data (knee flexion, knee extension, knee ROM, and hip abduction), and stride length were analyzed by comparing the operated limbs of the B-UKR group and the non-operated contralateral limb of the other two groups (H-UKR, and P-UKR).

The normal distribution of each gait parameter was then checked six times (two time frames × three groups) with the Shapiro–Wilk test. The non-normal distributed variables were tested using non-parametric methods. Mixed ANOVA was applied to each gait parameter. First, we established whether there was an interaction between the two factors, within-subjects factor (time) and between-subjects factor (groups). Second, we evaluated the simple main effects of group and time. The group effect was assessed using two separate one-way ANOVA (one for PRE and one for POST) followed by the Tukey–Kramer post hoc test for differences in the gait parameters between B-UKR, H-UKR, and P-UKR. The effect of time was determined by evaluating with three separate paired Student's *t*-tests the differences in each gait parameter between the PRE and POST conditions.

Cohen's *d* was used to quantify the effect size (ES) for significant outcome in the paired *t*-tests, and partial eta squared ($\acute{\eta}_p^2$) was used to determine the magnitude of the effect for significant outcomes ($\alpha = 0.05$) in ANOVA. Values <0.2, <0.6, <1.2, and >2.0 were interpreted as trivial, small, moderate, large, and very large, respectively [21]. Significance was set at $P < 0.05$. All gait parameters are expressed as mean ± SD. Statistical analysis was performed using GraphPad Prism version 6.00 (GraphPad Software, San Diego, CA, USA).

3. Results

3.1. Spatiotemporal variables

There were no significant differences in preoperative and postoperative stance, swing or double support phases or in preoperative and postoperative acquisitions between the groups. There was a statistically significant difference in gait cadence and walking speed between the H-UKR and B-UKR groups in the preoperative acquisition ($P < 0.05$) (gait cadence at PRE: $F_{(2,35)} =$

Table 1
Baseline characteristics of the three patient groups B-UKR, H-UKR, and P-UKR.

	B-UKR (N = 13)	P-UKR (N = 12)	H-UKR (N = 12)
Age (years)	68 ± 5.61	69.75 ± 4.43	64.91 ± 7.95
Height (m)	1.65 ± 0.08	1.69 ± 0.08	1.67 ± 0.06
Weight (kg)	77.63 ± 18.92	81.25 ± 10.10	79.82 ± 5.34
BMI (kg/m^2)	28.15 ± 5.43	28.24 ± 1.88	28.65 ± 2.28

Abbreviations: B-UKR, bilateral-unicompartmental knee replacement; H-UKR, healthy-unicompartmental knee replacement; P-UKR, pathological-unicompartmental knee replacement; ROM, range of motion. BMI, body-mass index.
The data are reported as mean ± SD. Ns: no significant differences.

Table 2
Changes in spatiotemporal parameters for B-UKR, H-UKR, and P-UKR before (PRE) and after surgery (POST).

Gait parameters	PRE			POST						
	B-UKR (N = 13)	H-UKR (N = 12)	P-UKR (N = 12)	B-UKR (N = 13)	H-UKR (N = 12)	P-UKR (N = 12)	Interaction (group × time)	Effect of group	Contrasts	Effect of time
Gait cadence (steps/min)	97.8 ± 6.4	105.4 ± 6.6	101.7 ± 5.6	106.8 ± 8.4	106.6 ± 8.4	105.4 ± 8.4	ns	PRE: $P = 0.037$ POST: ns	B-UKA ≠ H-UKA	B-UKA: $P = 0.005$ H-UKA: ns P-UKA: ns
Gait speed (meters/s)	0.72 ± 0.15	0.89 ± 0.18	0.84 ± 0.17	0.83 ± 0.21	0.81 ± 0.16	0.87 ± 0.26	$P = 0.004$	PRE: $P = 0.036$ POST: ns	B-UKA ≠ H-UKA	B-UKA: $P = 0.02$ H-UKA: ns P-UKA: ns
Stride length (meters)	0.95 ± 0.34	1.09 ± 0.16	1.13 ± 0.09	1.12 ± 0.11	1.17 ± 0.17	1.16 ± 0.13	ns	PRE: ns POST: ns	ns	B-UKA: $P = 0.025$ H-UKA: $P = 0.032$ P-UKA: ns
Stance phase (percentage)	63.3 ± 2.8	64.5 ± 2.7	60.9 ± 2.7	62.7 ± 1.7	63.9 ± 2.1	60.8 ± 2.1	ns	ns	–	ns
Swing phase (percentage)	36.7 ± 2.8	35.5 ± 2.7	39.1 ± 2.7	37.3 ± 1.7	36.1 ± 2.1	39.2 ± 2.1	ns	ns	–	ns
Double support phase (percentage)	12.4 ± 2.2	11.1 ± 1.5	9.8 ± 2.1	11.9 ± 2.3	11.3 ± 2.6	10.4 ± 1.9	ns	ns	–	ns

The table presents the results of mixed ANOVA with relative *P*-values for: 1) interaction between group and time; 2) the effect of group with associated contrasts; 3) the effect of time for the three patient groups (statistical analysis).
Abbreviations: B-UKR, bilateral-unicompartmental knee replacement; H-UKR, healthy-unicompartmental knee replacement; P-UKR, pathological-unicompartmental knee replacement.
The data are reported as mean ± SD. Ns: no significant differences.

3.74 and $\hat{\eta}_p^2 = 0.17$; gait velocity at PRE: $F_{(2,35)} = 6.57$; $\hat{\eta}_p^2 = 0.27$). A postoperative improvement in gait cadence, walking speed, and stride length ($P < 0.01$ and ES = 1.20 for gait cadence, $P < 0.05$ and ES = 0.58 for walking speed, $P < 0.05$ and ES = 0.67 for stride length) was noted in the B-UKR group; stride length was significantly improved after surgery in the H-UKR group ($P <$ 0.05 and ES = 0.48); no postoperative change in any spatiotemporal variable was observed for the P-UKR group. Table 2 presents the results of the mixed ANOVA for all spatiotemporal parameters and Figure 1 shows the mean ± SD of gait cadence, gait velocity, and stride length for the three groups.

3.2. Kinematic variables

The preoperative knee flexion peak values at swing were lower in the B-UKR group than in either the H-UKR ($P < 0.01$) or P-UKR group ($P < 0.05$) (knee flexion at PRE: $F_{(2,35)} = 8.34$; $\hat{\eta}_p^2 = 0.33$). Preoperative ROM was significantly lower in the B-UKR group than in the H-UKR group ($P < 0.01$) (knee ROM at PRE: $F_{(2,35)} = 5.57$; $\hat{\eta}_p^2 = 0.24$). Comparison of preoperative and postoperative parameters showed postoperative improvements in knee ROM ($P < 0.05$ and ES = 0.89) and knee flexion peak values at swing ($P < 0.05$ and ES = 0.94) in the B-UKR group, as well as an increased knee extension peak value at mid-stance after surgery ($P < 0.05$ and ES = 0.70). Hip abduction peak value was decreased after surgery only in the B-UKR group ($P < 0.001$ and ES = 1.16). Comparison of preoperative and postoperative data showed no differences in any kinematic variables for the H-UKR and P-UKR groups. A significant postoperative difference in the hip abduction peak value was noted only between the B-UKR and P-UKR groups ($P < 0.05$) (hip abduction at POST: $F_{(2,35)} = 4.28$; $\hat{\eta}_p^2 = 0.19$). Table 3 presents the results of mixed ANOVA for all kinematic parameters, and Figure 2 displays the means ± SD of knee ROM and hip abduction for the B-UKR, H-UKR, and P-UKR groups.

4. Discussion

The most important finding of the present study was that simultaneous bilateral UKR improved several spatiotemporal and kinematic variables; unilateral UKR in a setting of bilateral OA did not change any parameter of gait. Postoperatively, the B-UKR group alone of the three showed a clear improvement in gait cadence, gait speed, stride length, knee peak flexion at swing, and knee ROM, as well as reduced hip abduction during gait. As expected, the patients with bilateral knee OA showed lower gait cadence, gait speed, knee peak flexion, and knee ROM as compared with patients with unilateral disease (B-UKR vs. H-UKR) before surgery. Postoperatively, the patients with unilateral knee OA who underwent UKR (H-UKR group) showed improvement only in greater stride length, while the other variables remained changed. An explanation for this difference is that unilateral OA has a lower impact on gait pattern than bilateral OA; consequently, treating bilateral disease led to greater changes in gait pattern than treating unilateral knee OA. No gait parameters changed after unilateral surgery in patients with bilateral OA (P-UKR group). Even the compensation mechanism of the ipsilateral hip (greater hip abduction during the swing phase to compensate for less knee flexion) was still present after surgery; this compensation mechanism disappeared after surgery in the B-UKR group with the greater knee peak flexion of the replaced knees. Consequently, leaving a knee untreated in a patient with bilateral disease did not modify the gait pattern; this situation is typical of two-stage surgery in the period between knee replacements, in which the residual arthritic knee limits patient function.

Previous studies have evaluated changes in gait variables in patients undergoing different knee replacement procedures for end-stage knee OA. Ro et al. compared 34 female patients that underwent simultaneous or staged bilateral TKR and 42 healthy controls [22]. They reported postoperative improvement in stride length, and consequently in gait speed but not in cadence,

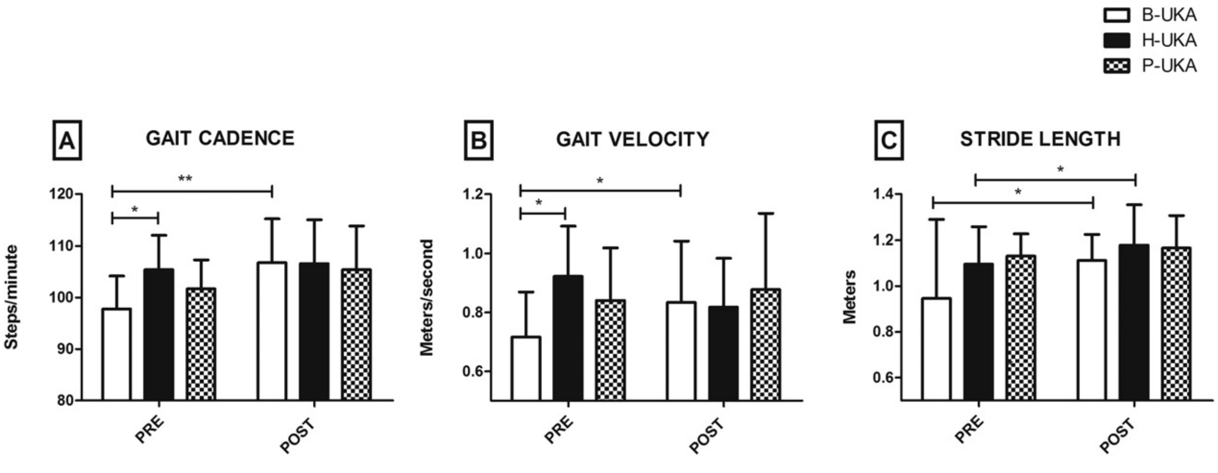

Figure 1. Mean ± standard deviation (SD) of gait cadence (a), gait velocity (b), and stride length (c) parameters for bilateral unicompartmental knee replacement group (B-UKR; n = 13; white histograms), pathological unicompartmental knee replacement group (P-UKR; n = 12; dotted histograms), and healthy unicompartmental knee replacement group (H-UKR; n = 12; black histograms) before (PRE) and after surgery (POST). *$P < 0.05$, **$P < 0.01$.

Table 3
Changes in kinematic parameters for B-UKR, H-UKR, and P-UKR before (PRE) and after surgery (POST).

Gait parameters	PRE			POST						
	B-UKR (N = 13)	H-UKR (N = 12)	P-UKR (N = 12)	B-UKR (N = 13)	H-UKR (N = 12)	P-UKR (N = 12)	Interaction (group × time)	Effect of group	Contrasts	Effect of time
Knee flexion(degrees)	47.1 ± 6.8	56.1 ± 7.1	55.1 ± 4.6	53.2 ± 6.1	54.6 ± 8.0	52.4 ± 8.3	*P* = 0.010	PRE: *P* = 0.001 POST: ns	B-UKA ≠ H-UKA B-UKA ≠ P-UKA	B-UKA: *P* = 0.015 H-UKA: ns P-UKA: ns
Knee extension(degrees)	1.4 ± 6.9	4.5 ± 7.2	7.5 ± 6.3	5.2 ± 3.2	2.4 ± 5.2	4.8 ± 7.1	ns	PRE: ns POST: ns	ns	B-UKA: *P* = 0.041 H-UKA: ns P-UKA: ns
Knee ROM(degrees)	45.7 ± 4.6	51.5 ± 5.6	47.5 ± 3.9	48.0 ± 4.6	52.1 ± 9.2	47.6 ± 6.5	ns	PRE: *P* = 0.007 POST: ns	B-UKA ≠ H-UKA	B-UKA: *P* = 0.033 H-UKA: ns P-UKA: ns
Hip abduction(degrees)	7.8 ± 3.9	5.7 ± 4.1	8.1 ± 3.9	3.7 ± 3.1	6.4 ± 3.7	7.7 ± 2.9	*P* = 0.003	PRE: ns POST: *P* = 0.022	B-UKA ≠ P-UKA	B-UKA: *P* = 0.0006 H-UKA: ns P-UKA: ns

The table presents the results of mixed ANOVA with relative *P*-values for: 1) interaction between group and time; 2) the effect of group with associated contrasts; 3) the effect of time for the three patient groups (Statistical Analysis).
Abbreviations: B-UKR, bilateral-unicompartmental knee replacement; H-UKR, healthy-unicompartmental knee replacement; P-UKR, pathological-unicompartmental knee replacement; ROM, range of motion.
The data are reported as mean ± SD. Ns: no significant differences.

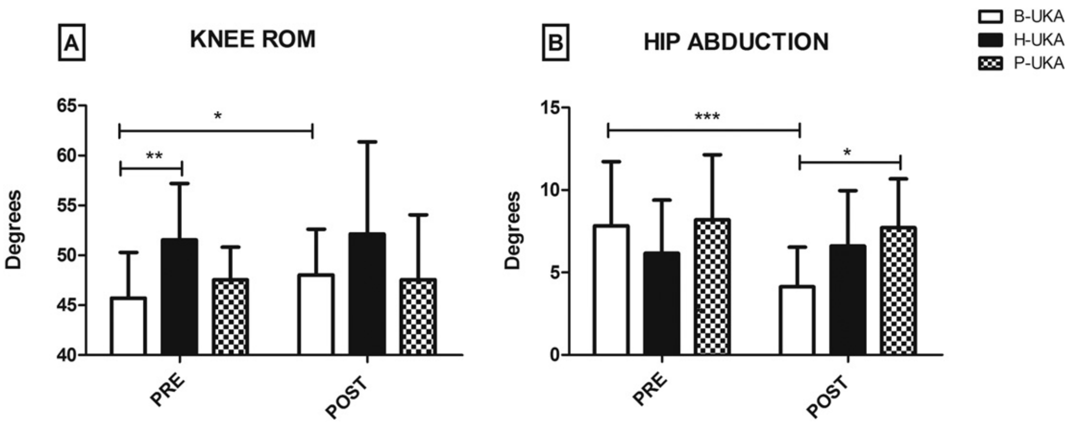

Figure 2. Mean ± standard deviation (SD) of knee range of motion (ROM) (a) and hip abduction (b) for bilateral unicompartmental knee replacement group (B-UKR; n = 13; white histograms), pathological unicompartmental knee replacement group (P-UKR; n = 12; dotted histograms), and healthy unicompartmental knee replacement group (H-UKR; n = 12; black histograms) before (PRE) and after surgery (POST). **P* < 0.05, ***P* < 0.01, ****P* < 0.001.

while knee ROM improved after surgery. However, all postoperative spatiotemporal and kinematic variables remained lower than those noted for the healthy controls. Wiik et al. compared outcome after UKR (n = 23 patients) vs. TKR (n = 23 patients) via gait analysis and found that the maximum walking speed for the UKR patients was 11% faster than that for the TKR patients, in addition to a similar trend for stride length data [23]. Only the UKR group achieved walking speed, cadence, and stride length similar to the healthy controls. The authors concluded that UKR enabled a near-normal gait, whereas TKR did not. In a later study, they evaluated 19 UKR and 14 TKR patients during downhill gait and compared them with 19 healthy controls [24]. They found that the UKR group walked 15% faster than the TKR group, mainly due to a longer stride length. As compared with the control group, both arthroplasty groups had significantly inferior gait speed and step length, but this inferiority was more pronounced in the TKR group. The authors concluded that these differences between UKR and TKR during downhill gait could be explained by better proprioception thanks to preservation of the anterior cruciate ligament in the UKR procedure. A recent meta-analysis of seven studies comparing the gait patterns of patients after UKR and healthy controls during level walking disagreed with this conclusion [25]. The UKR patients and healthy controls showed similar kinematic data in the sagittal plane (knee flexion), whereas cadence, stride length, and walking speed differed significantly between the groups.

To the best of our knowledge, ours is the first study to compare changes in gait analysis variables in patients after bilateral, single-stage UKR and those in two groups of patients who underwent unilateral UKR, one group with bilateral knee OA and one with a healthy contralateral knee. All patients were operated on by the same surgeon, with the same surgical approach and prostheses. The rehabilitation program was the same for all three groups.

The present study had several limitations. First, the relative small simple size; this was mainly due to the difficulty in finding patients who would undergo simultaneous bilateral UKR for bilateral OA with no previous bone surgery to the lower limbs, no unilateral or contralateral hip or ankle OA or arthroplasty, no neurological diseases affecting gait, and, finally, who were willing to undergo preoperative and postoperative gait analysis and clinical examination. Second, the lack of a control group of patients without knee OA; this was a consequence of the retrospective nature of this study that evaluated only patients who underwent knee replacement. Third, we did not create a group of patients with bilateral OA underwent two-stage bilateral UKR. The three groups were collected in a cohort of patients who underwent gait analysis, and an inclusion criterion for being involved in this study was the absence of previous bone surgery in the lower limbs, including any replacement of any joint of the lower limbs. For this reason, we were not able to recruit a fourth group of patients with bilateral OA who underwent two-stage bilateral UKR. Further studies should take into serious consideration this limitation. Fourth, because the patients were all aged 55–75 years, our results cannot be generalized; nonetheless, the study population represents the most common patient subgroup that undergoes bilateral knee replacement.

5. Conclusion

Bilateral knee OA has a considerable impact on gait patterns. In a setting of bilateral knee OA requiring bilateral UKR, simultaneous replacement of both knees appears beneficial whenever possible. Replacing only one knee and leaving the other osteoarthritic one untreated did not improve any spatiotemporal or kinematic gait variables in this patient sample.

Declaration of competing interest

S.R. is a paid consultant for Zimmer Biomet. The other authors report no conflict of interests.

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