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A comparison of gait one year post operation in an RCT of robotic UKA versus traditional Oxford UKA

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ABSTRACT

Robot-assisted unicompartmental knee surgery has been shown to improve the accuracy of implant alignment. However, little research has been conducted to ascertain if this results in a measureable improvement in knee function post operatively and a more normal gait.

The kinematics of 70 OA knees were assessed using motion analysis in an RCT (31 receiving robotic-assisted surgery, and 39 receiving traditional manual surgery) and compared to healthy knees. Statistically significant kinematic differences were seen between the two surgical groups from foot-strike to mid-stance. The robotic-assisted group achieved a higher knee excursion (18.0°, SD 4.9°) compared to the manual group (15.7°, SD 4.1°). There were no significant difference between the healthy group and the robotic assisted group, however there was a significant difference between the healthy group and the manual group ($p < 0.001$). Hence robotically-assisted knee replacement with Mako Restoris Implants appears to lead not only to better implant alignment but also some kinematic benefits to the user during gait.

1. Introduction

Unicompartmental knee arthroplasty (UKA) has been re-emerging as a treatment for medial compartmental osteoarthritis (OA), and a popular alternative to total knee arthroplasty (TKA) when the disease is limited to the medial compartment and the soft-tissues remain intact [1,3,17].

The advantages of this procedure include reduced hospital time, faster recovery, better post-operative range of motion [4,5] and improved gait compared to TKA [36,37]. While UKA popularity waned in the 1980s due to high revision rates [33], current long term data show UKA is surviving into the second decade [18,19]. However performing UKA is technically demanding, and in some cases component malalignment has resulted in poor post-operative function and early revision [6–9].

To aid in component alignment, navigated and robotic-assisted UKA systems have been developed [12–14]. Using robot-assisted surgery the accuracy of implant alignment can be improved [11,15,16,20]. These systems also give the ability to make adjustments in implant placement during the procedure based on soft-tissue tension [10] and to use three dimensional curved implants which are claimed to better match knee joint anatomy and produce better function.

The aim of this study was to determine if the functional performance during gait of patients that have undergone robotic-assisted UKA (MAKO Surgical Corp., Ft Lauderdale, FL, USA) compared to manually implanted UKA (Biomet, Swindon, United Kingdom) showed a measureable improvement during walking in knee function and if the patients were returned to normal knee function post operatively.

2. Methods

2.1. Subjects

A total of 70 knees were assessed for this study taken from a larger randomised group of 129 participants. 31 were in the robotic-assisted UKA group, and 39 in the manual group. UKA surgery was performed at Glasgow Royal Infirmary from 2010 to 2013. Written informed consent was obtained from all patients. Patients were assessed one year post-operatively.

Control group older adult data (n = 50) were obtained from the University of Strathclyde normal archive. The data consisted of 50 typical gait cycles, recorded with the same system and protocol as for the knee RCT and with subjects from the Glasgow area. This data has been previously published [41,42]

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2.2. Test protocol

Three dimensional gait analysis was performed for both robotic-assisted and manual UKA groups. Subjects were asked to walk a total distance of 10 m across the biomechanics lab in order to reach steady speed, and their data were recorded within the middle 5–6 m camera capture measurement volume. The groups were asked to walk at a comfortable self-selected pace three times, during which their gait was recorded.

2.3. Data collection and processing

The subjects underwent their biomechanical gait assessment at the University of Strathclyde Biomedical Engineering Department. Kinematic data were obtained using the Vicon Nexus motion analysis system (Oxford Metrics Ltd. UK) with twelve infra-red cameras, powered by two MX Giganet servers and sampled at 100 Hz. The lower limb biomechanical model used was developed by Papi, [21] in which a combination of marker points and marker clusters were used to determine the anatomical model for each subject [35]. A single well-trained physiotherapist fixed the markers onto the lower limbs according to the protocol. Foot contacts were detected using four force plates (Kistler Instruments AG, Switzerland). The speed for each trial was calculated via the Vicon velocity function, whereby the pelvic segment was used as a reference across the entire length of the measurement volume, checked for irregularities, and averaged.

2.4. Data analysis

Data were extracted using the Vicon Nexus software (Oxford Metrics Ltd., UK) and further processing was performed in Matlab (MathWorks, Natick, MA).

Graphs were generated for each gait cycle, and observed for any errors such as dropout of markers, jumps in data or irregularities caused by mislabelling and if required reprocessed. Marker trajectories were filtered using a Woltring filter (MSE = 15). Each patient performed three walking tasks on their operated side. Each sagittal plane walking cycle was time-normalised from foot strike to foot strike. From these data three values for knee excursion were derived – total knee excursion, excursion from foot-strike to peak mid-stance, and excursion from peak mid-stance to minimum in terminal stance. The three values and the kinematic cycle were averaged for each subject. These same knee excursion values were obtained from the normal data, thus provided a baseline for normal older adult knee behaviour.

2.5. Statistical analysis

Each comparative test was first given an Anderson-Darling (AD) test in order to ascertain if the data were normally distributed. If the data were not normally distributed, the Mann Whitney (U) test was used to analyse any statistical differences. If the data were normally distributed then the comparison used a two tailed independent *t*-test. The alpha level was set at 0.05. The null hypothesis was H0 = no difference between the two groups. This hypothesis was rejected only when $p < 0.05$. Other group differences such as gender differences, knee, and age were evaluated by using the Chi Squared Test.

3. Results

Both patient groups that underwent UKA surgery were significantly younger than the healthy volunteer control group (both groups *p*-value < 0.001), albeit by only six years on average (Table 1). However it is important to note that while the control group was significantly older than the UKA patients, they were given a health screening before taking part and were fit and able. This screening excluded subjects with pain during gait, arthritis, cardiovascular or neurological issues likely

Table 1
Mean participant demographic characteristics of the control group and the two surgical groups. Standard deviations in brackets.

	Control (n = 50)	Robotic-assisted (n = 31)	Manual (n = 39)
Age (years)	70.4 (6.6)	62.7 (7.0)*	64.6 (6.1)*
Gender (m/f)	28/22	19/12	24/15
Operated knee (left/right)	n/a	16/15	26/13
Height (cm)	167.2 (7.0)	168.3 (11.5)	168.8 (8.9)
Body Mass (Kg)	74.1 (12.7)	95.9 (22.4)*	87.9 (16.0)*

* *Significantly different than the control group.*

to affect gait. The subjects were therefore healthier individuals than a typical person of their age and hence their data can be considered a suitable comparison for UKA. They also weighed significantly less than the two surgical groups, however there was no statistically significant difference between the robotic-assisted and manual UKA groups in terms of weight (p = 0.11). The two surgical groups were also not significantly different in terms of height (p = 0.85), operated knee (p = 0.20), gender balance (p = 0.98) and age (p = 0.25). All data in each group were normally distributed, therefore independent *t*-tests could be used for analysis.

Statistically significant differences (Table 2) were seen in the knee joint kinematics during level walking between the robotic-assisted and manual UKA groups (Fig. 1). These differences were between foot-strike and mid-stance where the robotic-assisted group achieved a higher knee excursion (18.0°, SD 4.9°) compared to the manual group (15.7°, SD 4.1°). This difference was statistically significant at a *p*-value of 0.04. When compared to the control group no statistically significant differences were seen in the robotic-assisted UKA group (p = 0.15), however this difference was significant in the manual UKA group ($p < 0.001$). This implies the robotic assisted UKA knees behave normally in this region of the gait cycle whereas the manual UKA group do not.

Neither UKA group managed to achieve comparable levels of knee excursion between mid stance and the minima in terminal stance when compared to the control group (robotic-assisted UKA group p = 0.03, manual UKA group $p < 0.001$). While the robotic-assisted UKA group showed a higher knee excursion in this phase (12.9°, SD 6.1°) compared to the manual UKA group (10.8°, SD 4.7°) this difference was not statistically significant with a *p*-value of 0.11.

Both UKA groups had comparable total knee excursion values when taken over the whole gait cycle and neither were statistically different from the control group.

There were no statistically significant differences seen in the average walking speeds between the surgical groups, or the control group. A marginal correlation between speed and flexion during stance was seen ($R^2 = 0.21$)

4. Discussion

The 1 year post-operative gait data showed that overall the robotic-assisted UKA group had normal knee flexion during loading response whereas the manual UKA group continued to show statistically significant loss of this gait variable post-operatively. From foot-strike to mid-stance on average the robotic UKA group achieved a knee excursion of 18.0° (SD 4.9°) compared to the manual UKA group 15.7° (SD 4.1°). The control group achieved knee excursion values of 19.5° (SD 4.0°) – not significantly different from the robotic-assisted UKA group (*p*-value = 0.15), but significant in the manual UKA group ($p < 0.001$). The literature suggests that 18–20° is the normal range for knee flexion for healthy patients at this stage of gait [22] indicating the robotic-assisted group showed normal knee kinematics during weight acceptance while the manual group did not. Neither group achieved similar knee excursion during push off from mid-stance to