A case-matched series comparing functional outcomes for robotic-assisted unicompartmental knee arthroplasty versus functionally aligned robotic-assisted total knee arthroplasty

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Aims
Unicompartmental knee arthroplasty (UKA) and total knee arthroplasty (TKA) have both been shown to be effective treatments for osteoarthritis (OA) of the knee. Many studies have compared the outcomes of the two treatments, but less so with the use of robotics, or individualized TKA alignment techniques. Functional alignment (FA) is a novel technique for performing a TKA and shares many principles with UKA. Our aim was to compare outcomes from a case-matched series of robotic-assisted UKAs and robotic-assisted TKAs performed using FA.

Methods
From a prospectively collected database between April 2015 and December 2019, patients who underwent a robotic-assisted medial UKA (RA-UKA) were case-matched with patients who had undergone a FA robotic-assisted TKA (RA-TKA) during the same time period. Patients were matched for preoperative BMI, sex, age, and Forgotten Joint Score (FJS). A total of 101 matched pairs were eligible for final review. Postoperatively the groups were then compared for differences in patient-reported outcome measures (PROMs), range of motion (ROM), ability to ascend and descend stairs, and ability to kneel.

Results
Both groups had significant improvements in mean FJS (65.1 points in the TKA group and 65.3 points in the UKA group) and mean Oxford Knee Score (OKS) (20 points in the TKA group and 18.2 in the UKA group) two years following surgery. The UKA group had superior outcomes at three months in the OKS and at one year in ROM (5°), ability to kneel (0.5 points on OKS question), and ascend (1.3 points on OKS question) and descend stairs (0.8 points on OKS question), but these were not greater than the minimal clinically important difference. There were no differences seen in FJS or OKS at one year postoperatively. There were no statistically significant differences between the groups at 24 months in all the variables assessed.

Conclusion
FA-RATKA and RA-UKA are both successful treatments for medial compartmental knee arthritis in this study. The UKA group showed a quicker recovery, but this study demonstrated equivalent two-year outcomes in all outcomes measured including stair ascent and descent, and kneeling.

Take home message
- Excellent results can be achieved with both robotic partial and total knee arthroplasties.
- Partial knee arthroplasties achieve superior outcomes in the early postoperative period.

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- Longer-term outcomes were equivalent between the two procedures.

Introduction

Unicompartmental knee arthroplasty (UKA) and total knee arthroplasty (TKA) are both well-recognized treatments for end-stage medial compartmental arthritis that has failed non-surgical treatment. As the incidence of osteoarthritis (OA) increases, there has been a concomitant rise in rates of knee arthroplasty being undertaken.[1–4] In patients with medial compartment OA, an intact ACL, and no varus thrust, there is a choice to be made between UKA and TKA as the preferred arthroplasty treatment.

That choice is framed by the quicker recovery, lower cost, lower complication rate, and improved function obtained by UKA, and the improved survival of the less technically demanding TKA.[5] With the introduction of robotic-assisted UKA (RA-UKA) there has been early evidence of improved survival and a decreased learning curve.[6] There have also been changes in the use of individualized alignment philosophies in TKA that have shown evidence of potentially improved clinical outcomes compared to mechanical alignment.[7,8] In view of these changes, contemporary information on these factors is paramount, to allow surgeons to make the best decision of the preferred procedure for each individual patient.

Multiple case-controlled studies have been performed comparing UKA and TKA, with UKA shown to achieve higher functional scores in both the short and longer term, as well as an earlier return to work.[9–12] Additionally, both UKA and TKA have similar reoperation rates,[13,14] with early reoperation more common in those undergoing TKA.[5] Venous thromboembolism, cardiac events, and mortality are also higher in those undergoing TKA compared to UKA.[5] However, other studies have shown that patient satisfaction is equivalent following the two procedures.[15–17] RA-UKA improves implant accuracy and, in some studies, functional outcomes when compared to manual UKA.[6,18–22] RA-UKA is also associated with a more rapid recovery than conventional UKA.[23] RA-arthroplasty decreases the soft-tissue damage that occurs,[24,25] leading to improved early outcomes in both UKA and TKA.[26] In addition, TKA outcomes may also be positively affected by individualized alignment techniques.[27,28]

Direct comparison of UKA and TKA cohorts is often difficult due to the innate selection bias present. This study aims to compare clinical outcomes of both robotic-assisted UKA and TKA utilizing the Mako Robotic Arm Interactive Orthopaedic system (Stryker, USA), as well as UKA to a TKA aligned using an individualized (functional alignment (FA)) philosophy. A case-matched protocol has been used to minimize selection bias between the UKA and TKA groups. Our hypothesis was that UKA would result in superior clinical outcomes when compared to a functionally aligned TKA, as the technique better replicates the native knee.

Methods

All patients undergoing a knee arthroplasty under the care of two consultant surgeons (GWC, DC) between April 2015 and December 2019 were consented to participate in a Human Research Ethics Committees-approved prospective clinical registry (Australian New Zealand Clinical Trials Registry (ANZCTR) U1111-1257-2291). Patient demographics, pre- and postoperative clinical and functional outcomes, and intraoperative robotic data were collected. Patients who had undergone a medial RA-UKA were case-matched to patients who underwent a RA-TKA utilizing FA during the same time period. Patients were matched for BMI, sex, age, and preoperative Forgotten Joint Score (FJS).[29] FJS was chosen as a surrogate for disease severity. Patients who underwent TKA were not excluded if they did not meet criteria for a UKA, and hence were not limited to isolated medial compartment OA. Patients who had a primary diagnosis other than OA, patients without complete follow-up, and those who were unable to be matched within required parameters were excluded, leaving 101 case-matched pairs. The patient selection flow diagram is seen in Figure 1.

There were no significant differences between the cohorts for the case-matched variables (Table I). Table II shows the UKA cohort were less severely affected by their OA than the TKA cohort in the non-case-matched criteria assessed, with the Oxford Knee Score (OKS)[30,31] of 26.5 (7 to 44) in the UKA group and 23.4 (7 to 44) in the TKA group.

Surgical technique

All procedures were performed by two experienced arthroplasty surgeons across three hospitals (St John of God Healthcare Subiaco, Midland, and Murdoch hospitals). The TKA group used the Triathlon knee system (Stryker) and all preserved the posterior cruciate ligament using a cruciate-retaining (CR) or cruciate-substituting (CS) poly insert. All patients undergoing TKA had hybrid fixation technique with patella resurfacing (cementless femur and cemented tibia and patella). The Restoris MCK partial knee implant system (Stryker) was used for the UKA group. The TKAs routinely had the patella fat pad excised, whereas it was preserved in the UKA group.

All TKAs were CR robotic-assisted FA (Mako TKA) performed through a medial parapatellar approach with significant fat pad excision. An initial KA plan was adjusted to balance soft-tissues with preferential adjustment of the tibial component.[7] Overall lower limb coronal alignment was limited to between 6° varus and 3° valgus, with soft-tissue releases performed if balance (within 2 mm between the medial and lateral compartments) could not be achieved within these boundaries. Tibial varus was limited to 6°, as was femoral valgus.

The UKAs were performed with preoperative optimal implant positioning for resurfacing the natural joint line, considering the worn cartilage, using the MAKO Planning Software. Intraoperatively, implant positions were adjusted to achieve a balanced 1 mm to 2 mm gap throughout the range of motion (ROM).

Data collection

Patient-reported outcome measures (PROMs) were collected prospectively preoperatively, then at three, 12, and 24 months, and analyzed retrospectively for FJS, OKS, and visual analogue scale (VAS) for pain levels and knee ROM. Data were also collected on the ability to ascend and descend stairs as well as kneel, using questions from the OKS and FJS. These were assessed using a scale of 1 to 5, where 1 represented no difficulty or symptoms and 5 represented inability or severe symptoms; an improvement of more than one point was

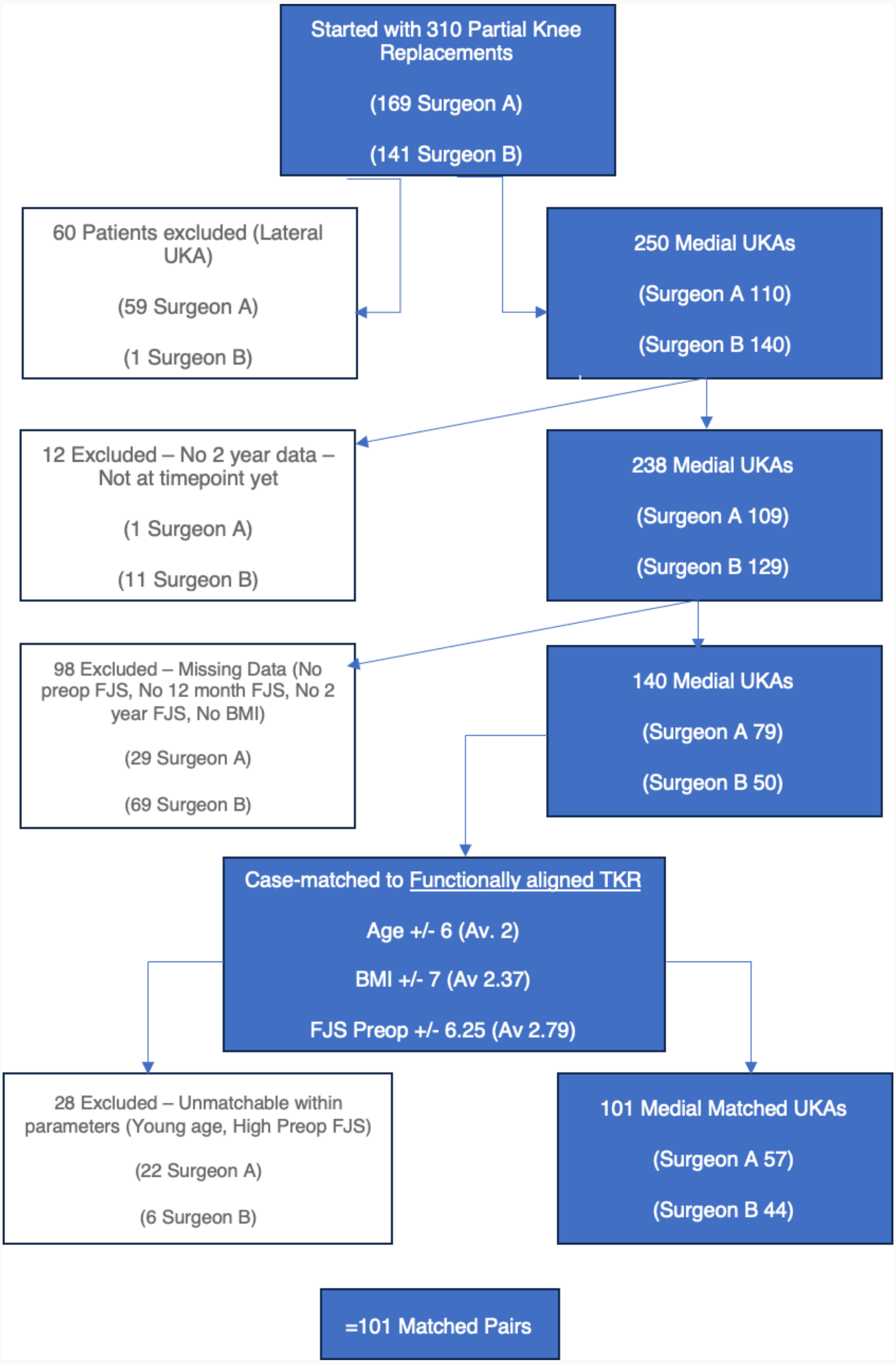

Fig. 1

Patient selection flow diagram. FJS, Forgotten Joint Score; UKA, unicompartmental knee arthroplasty.

considered a positive response. Follow-up for the PROM scores was 89% at three months then 100% at 12 and 24 months.

Statistical analysis

Comparative data were analyzed using the independent-samples *t*-test for numeric and chi-squared for categorical data, with a p-value < 0.05 deemed to be statistically significant.

Results

Table III shows the outcomes for the variables at three months, and one and two years. Two patients (one in each group) had postoperative cellulitis around the tibial pin sites, treated with antibiotics, but there were no revisions or reoperations within either group. The postoperative FJS showed no statistical difference at three months between the UKA and

Table I. Preoperative case-matched variables.

Variable	TKA	UKA	p-value*
Mean age, yrs (range)	64.5 (40 to 84)	64.0 (37 to 84)	0.647
Female sex, n (%)	18 (35.6)	17 (37.6)	0.770
Mean BMI, kg/m² (range)	30 (22 to 40)	29.2 (21 to 43)	0.141
Mean FJS (range)	13.2 (0 to 71)	13.9 (0 to 68.8)	0.763

*Age was compared using the independent-samples *t*-testand sex using z-score.
FJS, Forgotten Joint Score; TKA, total knee arthroplasty; UKA, unicompartmental knee arthroplasty.

Table II. Preoperative non-case-matched variables.

Variable	Preoperative UKA	Preoperative TKA	p-value
Mean Oxford Knee Score (range)	26.5 (7 to 44)*	23.4 (7 to 44)	< 0.001†
Mean VAS pain (range)	60.4 (0 to 100)*	69.7 (13 to 100)	< 0.001†
Mean range of motion, ° (range)	124.4 (108 to 140)*	119.5 (80 to 140)	< 0.001†
Minimal symptoms on kneeling, %‡	1.5*	0.0	0.042§
Minimal symptoms on climbing stairs, %‡	3.0*	0.0	< 0.001‡
Minimal symptoms on descending stairs, %‡	46.6*	19.8	< 0.001§

*Denotes significance.
†Independent-samples *t*-test.
‡Score 1 or 2.
§Chi-squared test.
OKS, Oxford Knee Score; TKA, total knee arthroplasty; UKA, unicompartmental knee arthroplasty; VAS, visual analogue scale.

TKA groups (52.47 vs 45.93; p = 0.143), which was maintained at 12 months (76.14 vs 73.71; p = 0.415) and at 24 months (79.24 vs 78.65; p = 0.858).

UKA patients had a higher mean OKS at the three months post-surgery (40.36 vs 34.48, p ≤ 0.001), but this was not present at 12 months (44.37 vs 43.13, p = 0.079) or at 24 months (44.68 vs 44.47, p = 0.688).

Similar results were seen in VAS for pain with the UKA group having a significantly lower score at three months (15.9 vs 33.0, p ≤ 0.001). There were no differences at 12 months (11.1 vs 14.1, p = 0.276) or at 24 months (12.6 vs 9.5, p = 0.279) between UKA and TKA patients.

Regarding stair climbing and kneeling, the pattern at three months in the three criteria was significantly in favour of the UKA cohort in ascending stairs (47.7% vs 29.4% p = 0.009) and descending stairs (87.5% vs 64.9%, p ≤ 0.001), and kneeling (50.5% vs 28.6%, p = 0.002). At 12 months, ascending stairs favoured the TKA group (31.7% vs 74.2%, p < 0.001), descending stairs favoured the UKA group (99% vs 90.9%, p = 0.021), and the ability to kneel favoured the UKA group (67.3% vs 57.6%, p = 0.008). By 24 months, the two groups showed no significant differences in all three criteria: ascending stairs (79.2% vs 80.2%), descending stairs (97% vs 96%), and kneeling (69.3% vs 66.7%).

Table III. Outcomes postoperatively.

Measure	Timepoint	UKA	TKA	p-value*
Mean FJS (SD)	3 months	52.5 (6.3)	45.9 (5.9)	0.143
	1 year	76.1 (4.5)	73.3 (5.1)	0.415
	2 years	79 (4.7)	78.4 (4.6)	0.799
Mean OKS (SD)	3 months	40.3 (1.3)†	34.5 (1.6)	< 0.001
	1 year	44.4 (0.7)	43.2 (0.9)	0.059
	2 years	44.7 (0.7)	44.4 (0.8)	0.599
Mean VAS (SD)	3 months	15.9 (3.3)†	33.0 (5.6)	< 0.001
	1 year	11.2 (2.9)	14.1 (4.5)	0.276
	2 years	12.6 (4.5)	9.5 (3.5)	0.279
Mean ROM (SD)	3 months	127.8 (1.9)†	123.1 (1.7)	< 0.001
	1 year	130 (1.7)†	126 (1.7)	0.002
	2 years	125 (4.8)	126 (2.7)	0.570

*Independent-samples *t*-test.
†Denotes significance.
OKS, Oxford Knee Score; ROM, range of motion; TKA, total knee arthroplasty; UKA, unicompartmental knee arthroplasty; VAS, visual analogue scale.

Preoperatively, when compared to the UKA group, the patients in the TKA group had slightly decreased ROM (124.43 vs 119.45, p ≤ 0.001). Follow-up in this criterion was more limited (63%), with the TKA cohort continuing to be slightly worse in regard to ROM at three months (127.83 vs 123.04, p ≤ 0.001) and 12 months (129.49 vs 125. 83, p = 0.002). However, by 24 months, there was no difference seen in ROM (125.16 vs 126.51, p = 0.553) between the two groups.

Discussion

This study demonstrates TKA can achieve equivalent clinical outcomes to UKA. Traditionally, UKA has been seen as a procedure that has improved clinical outcomes but at the expense of survival.[14] We found, in keeping with current evidence, that UKA is associated with a shorter recovery and improved function in the first year. However, at 12 months, there was minimal difference between the UKA and TKA groups, and no differences were observed by 24 months in all criteria assessed.

Mikkelsen et al[32] found in a matched cohort of patients with isolated anteromedial OA treated with either TKA or UKA that the improvement in OKS was 16 and 19 points, respectively, thus favouring UKA. Our cohort was not matched radiologically; however, previous studies have shown the mean OKS improvement is 15 points after a TKA in all arthritis patterns.[33] This would indicate anteromedial OA (AMOA) may be a slightly more favourable pattern of arthritis as predictor of postoperative PROMs. It also indicates our TKA cohort may have been disadvantaged by including other arthritis patterns, despite the matching process.

An explanation for superior UKA outcomes in the early postoperative period is likely to be due the shorter incision into the quadriceps tendon (which has been shown to weaken the muscle by 62% following a TKA),[34] less soft-tissue dissection, preservation of both cruciate ligaments, leading to improved proprioception,[35] as well as improved mobility and reduced fatigue levels. RA-TKA has been shown to decrease soft-tissue damage and have a more rapid recovery compared to conventional techniques, with recovery from a RA-TKA exceeding that of conventional TKA.[22,36]

Peersman et al[9] performed a similar study of 57 UKAs and 62 TKAs, but using conventional instrumentation and mechanically aligned TKAs, with case matching for demographics and preoperative FJS to determine the functional outcomes at different timepoints, up to 12 months. They showed a statistically significant higher FJS in the UKA cohort at six and 12 weeks, and six and 12 months. A comparative case-controlled study performed by Hauer et al[10] matched 35 UKAs and 35 TKAs for preoperative PROMs and demographics, finding a statistically significant higher Tegner Activity Scale, ROM, Knee Society Score (KSS) clinical component, and 36-Item Short Form Survey (SF-36) health survey (mental and social components) in the UKA cohort, but no difference in KSS functional component and SF-36 physical component over the TKA group. Our study differs from these with the use of a robotic-assisted FA technique. FA is an individualized alignment technique that maintains joint line obliquity and recreates native limb alignment utilizing soft-tissue balance to guide that final limb alignment, and thus is similar to a UKA in alignment philosophy. The longer follow-up of two years also allows the slower-recovering TKA cohort to reach their full recovery, and may provide a more accurate reflection of long-term function.

The ability to kneel is a growing expectation among patients after a knee arthroplasty.[37] It has been attributed to many factors ranging from fear of damaging the implant through to pain on kneeling. Hassaballa et al[38] reported 58% of patients had extreme difficulty or an inability to kneel at one year following a TKA. Baker et al[39] performed a registry study looking at over 8,000 patients and found that 57% had extreme difficulty or an inability to kneel beyond one year from surgery. Our TKA cohort performed favourably in comparison with 11.1%, reporting extreme difficulty or an inability at two years, although only 18.2% reported no difficulty, suggesting that kneeling remains a problem for patients after TKA. The UKA group performed better, with 8% reporting extreme difficulty or an inability at two years and 26.7% reporting no difficulty, although kneeling was less of a problem preoperatively. Jenkins et al[40] found improvement in kneeling in those patients who had targeted kneeling physiotherapy after a UKA at six weeks. Our study would suggest that while the time to achieve kneeling is longer in the TKA cohort, there is no difference in the final ability to kneel. While the ability to kneel after any arthroplasty is clearly multifactorial, our results would suggest the routine excision of the patella fat pad does not significantly influence kneeling in the long term.

Walsh et al[41] showed patients who have undergone a TKA are 51% slower climbing stairs compared to an age-matched cohort. While this was not assessed in our study, at 24 months, 80.2% of TKA patients and 79.2% of UKA patients stated they were never or were almost never aware of their joint when ascending stairs. A total of 96% of TKAs and 97% of UKAs reported they were never or almost never aware of their joint when descending stairs. This indicates clinically that stairs are not seen as a significant problem in either group following an arthroplasty. These results are better than previously published results for TKA, potentially due to the case matching with UKA selecting a younger, less obese cohort.

While differences in ROM were statistically significant at three and 12 months, it is unclear whether this was clinically significant, with some evidence suggesting the mean clinically important change in ROM is between 3.8° and 6.4°.[42]

Limitations

The limitations of our study include that while patients were matched for age, sex, and BMI, there is an inherent patient selection bias, in that those who underwent TKA were not restricted to medial compartment OA and may not have been eligible for UKA. In the same respect, while patients were matched for severity of disease using the preoperative FJS as a surrogate, the UKA group did have higher OKS, lower pain scores, and better ROM than the TKA group. While our study appears to show in the medium term that FA-RATKA and RA-UKA produce similar clinical results, the long-term survival data of both FA-TKAs and RA-UKAs are not yet known. The number of patients with missing data for ROM at 24 months was significant, and these results should be interpreted with caution. The matching criteria led to approximately one-third of patients being female, which is lower than average in registry data. The study findings cannot be extrapolated to other surgical and alignment techniques for TKA, and will require similar studies to compare these techniques with UKA.

In conclusion, functionally aligned RA-TKA and RA-UKA both produced excellent outcomes for patients with end-stage OA within their respective cohorts in this study. RA-UKA demonstrated quicker return to function levels, with superior results in the first 12 months. The final functional outcome was equivalent between RA-TKA and RA-UKA in every analyzed outcome measure by two years. These findings, in conjunction with other factors such as incidence of complications, speed of recovery, cost, morbidity, and survival, allow clinicians and patients to make more informed decisions regarding the type of arthroplasty they wish to consider.

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Data sharing

The datasets generated and analyzed in the current study are not publicly available due to data protection regulations. Access to data is limited to the researchers who have obtained permission for data processing. Further inquiries can be made to the corresponding author.

Ethical review statement

All patients were included in the Australian New Zealand Clinical Trials Registry (ANZCTR).

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