Novel Algorithm for Gap Balancing and Bone Cuts in Robotic Total Knee Replacements significantly improves Accuracy and Surgical Duration

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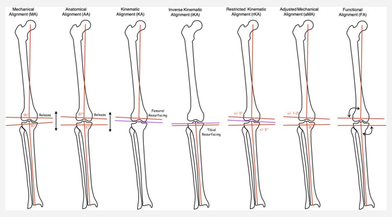
Introduction

- **Robotic total knee replacements (rTKR)** has been gaining in popularity over the past few years, with better implant positioning and superior mechanical and anatomical alignment while having similar clinical and functional outcomes (1,2).

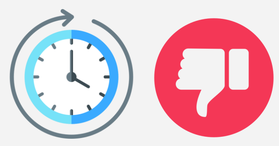
- Regardless of which robotic system is used, there will always a **planning step** during the rTKR process before actual bone cuts are made, where the surgeon needs to **manually input** a set of parameters to position the femoral and tibial implants with the knee in at least 0 and 90 degrees (3).

- The aim of the planning step is to achieve a result that **balances the knee** and **aligns as closely as possible to the surgeon's alignment philosophy**. Currently, there exists numerous alignment philosophies (4), and there is no clear consensus on which is the superior philosophy to use (5).



- Since the knee implants can be adjusted in so many degrees of freedom, **thousands of unique alignment solutions exist for each rTKR case**, and it is close to impossible for the surgeon to manually run through all possible solutions in a systematic manner to consider which solution best suits their alignment philosophy and personal tolerances.

- Frequently, the surgeon ends up taking an **extended period of time** during the planning step, and settling for a solution that **may not be the most optimal solution** they are looking for.



Aims

- Our team has created a **novel computational algorithm** that can quickly compute the set of parameters that the surgeon can input to achieve the optimal positioning of the implants in three-dimensional space.
- The aim of our study is to demonstrate the effectiveness of utilising this novel algorithm clinically in terms of gap balancing accuracy and surgical duration.

Methodology

Novel algorithm was developed entirely in-house by authors ZQG Liau and MSP Ng

For ease of use within the OT, the algorithm was packaged into a **standalone application with a GUI** that can run on any computer without an internet connection.

Prospective study of 67 consecutive patients who underwent a rTKR at a tertiary institution from November 2021 to December 2023 was performed

- All cases were performed by a total of three arthroplasty surgeons.
- All cases were performed with the ROSA system by Zimmer Biomet.

Algorithm group (n=25)
Algorithm used intra-op

Non-algorithm group (n=42)
Algorithm not used intra-op

Comparison between both groups

Primary outcomes

- Proportion of rTKR cases whose final gaps were within ±1.5mm of the surgeon-defined target gaps
- Average deviation (mm) from the surgeon-defined target gaps

Secondary outcomes

- Average gap balancing duration (mins)
- Average total surgical duration (mins)

Statistical analysis

All demographic and outcome variables

→ Discontinuous (proportion of rTKA cases): **Chi-square** test

→ Continuous (deviation from target gaps, surgical duration): Parametric **T-test**

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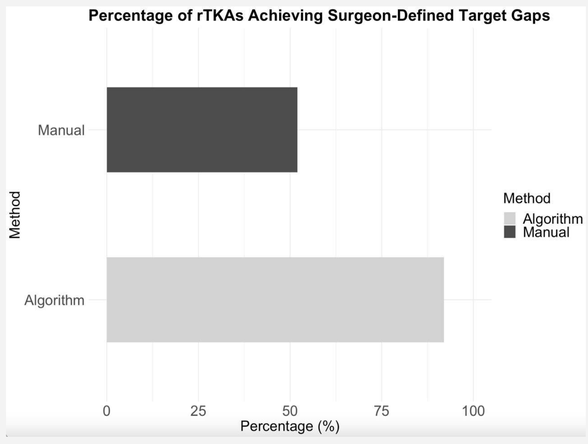
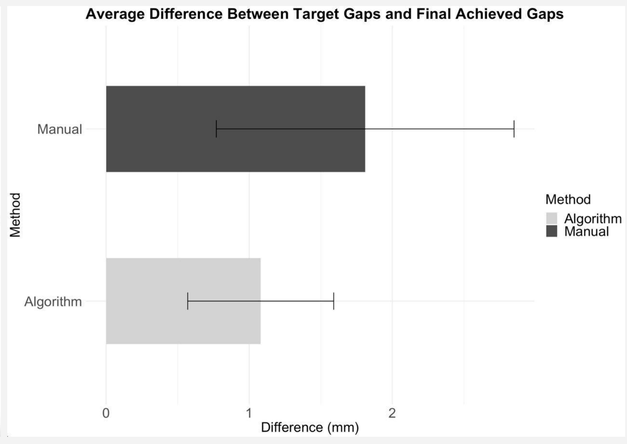
Results

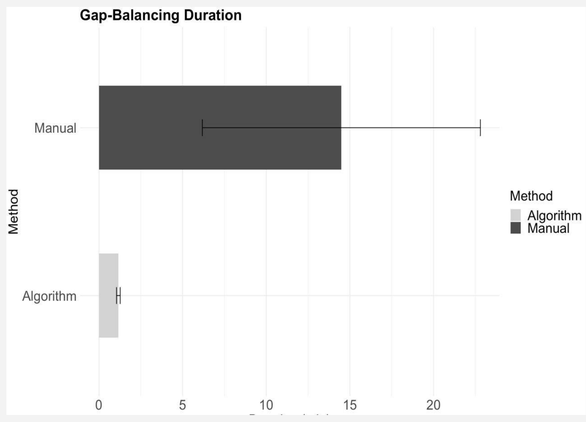
	Algorithm	Non-Algorithm	P-Value
Demographic variables			
Age (y)	70.4 years ±7.3	70.5 years ± 6.9	0.6
Male (%)	44.0%	42.9%	0.8
Primary outcomes			
Gap-Balancing Accuracy (%)	92%	52%	**< 0.003**
Average Difference between Target and Final Gaps (mm)	1.08mm±0.51	1.81mm±1.04	**0.003**
Secondary outcomes			
Gap-Balancing Duration (min)	1.16min ±0.11	14.49min ±8.31	**< 0.0001**
Surgical Duration (min)	38.4min ±14.94	73.66min ±19.61	**0.0002**

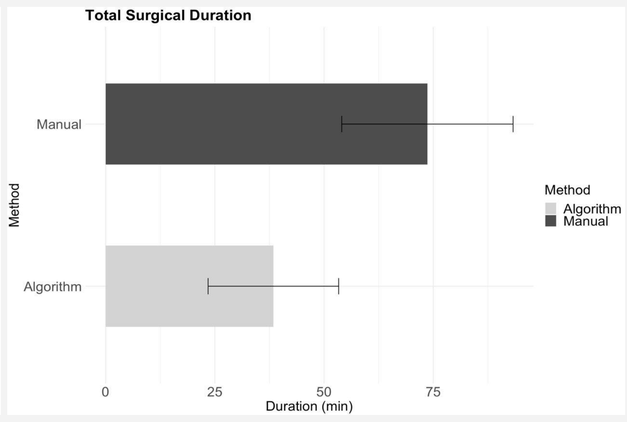
* Statistical significance was taken with p less than .05

- **Greater proportion (92%)** of rTKRs achieved the surgeon-defined target gaps of ±1.5mm for the algorithm group (P = .003).
- **Smaller average difference** between the surgeon-defined target gaps and the final achieved gaps for the algorithm group (P = .003).
- **Shorter gap-balancing duration** for the algorithm group (P < .0001).
- **Shorter total surgical duration** for the algorithm group (P = .0002).









Discussion

Our study represents the **first clinical study** that has evaluated the effect of a rTKR algorithm in knee balancing

Only one other study by Young et al presents the use of a computerised algorithm that can rapidly generation and ranking of thousands of possible solutions for positioning rTKR implants (6). Limitations of their study are that:

- It was performed **virtually and not clinically**, based on values obtained from a primary TKR database
- It relies on a mathematical gap calculation method with **no clinical confirmation** that each solution provided by the algorithm would provide 'balance' after a TKA was implanted.
- It **did not evaluate** if there was an increase in accuracy or a reduction in surgical duration using their algorithm.
- It can only be used on the MAKO robotic TKR system

Limitations

Different surgeons involved - the rTKAs in this study were not performed by a single surgeon, but by three surgeons. However, it is worth noting that all surgeons are board-certified arthroplasty surgeons who are well-versed in the ROSA Knee system.

Study method - this a prospective consecutive series instead of a randomised controlled trial, which increases the risk of selection bias. However, while the surgeons knew they were participating in our research study, they were purposefully blinded towards the aims of the study, hence reducing the risk of selection bias that could occur

Conclusion

- Our **novel computerised algorithm** for gap-balancing in rTKRs represents the first clinically applied algorithmic way of **improving the accuracy** of achieving the surgeon's target extension and flexion gaps significantly.
- It also **reduces the duration** needed for gap balancing and reduces the overall surgical duration.
- This is the **first study** that demonstrates the usefulness of such an algorithm in terms of achieving both reproducibility and efficiency in rTKRs.