Robotic-arm assisted total knee arthroplasty demonstrated greater accuracy to plan compared to manual technique

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Introduction

- Total knee arthroplasty (TKA) has demonstrated clinical success[1,2], however component alignment found mechanical axis malalignment of greater than 3° in 9.0% of computer-assisted and 31.8% of conventional TKA surgeries[3].
- Primary study aim: Determine whether robotic-arm assisted total knee arthroplasty(RATKA) allows for accurate final bone cuts and final component position to plan, compared to manual total knee arthroplasty (MTKA).
- Secondary study aim: Investigate whether RATKA allows an experienced user of MTKA, who is inexperienced in RATKA, to make final bone cuts and final implant positions accurate to plan.

Materials and methods

- Sample Size: 6 cadaveric specimens (12 knees) prepared by single surgeon.
- RATKA performed on the right leg and MTKA performed on the left leg for n=6.
- Fiducial clusters assembled to femoral and tibial bones.
- Preop CTs segmented to create 3D plans with TKA component positional targets relative to fiducial clusters.
- NDI Polaris optical tracking system and navigated probe were used to measure final bone cut and final component position relative to the fiducials:Final bone cut to plan
  = final bone cut error
  = bone registration error
  + bone cut error
  - **Final component position to plan**
  = implant and cementation error
  + final bone cut error
- Implants modified to accept measurement probe **(Figure 1)**.
- Means and standard deviations for each final measurement were compared between RATKA and MTKA for each planar bone cut and component position in the sagittal, coronal, and axial planes.
- Measurements were made as the absolute deviation from plan, where:
  - **Accuracy = Mean Value of Measurements**
  - **Precision - Standard Deviation if Measurements**

- Average RATKA/MTKA error ratio was calculated for final bone cut (FBC) and final component position (FCP) to plan to compare overall accuracy and precision between RATKA and MTKA.

$$\frac{1}{12}\sum_{x\in 12\ FBC} f(x) \text{ and } \frac{1}{5}\sum_{x\in 5\ FCP} f(x),$$

$$\text{where } f(x) = \frac{Mean\ MTKA_{n=6}}{Mean\ RATKA_{n=6}}, \text{ or } f(x), = \frac{St.\ Dev.\ MTKA_{n=6}}{St.\ Dev\ RATKA_{n=6}}$$

- **Statistical Analysis:** Individual and Moving Range (I/MR) graphs were used to assess and compare the mean location of the two methods. Two-Variance assessment using Levene's test was performed with alpha=0.05 to evaluate for significant differences between the precision of the two methods.

Fig. 1
Navigated probe and example measurements of bone resection (shown for anterior chamfer cut on femur).

For measurements of component position, the femoral component was modified with posterior flats.

Results

Accuracy

- Comparing the means for all six matched pairs (n=6), RATKA final bone cuts and final component positions were as or more accurate to plan than MTKA control, for 11/12 and 5/5 measurements, respectively, and all (17/17) measurements when comparing the last three matched pairs(n=3).
- On average, RATKA (n=6) final bone cuts and final component positions were 4.2 and 3.2 times more accurate to plan than the MTKA control, respectively.

Precision

- Comparing the standard deviations for all six matched pairs (n=6), RATKA final bone resections and final component positons were as or more precise to plan than the MTKA control on all femoral and tibial V/V measurements, and all measurements when comparing the last three matched pairs (n=3).
- On average, RATKA (n=6) final bone cuts and final component positions were 5.0 and 3.1 times more precise to plan than the MTKA control, respectively.

Discussion

- RATKA demonstrated greater accuracy and precision of final bone cuts and final component placement to plan, compared to MTKA in this cadaveric study.
- Further, RATKA has the potential to increase both the accuracy and precision of bone cuts and implant positioning to plan for an experienced manual surgeon who is new to RATKA.
- Errors in tibial slope are attributed to the learning curve for tibial bone registration due to the surgeon's inexperience in RATKA, since the greatest deviation from plan for tibial slope cut and implant position occurred in the first two RATKA cases.
- For further confirmation, RATKA accuracy of component placement should be investigated in a clinical setting.

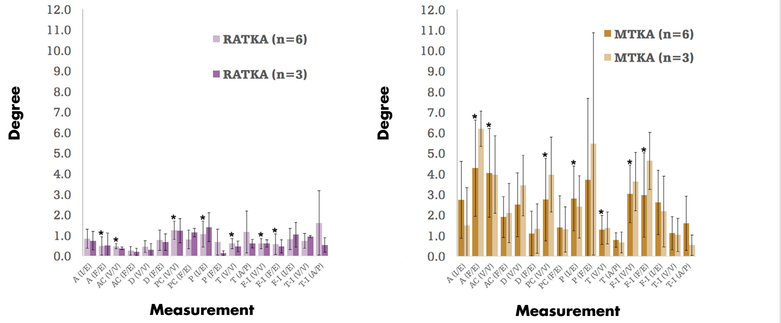

Fig. 2
Comparison of RATKA and MTKA mean cuts and implant position to plan for all 6 matched pairs (n=6) and last 3 matched pairs (n=3). For final bone cut to plan, on the femur, A=Anterior, AC=Anterior Chamfer, D=Distal, PC=Posterior Chamfer, and P=Posterior, and on the tibia, T=Tibia. For final component position to plan, F-I=Femoral Implant, T-I=Tibial Implant, V/V=Varus or Valgus, F/E=Flexion or Extension, I/E=Internal or External, and A/P=Anterior or Posterior slope. Error bars represent standard deviation. *Indicates a significant difference between RATKA and MTKA for n=6, with RATKA having less variance.

Significance

RATKA has the potential to increase the accuracy of TKA bone cuts and component placement to plan, even for an experienced user of manual instrumentation who is new to robotic technology.

Reference:
1. National Joint Registry (NJR) for England, Wales, Northern Ireland and the Isle of Man. 13th Annual Report. Available at: http://www.njrreports.org.uk/. Accessed Dec. 10, 2016.
2. Julio J., et al. J Arthroplasty. 2015. 30(12): p. 2164-6.
3. Mason J., et al. J Arthroplasty. 2007. 22(8): p. 1097-1106.

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