EPiC Series in Health Sciences

Volume 4, 2020, Pages 246–249

CAOS 2020. The 20th Annual Meeting of the International Society for Computer Assisted Orthopaedic Surgery

Post Operative Analysis of a Novel Application of Surgical Navigation

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Abstract

A cohort of 84 patients underwent Total Knee Replacement surgery using Patient Specific Instrumentation fitted with an optical tracker that was monitored by a Computer Assisted Surgery system. The CAS system was low cost with small footprint in the operating theatre. The hip centre was collected and four other landmarks were recorded as rotational measures. The CAS system then reported the deviation in PSI placement against the targeted PSI placement, the surgeon then made a judgement whether to replace the guide. Post-operative analysis was done to determine the achieved alignment of the component and compared to the targeted alignment. From 45 results available for analysis the study found that the mean of rotational measures over the femur and tibia were found to be within ±3º of the targeted alignment, except for femur sagittal alignment. When a single outlier was removed from the femur sagittal alignment measures, the mean fell below ±3º of the targeted alignment. Distal femoral condyle resection measures fell below a mean of 1mm and posterior femoral condyle measures fell below a mean of 2mm. Lateral proximal tibial resection fell below a mean of 2.5mm as did medial proximal tibial resection when two outliers were removed. This shows that a CAS system incorporating the low cost, quicker time, and smaller footprint benefits of PSI with the accuracy of traditional navigation may be a feasible device.

1 Introduction

The final alignment of the component in Total Knee Arthroplasty (TKA) affects the post-operative patient outcome as it determines post-operative knee kinematics (Harman, 2012) (Werner, 2005) (Huang, 2012). Use of Computer-Assisted Surgery (CAS) in surgery exhibits a growing trend in orthopaedics due to a variety of factors. Navigation has been shown to achieve a significantly more accurate coronal alignment for the femur and more accurate coronal and sagittal alignment for the tibia when a neutral (mechanical) alignment is targeted (Cip J., 2014). However, computer assisted navigation is expensive, increases intraoperative theatre time, increases the surgical kit required, and decreases space available inside the operating theatre.

Patient Specific Instrumentation (PSI) has been used to achieve a targeted component alignment with mixed results (Sasson, 2015). Common arguments made for the use of PSI in surgery claim ease of use, reduction in surgical kit, and pre-operative determination of implant sizing and resection targets all result in decreased surgical time and cost (Sasson, 2015). The reduction in medical costs due to the decreased number of surgical trays, associated processing time, and associated logistical cost does seem to be borne out by the use of PSI to achieve a targeted resection (Nunley RM, 2012). PSI is not a more accurate technique than standard instrumentation when targeting a mechanical alignment. However, it has been shown that PSI usage reduces the frequency of outliers ±3º from mechanical alignment (Boonen B, 2012) (Daniilidis K, 2014) (Ng VY, 2012).

Here, we will present a novel use of PSI in conjunction with an ultra low-cost optical tracking CAS device (360CAS) that delivers an alignment within the accuracy envelope achieved by conventional CAS while still benefitting from the cost reductions associated with the use of the PSI.

2 Methods

A cohort of 84 patients underwent TKA surgery between March-2019 to October-2019. These patients were operated on by two surgeons and received a pre-operative and post-operative CT. The pre-operative CT was segmented, and the resulting 3D bone model was used to construct a PSI guide that targeted a mechanical alignment for that patient. An optical tracker with an accuracy of under 1mm and under 0.05º was attached to the PSI in order to track the position of the device. The optical tracker used reports its location 90 times per second to a computer, another tool with two optical trackers attached was used for landmarking.

Intraoperatively, the PSI with the tracker attached was placed onto the femur and secured in place with surgical pins. The patients hip centre was calculated by recording the movement of the tracker through circumduction of the patient's leg, the posterior condyles and TEA were also recorded as a rotational reference.

The 360CAS device then reported the deviation of the PSI placement in terms of sagittal, coronal, and transverse rotation and translation from the targeted placement. The surgeon then made a judgement as to whether the PSI should be repositioned. Femur resections then proceeded as normal and the process was repeated for the tibia.

Postoperatively, the patient underwent a second CT which was segmented and registered in order to find the achieved component alignment. This post-operative report was compared to the pre-operative report used to generate the PSI guide and the results were analysed.

3 Results

A total of 84 patients underwent the procedure, however only 45 patients had post-operative results ready for analysis.

The difference between the post-operative and pre-operative results was found for the following anatomical measurements:

- Distal lateral femoral condyle resection depth
- Distal medial femoral condyle resection depth
- Posterior medial femoral condyle resection depth
- Posterior lateral femoral condyle resection depth
- Femur sagittal alignment (flexion-extension)
- Femur coronal alignment (varus-valgus)
- Femur transverse alignment (internal-external)
- Proximal tibial lateral resection
- Proximal tibial medial resection
- Tibial sagittal alignment (slope)
- Tibial coronal alignment

Although the sample size is small, a power analysis indicates that the trial size was sufficient to show that if our device performed meaningfully worse than other systems, this would appear in the data. Using the data collected an analysis to determine if the results were meaningfully different from the ±3º degree outlier variation given from previous PSI studies (Boonen B, 2012) (Daniilidis K, 2014) (Ng VY, 2012).

The mean of rotational measures over the femur and tibia were found to be within ±3º of the targeted alignment, except for femur sagittal alignment. When a single outlier was removed from the femur sagittal alignment measures, the mean fell below ±3º of the targeted alignment. Distal femoral condyle resection measures fell below a mean of 1mm and posterior femoral condyle measures fell below a mean of 2mm. Lateral proximal tibial resection fell below a mean of 2.5mm as did medial proximal tibial resection when two outliers were removed.

4 Discussion

This cohort of patients shows that accuracy between the pre- and post- operative alignments can fall within that delivered by conventional CAS systems. The results however do not take into account deviations from the pre-operative plan that the surgeon may have instituted.

A high economic burden healthcare system will apply increasing pressure to public and private budgets over the coming generations as the effect of an ageing population and declining workforce

become more keenly felt. High capital systems will also come under pressure to prove their effectiveness justifies the investment (Maniadakis N., 2000).

High cost systems that utilise a patient specific registration have been shown to have some benefit for postoperative function (Sires J. D., 2020), however low-cost systems that hybridize the most functional elements of surgical technologies may become more necessary in the future.

5 Conclusion

This study has shown that it is feasible to combine the benefits of low instrument and cost footprint evident in PSI based surgical approached with the accuracy of a CAS system.

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