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Clinical Variability of Landmark Collection in an Imageless Robot-Assisted Total Knee Arthroplasty System

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Abstract

Use of computer-assisted Total Knee Arthroplasty systems enable more accurate implant placement, better tissue balancing and improved leg alignment. Image-free computer-assisted TKA systems rely on accurate identification of femoral and tibial landmarks to guide the implant planning process. Previously, researchers have studies the variability in collection of these landmark positions and the impact of this variability on the final implant position. Here, for the first time, we present a study assessing the variability of seven landmarks during anonymized clinical cases. Of all the landmarks, we found that there was maximum variability in collection of the femoral anterior notch point.

1 Introduction

Total Knee Arthroplasty (TKA) is one of the most commonly performed orthopedic procedures used to replace parts of the knee joint with prostheses. Computer-assisted systems in TKA enable better outcomes through more accurate implant placement, improved tissue balancing and better mechanical axis alignment [1]. Image-free computer-assisted TKA systems rely on accurate identification of various femoral and tibial landmarks to guide the implant placement. Previously, researchers evaluated the impact of errors in landmark collection on the accuracy of implant placement. Brin et al. evaluated the impact of errors in the tibial mechanical entry point on the accuracy of the final tibial cuts for 70 saw bones [2]. Robinson et al. also carried out a study in virtual space and found that certain anatomic landmarks used in total knee arthroplasty are not reliable [3]. Here, for the first time, we present the variability of landmark collection in anonymized clinical cases when using the Navio robotically-assisted TKA system.

2 Materials and Methods

In this study, we used anonymized data collected over the course of 100 clinical cases performed by 6 surgeons. During a TKA case, the surgeon was instructed to collect four landmark points near the distal section of the femur and three landmark points at the proximal end of the tibia. The four femoral landmark points are: a) the femoral anterior notch point; b) the femoral knee center; c) the medial posterior condyle point; and d) the lateral posterior condyle point. The four tibial landmark points are: a) the tibial knee center; b) the lowest point on the medial tibial plateau; and c) the lowest point on the lateral tibial plateau. These landmark points guide generation of a patient-specific bone model and planning of implant placement. For each landmark point, the closest vertex on the patient-specific bone model was identified. Then, the corresponding vertex on the mean bone model was highlighted for visualizing the variability of landmark collection. We acknowledge that the patient-specific bone models vary in shape and size from the mean bone models. However, identifying the landmarks on the mean model allow us to visually assess the variability of the landmark collection using a common model. The mean vertex for each landmark was then found. Then, the Euclidean distance, on the patient-specific bone, of each landmark from the corresponding mean landmark vertex was computed.

3 Results

The distances of the landmark points from the mean landmark position are presented in Table 1. The visualization of the variability of the landmark collections is shown in Figure 1.

Landmark	Mean	Median	Standard deviation	Minimum	Maximum
Anterior notch point	9.25	7.34	6.55	1.00	37.32
Femoral knee center	3.77	3.48	2.36	0.51	12.49
Medial posterior condyle	6.54	5.98	3.82	0.32	19.07
Lateral posterior condyle	6.47	5.65	3.83	0.24	22.07
Tibial knee center	5.18	4.56	2.95	0.47	20.14
Medial low point	4.22	3.56	2.67	0.26	14.48
Lateral low point	5.81	5.13	3.66	0.69	18.70

Table 1: The distances (in mm) of each landmark point from the vertex of the mean landmark position.

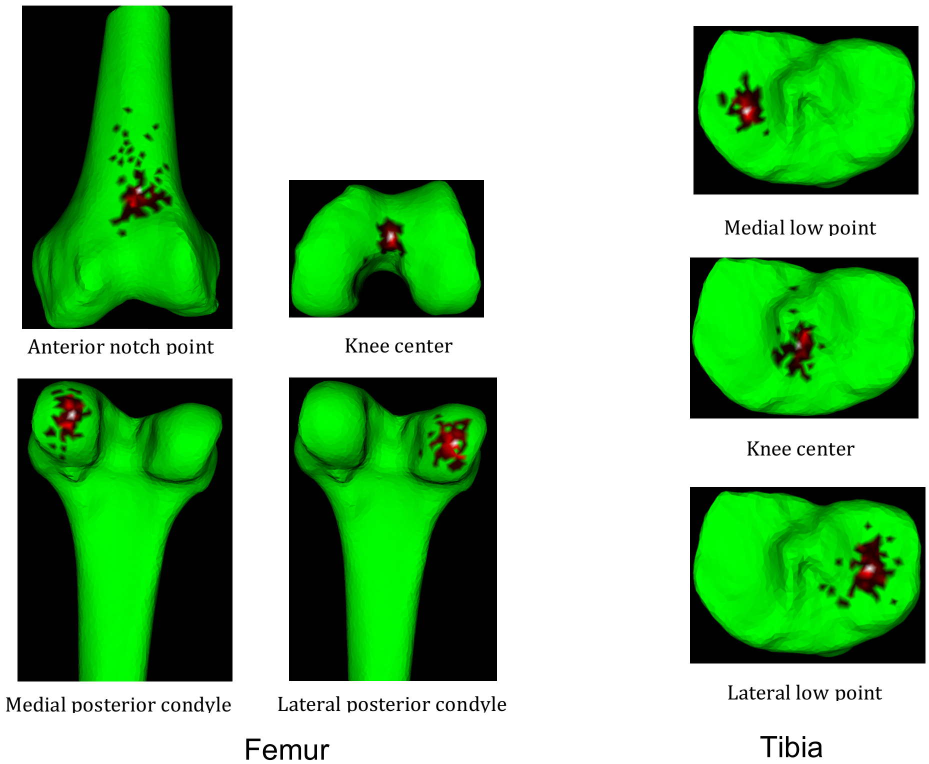

Figure 1: Distribution of landmark point collected from the femur and tibia for multiple clinical cases by multiple surgeons. Brighter red regions indicate higher density of collection and the darker regions indicate lower density. The white point is the vertex of the mean landmark position.

4 Discussion

Previous work has shown that collection of landmark point potentially has high inter-user variability [3]. Other researchers have also evaluated the impact of errors in collection of landmark points on the final implant placement [2]. Here, we use the Navio robotics-assisted TKA system. This system relies on articular bone surfaces mapped during the TKA procedure. The various landmarks that are collected serve as bone-region extremity markers to assist in the implant planning.

This study shows a large variability in selecting the anatomic location of key landmarks. Relying exclusively on user-selected discrete landmarks may be misleading and may result in suboptimal selection and placement of components. Even though the Navio system does not rely on individual points for planning the implant placement, poorly placed landmarks could potentially affect the initial implant placement. Our results show that the seven landmark points in increasing order of variability are as follows: 1) femoral knee center, 2) tibial medial low point, 3) tibial knee center, 4) tibial lateral low point, 5) femoral medial posterior condyle point, 6) femoral lateral posterior condyle point, 7) femoral anterior notch point. We also observe a large number of outliers present in case of the anterior notch point. Either use of guidance regions or fully automated algorithms for landmark estimation can help reduce the variability in collection of these landmarks.

5 References

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