ACCURACY AND INTER-USER VARIABILITY OF UKR COMPONENT VARUS/VALGUS MEASUREMENTS USING SIMULATED LONG STANDING AP RADIOGRAPHS

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INTRODUCTION

Uni-compartmental Knee Replacement (UKR) is an orthopaedic surgical procedure to reduce pain and improve function in the knee [1]. Postoperative radiological assessment of the implant alignment is an important predictor of the success of the procedure. Load bearing long-standing anterior-posterior (AP) radiographs are typically used postoperatively to measure the leg alignment and assess the varus/valgus implant orientation. In this assessment, errors arise due to using 2D measurements to make 3D alignment evaluations. These errors are aggravated when the implants have out-of-plane rotations. Inter-user variability and variations in x-ray acquisition parameters also contribute to errors in this assessment. Previously, Lonner et al. and Radtke et al. studied the effect of foot rotation and knee flexion on assessment of knee alignment in total knee arthroplasty [2,3]. However, we are not aware of any previous work on effect of x-ray acquisition parameters and varying implant orientations on the accuracy of implant varus/valgus measurements using AP long-standing x-rays. In this paper, we present work to evaluate inter-user variability in assessment of implant varus/valgus angles when using long-standing AP x-ray measurements under varying implant out-of-plane rotations, and variations in the x-ray acquisition process.

MATERIALS AND METHODS

For evaluating the measurement error in varus/valgus angle, we used a hip-toe computed tomography (CT) image of a cadaver. This CT data was then processed so that it could be imported into the Navio system [4]. The validated Navio planning software was then used to determine the implant sizes and position them under varying orientations (12 orientations for the tibial and femoral implant) in the CT volume. Thus, for each CT image, the implant sizing and the transformations associated with positioning the implants in the CT volume, were obtained. The hip center, femoral knee center, tibial knee center, and medial and lateral malleolus points used by the planning system to define the anatomical axes were also noted down. Subsequently, a software application developed using the VTK and ITK libraries was used to position 3D surface models of the femoral and tibial implants in the CT volume. The "RayCastInterpolateImageFunction" filter from the ITK library was then used to vary the projection center and obtain two long-standing digitally reconstructed radiographs (DRRs) from the CT volume for each implant orientation (Fig. 1) [5]. The landmark points that were noted down earlier, were also projected using the same x-ray acquisition parameters and their positions in the DRRs were obtained. The orientations of the implants were marked in the 3D CT volume and this volume was also projected to obtain DRRs that were used to measure "best-case" ideal measurements [6]. Two users were asked to mark the implant orientations in all the DRRs. All the user-identified and best-case measurements were then used along with the landmark points in the DRRs to calculate the implant component varus/valgus angles. All these calculated component varus/valgus angles were compared with the actual angles to obtain the errors.

RESULTS

We obtained the following overall rms measurement errors in implant varus/valgus angle: 1) "best-case": 0.77 degrees; 2) user 1: 4.68 degrees; and 3) user 2 error: 3.59 degrees. All these measurement errors are summarized in the plot shown in Fig. 2. The user measurement errors were inconsistent and varied (std: 3.03 and 2.13, respectively). Measurement error was slightly lower (0.70 degrees versus 0.82 degrees) when using projection center between the knees as compared to being at the center of the operative knee. Variation of 20 degrees of external rotation brought about up to 1.37 degree change in varus angle measurement for femur and up to 0.8 degrees for tibia. Five degrees of variation in flexion led to up to 0.6 degrees of variation in measured varus angle in case of tibia and only up to 0.2 degrees of variation in case of femur.

CONCLUSIONS

Our results indicate that manual measurements of implant orientation from long-standing AP x-rays are very unreliable. As expected, variations in femoral implant external rotation and tibial flexion lead to large changes in the measured component varus/valgus angles.

REFERENCES

[1] Kozinn SC, Scott RD. "Surgical treatment of unicompartmental degenerative arthritis of the knee." Rheum Dis Clin North Am.;14:545–564, 1988.

[2] Lonner JH, Laird MT, Stuchin SA. "Effect of rotation and knee flexion on radiographic alignment in total knee arthroplasties." Clin Orthop Relat Res.;(331):102-6, Oct 1996.

[3] Radtke K, Becher C, Noll Y, Ostermeier S. "Effect of limb rotation on radiographic alignment in total knee arthroplasties."Arch Orthop Trauma Surg.;130(4):451-7, Apr. 2010.

[4] Jaramaz B, Nikou C. Precision freehand sculpting for unicondylar knee replacement: design and experimental validation. *Biomedical Engineering/ Biomedizinische Technik*, Vol 57, Issue 4, 293–299. 2012.

[5] Ibáñez L., Schroeder W., Ng L., Cates J., Consortium T.I.S., Hamming R., "The ITK Software Guide," Kitware, Inc., Jan-2003.

[6] de Chaumont, F. et al., "Icy: an open bioimage informatics platform for extended reproducible research," Nature Methods, 9, pp. 690-696, 2012.

DISCLOSURES

Both the authors are employees of Blue Belt Technologies.

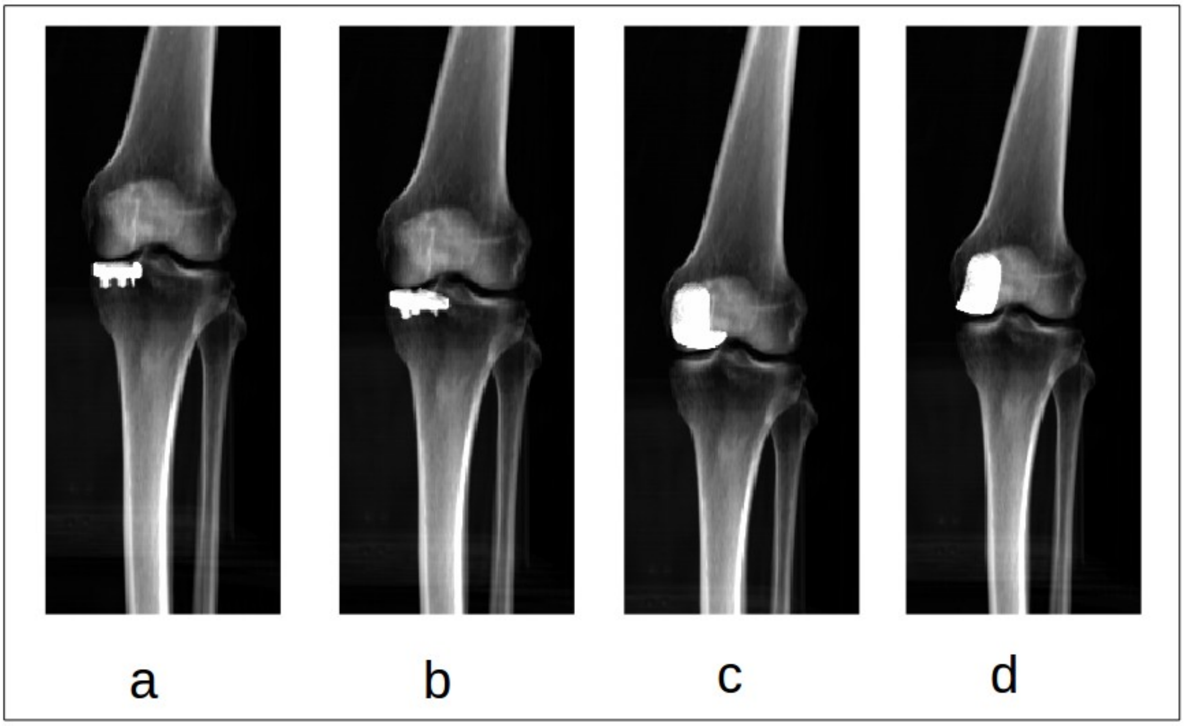

Figure 1: Partial view of DRR obtained for varying implant orientations. (a) and (b) shows the tibial implant under different orientations (0º varus, 5º posterior slope, 2º external rotation; 5º varus, 10º posterior slope, 22º external rotation;). (c) and (d) show the femoral implant under varying orientations (0º varus, 19º external rotation, 23º flexion; 5º varus, 1º internal rotation , 28º flexion).

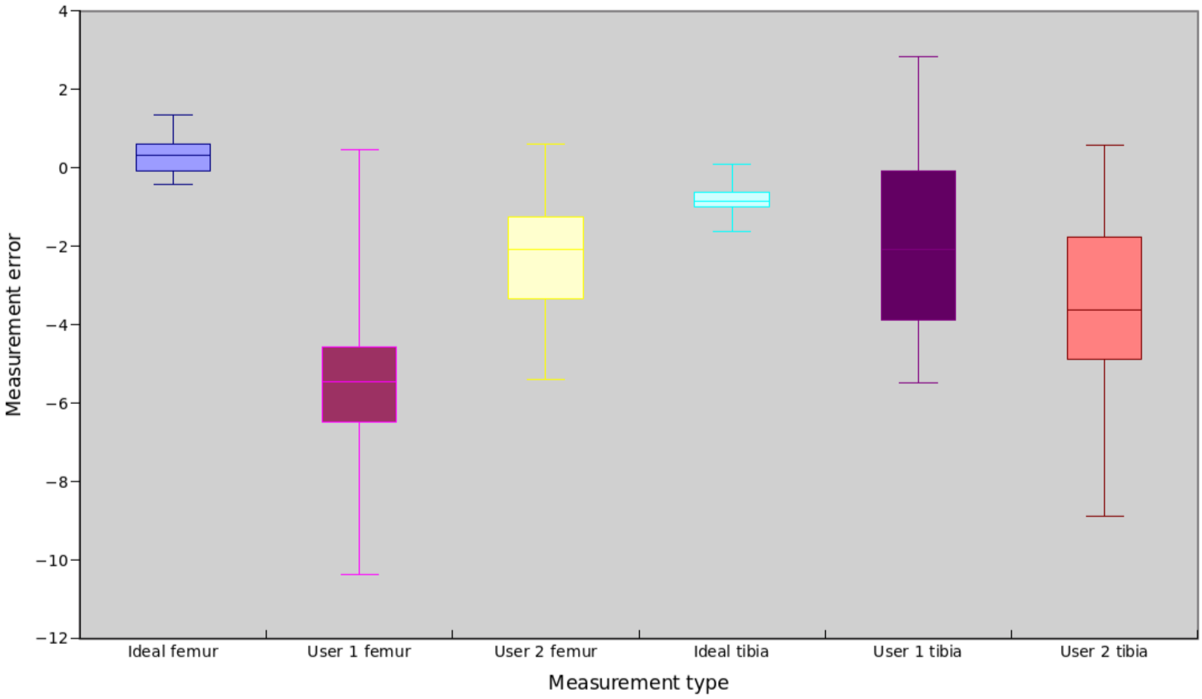

Figure 2: Box plot of all the measurement errors.