PROOF-OF-CONCEPT OF KINEMATIC ANALYSIS IN FAI PATIENTS: A DYNAMIC CT STUDY

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INTRODUCTION

Femoroacetabular impingement (FAI) is a recognised condition frequently resulting in hip joint pain and restricted movement. It arises due to abnormal bone shapes that lead to one bone impinging on another during movement. A possible treatment involves surgically removing the irregular bone portion through keyhole surgery, which aims to restore normal joint function. However, a specific guideline for the optimal amount of bone to be removed during surgery to is lacking. In order to create medical surgical-planning tools, it is crucial to acquire dynamic joint scans. A contemporary method for analysing joint motion utilises dynamic CT imaging. This research project shows how to employ dynamic CT technology to process motion data from FAI patients.

METHODS

A dynamic 4D CT scan was conducted during a standard pre-operative evaluation. An experienced radiographer moved the hip passively during the scan to mimic the flexion, adduction, internal-rotation (FADIR) test [1]. Image acquisition took place using a Toshiba Aquilion One CT scanner, capturing a total of 14 time 3D frames. Semi-automatic segmentation and rigid registration aligned all movement stages with a fixed image (hip in full extension), and pre-selected bony landmarks were propagated at each time point. These landmarks facilitated the creation of local, bone-embedded reference frames. The femur's motion relative to the pelvis was analysed, generating Cardan angles through the XYZ composition sequence. The relative transformation matrix was also employed to calculate the Finite Helical Axis (FHA) parameters for each time point. As segmentations were available from the image processing steps, hip joint proximity was also calculated.

RESULTS AND DISCUSSION

The analysis results for one right hip of a patient with FAI are reported. Figure 1 shows the rotations around the three axes, depicting 68.1° of flexion, 7.8° of internal rotation, and 14.0° of adduction. However, the magnitude of the XYZ components depend on how the reference frame is defined and the rotation sequence used.

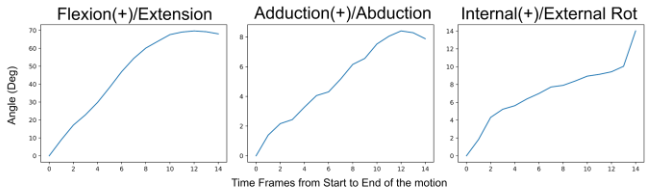

Figure 1: Rotation of the hip joint around the XYZ axes

FHA exhibited an overall rotation angle of 73.7°, demonstrating a gradual change in the orientation of the axis of rotation (Figure 2).

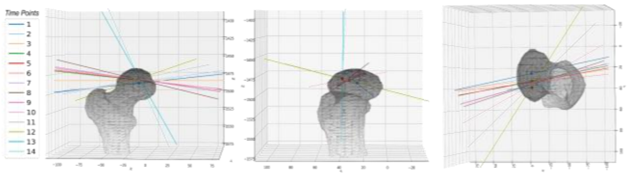

Figure 2: Axis of Rotation on different planes

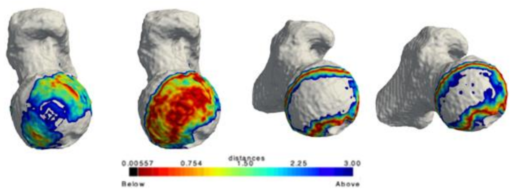

Figure 3: Joint proximity between the right femur and pelvis moving from neutral (left) to flexion (right)

Kinematic analysis showed restricted hip range of motion, with hip flexion not reaching 90° of flexion and limited adduction and internal rotation. Such analysis can help identify abnormal contact points (Figure 3), motion patterns between femur and pelvis, and behaviour of the axis of rotation.

CONCLUSIONS

This proof-of-concept analysis outlines the steps required to analyse the kinematics of FAI patients using 4DCT images. Such steps can be automated and be integrated into motion simulation models and, alongside 3D bone modelling, can help identify impingement areas and estimate the optimal amount of bone to be removed during surgery.

REFERENCES

1. Fernquest et al. (2017). Bone Joint J., **99(4)**: 41-48

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