Design of a Facet Joint Replacement for Cervical Spine and Modification of a Hip Simulator for Simultaneous Friction Analysis and Validation of the Testing Method

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1 Introduction

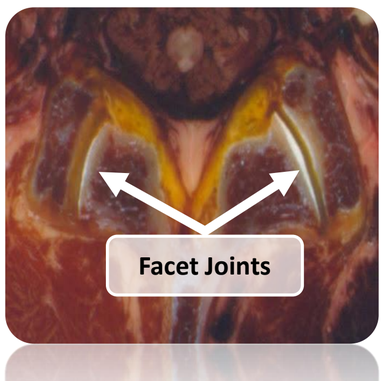

Figure 1. Facet joints at L2/L3 level

The zygapophysial joint, also known as the facet joint, is a diarthrodial joint that plays a vital role in back and neck pain, which has been a leading cause of global disability since 1990. It has been reported that up to 65% of individuals experience neck pain in their lifetime [1,2]. More specifically, 36% to 67% of them suffered from facet joint-mediated pain [3]. Despite its prevalence, the tribology and design of facet joints (FJ) resurfacing devices are currently understudied.

Gaps In the Literature

- Facet joint resurfacing bearing design focusing on the cervical spine (neck)
- A standard guide describing a wear test parameters for cervical facet joint replacements
- Tribological testing outputs such as frictional forces, friction factor, wear rate, volume and patterns for cobalt-chromium (CoCr) on ultra-high molecular weight polyethylene (UHMWPE) replacement system.

Figure 2. Facet joint replacement systems for lumbar spine [4-6]

2 Design Constraints & Solution

Design Constraints:

- ❑ the radius of curvature, width and length of the cervical facet joints,
- ❑ facet joint space gap,
- ❑ load-bearing capacity,
- ❑ range of motion (ROM).

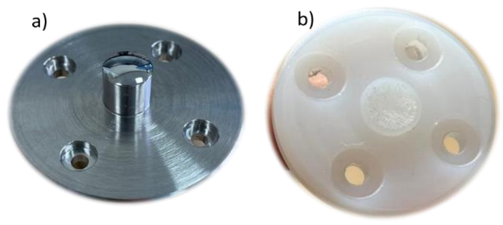

Figure3. Custom-designed a) convex low carbon CoCr bearing b) UHMWPE concave bearing

Design Solution:

1. The bearing made of UHMWPE on CoCr from the ball-on-socket model.
2. The ball radius was found as 11.0 mm for C56 joints (the 2D assessment methods).
3. The radial clearance, was set to be 0.1 mm
4. The motion analysis of the prosthesis confirmed that impingement prevention was achieved at ±15.0° in flexion and extension

3 Methodology Design

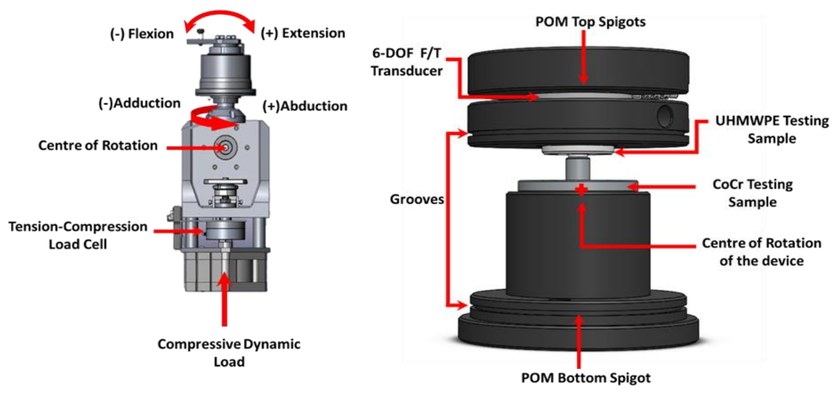

Figure 4. Schematic view of the Prosim 1-Station Deep Flexion Hip Simulator (left) and custom-designed tribological testing rig (right)

This system enables mimicking the facet joint motion and gather simultaneous friction data that will aid in comprehending the wear-friction behaviour of facet joint resurfacing devices.

4 Validation Rig Design and Results

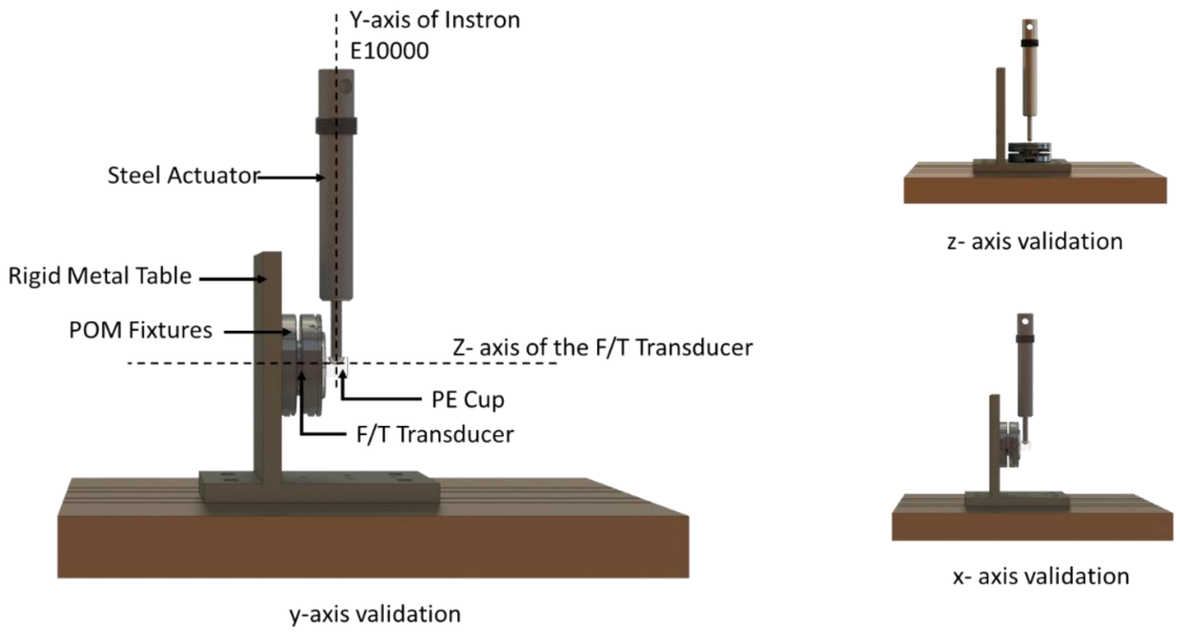

Figure 5. Schematics of validation rig design and different configurations of the setup in x, y and z- directions

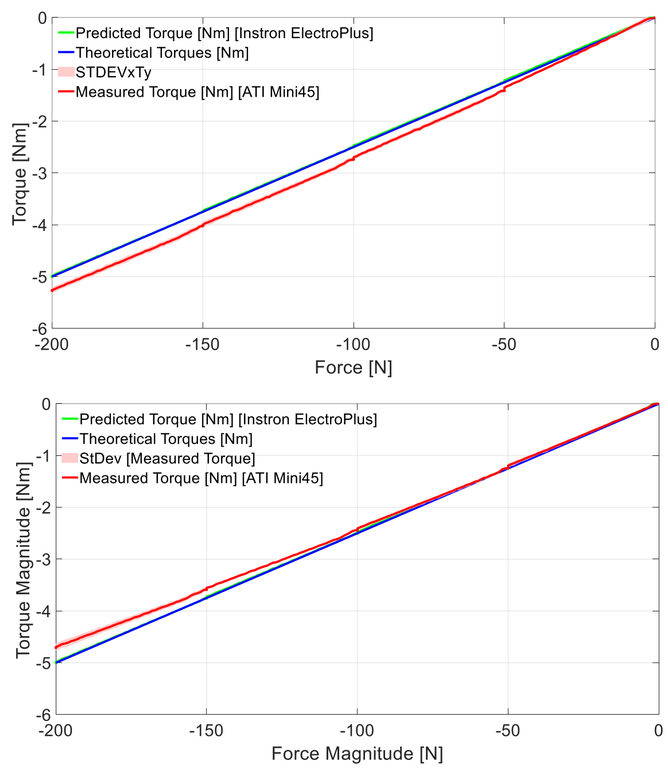

Figure 6. Force and torque relationship comparison in the x- and y-direction for predicted, theoretical and measured cases

Results:

- Figure 6 showed a reasonably linear relationship (R^2=0.999) between measured torque and force at the contact, indicating that the force and torque (F/T) transducer could accurately sense applied force when sandwiched between polyoxymethylene (POM) layers.
- The experiment in z-direction demonstrated that the applied force did not give rise to a torque formation around the z-axis of the F/T transducer, as expected, indicating that the actuator was centred almost perfectly at the origin of the testing rig.

5 Future Work

1. The wear and friction relationship will be explored for CoCr/UHMWPE facet joint resurfacing system under static and dynamic loading conditions.
2. The effect of wear-resistant coatings on reducing friction and wear in orthopaedic implants will be investigated.
3. Particle size distribution analysis will be done for the generated wear debris.

6 References

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