Phantom validation experiment of RSA-based impingement metric to assess component-on-component impingement *in vivo*

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INTRODUCTION: Component-on-component impingement in total hip arthroplasty may lead to limited range of motion and function, pain, dislodgement of the modular liner or loosening of the implant due to increased stress on the liner rim, accelerated metal wear, subluxation, and dislocation. Because of its consequences, many clinical studies are looking at methods to reduce risk of impingement following hip arthroplasty. However, the assessment of component-on-component impingement in clinical studies is largely limited to radiographic qualitative assessment of the hip joint, finite element analyses, and cadaver studies. There is a need for more precise measurements of impingement in vivo in the research setting. Radiostereometric analysis (RSA) is a minimally invasive dual-plane radiographic technique used to monitor 3D movements of musculoskeletal joints and is the gold standard for measuring implant kinematics. We aimed to validate a novel RSA-based impingement risk metric to measure component-on-component impingement.

METHODS: A phantom experiment of a standard metal-on-polyethylene total hip system was performed. RSA examinations were performed as typical for a traditional weight-bearing RSA exam for large joints. The phantom was placed in 10 possible impinged positions and one neutral position. Double exposure radiographs were taken to measure repeatability. Measurements of precision were given by repeatability standard deviation, s_r, and repeatability limit, r, of image exposures. A total of 11 image pairs were analyzed. The closest distance between the skirt of the head and the inner circumference of the acetabular cup liner was measured to assess impingement risk (Fig. 1).

RESULTS: Distances between the closest point of the head to the edge of the cup in 10 impinged positions ranged from 0.05 mm to 1.03 mm, with the average being 0.67 mm. In the neutral position, the distance measured is 11.02 mm. Excellent repeatability was observed, with a standard deviation of 0.03 mm with a repeatability limit of 0.09.

DISCUSSION: A validated RSA-based risk metric was established to evaluate in vivo hip impingement. A 1 mm threshold may be proposed to define impingement where distances approaching 1.00 mm are at a greater risk of impingement and distances. Repeatability of our metric is consistent with previous model-based rotation studies. It is however important to note certain potential errors that may be carried over into the impingement measurements. First, there is the slight dimensional variation between the implant's CAD model and the implant itself from casting and manual polishing, which makes achieving complete alignment between the detected and true contour of the implant unattainable. Moreover, the polyethylene liner present in standard metal-on-polyethylene implants acetabular components is not detected in the radiographic images and were accordingly removed from contour detection but reintroduced in impingement measurements. The polyethylene model was manually placed snugly into the acetabular component as would be implanted, allowing room for potential error. Nevertheless, errors attributing to a fraction of a millimeter or degree is marginally relevant in the assessment of component impingement risk.

SIGNIFICANCE: Component impingement is a problematic occurrence that needs to be more properly understood. Despite the growing interest in component impingement following total hip arthroplasty, there are no widely accepted radiographic techniques to quantifiably measure the occurrence of impingement. In this work, we validated a novel impingement tool using MBRSA that allows for the assessment of component impingement *in vivo.*

FIGURES:

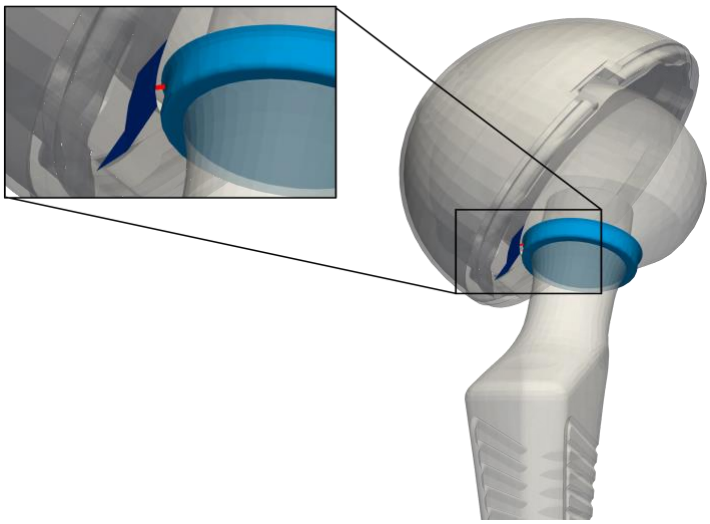

Figure 1: Representation of impingement distance measured as described, as the distance (red) between femoral head skirt (light blue) and the inner circumference of the cup liner (navy).