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Assessment of Congruence and Impingement of Prosthetic Hips during Everyday Tasks

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Introduction

Conventional pre-operative planning for total hip arthroplasty mostly relies on the patient anatomy for the positioning and choice of implants. This kind of planning essentially remains a static approach since dynamic aspects such as the joint kinematics are not taken into account, and is hence not able to fully consider the evolving behavior of the prosthetic joint that may lead to implant failures. In fact, kinematics plays an important role since some movement can create conflicts within the articulation and yielding possible dislocations. The goal of our study was to assess the relationship between acetabular implant positioning variations and resultant impingements and loss of joint congruence during daily activities.

Methods

3D models of prosthetic hip joints (pelvis, proximal femur, cup, stem, head) were developed based on variations of acetabular cup's inclination (40°, 45°, 60°) and anteversion (0°, 15°, 30°) parameters, resulting in a total of 9 different implant configurations. Femoral anteversion remained fixed and determined as "neutral" with the stem being parallel to the posterior cortex of the femoral neck. Motion capture data of daily tasks were applied to all implant configurations. The motions were obtained from 4 healthy volunteers (mean age, 28 years) during routine (stand-to-sit, lie down) and specific activities (lace the shoes while seated, pick an object on the floor while seated or standing) known to be prone to implant dislocation and impingement.

While visualizing the prosthetic models in motion, a collision detection algorithm was used to locate abnormal contacts between both bony and prosthetic components. Moreover, femoral head translations (subluxation) were computed to evaluate the joint congruence.

Results

The simulations showed that collisions occurred at maximal ranges of motion in the anterosuperior part of the acetabulum. The more the inclination and anteversion were important, the lower the frequency of impingements was noted (e.g. 23% at 40°/0°, 13% at 45°/15°, 5% at 60°/30°). Subluxations followed the same trend (e.g. 4.0 mm at 40°/0°, 1.5 mm at 45°/15°, 0.2 mm at 60°/30°) and were observed as a consequence of impingements.

Conclusion

Daily tasks could expose the prosthetic hip to subluxation and impingement located in anterosuperior position. This location could be explained by the high hip flexion required to execute

the motions (≥ 95°). Considering the kinematics solely, increasing inclination and anteversion seems to decrease possible conflicts, but mechanical aspects (stress, wear) should also be considered in the definition of ideal cup positioning.