INTRODUCTION

Prosthetic and bony impingement can affect hip range of motion after arthroplasty. Impingement has been shown to be an important factor in wear, subluxation, and dislocation. While, computer models have been used to show that hip range of motion is dependent on prosthetic design and component placement, the local bony anatomy has usually not been considered. This study determined the effect of local femoropelvic anatomy in a computer model designed to measure range of motion before impingement.

METHODS

A computer model of the surfaces of the bony pelvis and femur was generated using custom software. The geometry was obtained from CT cross-sectional data provided in the Visible Human CD v1.1 (RSI, Boulder, CO). The surfaces of a current generation hip arthroplasty design was also modeled from CAD files provided by the manufacturer. The femoral head and neck were resected at 1.5 cm above the lesser trochanter. The hip components were “implanted” in the pelvis and femur (Fig 1) in various orientations ranging from 35 to 55\(^\circ\) cup abduction, 0 to 30\(^\circ\) cup anteversion, and 0 to 30\(^\circ\) femoral stem antetorsion. The effect of four head sizes ranging from 22.2 mm to 32 mm was analyzed. The femur was rotated around the center of the hip in flexion-extension, abduction-adduction, and axial rotation. A collision-detection algorithm was implemented to detect impingement between prosthetic components and bone at the extremes of rotation. Hip range of motion was recorded as maximum flexion-extension, abduction-adduction, and axial rotation of the femur before any contact was detected between prosthetic components or bone.

RESULTS

Consistent with previous reports, there was a general increase in hip range of motion with increased head size (neck size being constant). Figure 2 shows the increase in range of motion from head size 22 mm to head size 32 mm for a component placement that is typically reported to be close to “optimal” (cup abduction 45\(^\circ\), cup anteversion 20\(^\circ\), and stem antetorsion 10\(^\circ\)). However, note that as the head size increased from 22.2 mm to 32 mm, the propensity for bony impingement increased, thus tending to reduce the beneficial effect of increased head size on range of motion. With the components in this orientation, abduction and adduction were mainly restricted by bony impingement; however, head size had no effect.

Bony impingement preceded component impingement in most cases especially in abduction and flexion. Figure 3 shows the effect of acetabular anteversion and stem antetorsion on hip range of motion in flexion. Note how flexion tends to increase with increasing cup anteversion. However, stem antetorsion has a larger effect on flexion because it increased the range of motion before bony impingement (in this case the neck of the femoral prosthesis impinged against the anterior-superior lip of the acetabulum: large solid arrows).

DISCUSSION

This model allows for a more clinically relevant assessment of range of motion after total hip arthroplasty. Including the bony anatomy while assessing impingement addresses a disadvantage of previously published computer models used to predict range of motion. Prosthetic design improvements may not always improve flexion range of motion since bony impingement can occur before prosthetic impingement. This model can also be used with patient specific geometry (such as that obtained from preoperative CT scans) for accurate preoperative planning.

Flexion is arguably the most important range of motion. Hip flexion range of motion was increased by head size, cup abduction, cup anteversion, and stem antetorsion. Femoral stem antetorsion had a significant effect on restriction of range of motion due to bony impingement. Stem antetorsion essentially changes the rotational relationship of the femoral anatomy as well as shifts the femoral anatomy posteriorly and medially relative to the pelvis. Increasing femoral antetorsion increased hip flexion, abduction, and internal rotation range, and reduced hip adduction, and external rotation range. Acetabular component abduction or anteversion did not affect bony impingement in the positions tested. This was because no impingement was recorded between the proximal femoral bony anatomy and the acetabular component.

The femoropelvic geometry used in this study was based on a single anatomic geometry. The effect of soft-tissue interposition and tension can have a significant effect of hip range of motion. The soft-tissues were not modeled in this study. Development and validation of a soft-tissue model of the hip that takes into account passive interpositional resistance and passive and active restraints is an extremely complex task. Additionally, very little can be done during surgery to reduce soft-tissue impingement in the hip. On the other, hand prosthetic impingement can be reduced by changing or selecting the appropriate implant design and by judicious placement of the components. Bony impingement can also be reduced by stem antetorsion and surgical excision of local osteophytes.

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