Introduction: Total hip arthroplasty (THA) is performed over 120,000 times annually in the United States alone. Following surgery, care must be taken to avoid common pitfalls, which may lead to serious complications. The second most common complication following the surgery (after loosening) is dislocation of the implanted prosthesis from the acetabular cup. Dislocation results from impingement of the femoral neck on the acetabular component or due to bony interference which creates a lever arm that forces the femoral head from the socket. Causes for impingement range from anatomical (soft tissue laxity, large osteophytes to technical (implant position, surgical approach, postoperative activities) to mechanical (prosthesis neck design, acetabular cup design, size of head). Determination of the allowable range of motion for the hip is essential to ensure that impingement between the stem and the cup or the bone does not occur. The object of this study was to investigate the effect of femoral neck design, cup orientation and polyethylene wear on hip range of motion using a simulation model.

Methods: CT data from the Visible Human Project (National Library of Medicine, Rockville, MD) was used to construct computer graphic models of the pelvis and femur. The reconstruction process used contouring algorithms from Analyze 7.5 (Mayo Foundation, Rochester, MN) and a triangulation mesh algorithm (NUAGES). The bone models were placed in an anatomically neutral position based on values from a gait analysis study (1). Femur flexion / extension and abduction / adduction were measured with respect to a pelvic coordinate system. The head of the femur was modeled as a sphere to calculate the hip center of rotation. Flexion / extension was measured about an axis connecting the left and right anterior iliac spines. A second axis connecting a sacral marker 10 cm posterior to the top of the sacrum (L4-L5) to the first axis was used to measure abduction / adduction. Femur internal / external rotation was calculated about a femoral axis connecting the hip center and a point midway between the femoral condyles. The embedded reference axes and average neutral stance position were used to align the bone / prosthesis. The bone models were incorporated into custom computer software, which is a part of our Visual Interactive Computational Anatomical Modeling (VICAM) developed in our laboratory. This program allows the implementation of a spatial hierarchy to define the placement and orientation of locally fixed coordinate systems on the digitized bone or prostheses geometries. The software automatically generates the Euler parameters for the desired motion, modeling the hip as a ball and socket joint. The software also includes an automated collision detection algorithm (RAPID, UNC - Chapel Hill) for rapid processing of range of motion. Once the bones were positioned in the correct anatomical position, a simulated total hip arthroplasty was performed. The femur was osteotomized approximately 1 inch above the greater trochanter and the anterior inferior iliac spine. The Exactech AurA® Hip femoral stem geometry was inserted in the medullary canal and centered with the tip of the stem placed exactly at the hip center of rotation. The acetabular cup, with an outside diameter of 54 mm and inner canal and aligned with the tip of the stem placed exactly at the hip center and a point midway between the femoral condyles. The embedded reference axes and average neutral stance position were used to align the bone / prosthesis. Since the prosthesis and femur positions were described in the pelvis and femur. The reconstruction process used contouring algorithms from Analyze 7.5 (Mayo Foundation, Rochester, MN) and a triangulation mesh algorithm (NUAGES). The bone models were placed in an anatomically neutral position based on values from a gait analysis study (1). 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The acetabular cup, with an outside diameter of 54 mm and inner canal and aligned with the tip of the stem placed exactly at the hip center of rotation. The software automatically generates the Euler parameters for the implementation of a spatial hierarchy to define the placement and orientation of locally fixed coordinate systems on the digitized bone or prosthesis

Discussion: Bone on bone impingement does influence the maximum flexion / extension and abduction / adduction. For flexion / extension, this occurred only for large internal or external rotations, which are not physiological. However, for abduction / adduction combined with external rotation, the influence of bone geometry was of immediate importance. In all cases, maximum flexion decrease with internal rotation and increased with external rotation. Wear in the superior direction reduced range of motion more than anterior wear. The cylindrical neck of the skirted ball in constraint to the AurA® hip stem’s cyclotrapezoidal design, greatly limited the achievable range of motion. Cup position significantly influenced the allowable internal rotation. Internal rotation at 90° flexion is vital during the early postoperative period since patients often need this range of motion when rising from a seated position. Due to weakened muscles around the hip following surgery, patients often internally rotate their hips to rock themselves up from a seated position. The risk of impingement during this maneuver increased with decreased cup abduction and anteversion.


Figure 1: a) Maximum Flexion at 0° Abduction b) Maximum Abduction at 0° Flexion

Bony Impingement: *) greater trochanter and the anterior inferior iliac spine (***) greater trochanter and the ischial tuberosity (****) lesser trochanter and the pubis

Figure 2: Max. Int. Rot. at 90° Flexion (only positive values are plotted) **Exactech, Gainesville, FL