EFFECT OF CUP ORIENTATION AND NECK LENGTH IN RANGE OF MOTION SIMULATION

Jaramaz B.[1,2], Nikou C.[2], DiGioia A.M.[1,2], [1]Center for Orthopaedic Research, Shadyside Hospital, and [2]Center for MRCAS, Robotics Institute, Carnegie Mellon Univesity, Pittsburgh, Pennsylvania.

INTRODUCTION

Improving range of motion (ROM) and relieving pain are the goals of total hip replacement. Prosthetic range of motion (PROM) is one of the components of ROM, defined by prosthetic component design and alignment. Because the PROM is the most significant component in the post-operative range of motion, maximizing PROM will maximize the post-operative mobility of a patient's limb. Pre-operative geometric simulations allow for the optimal placement of the implant to be determined prior to surgery. We have developed an analytical methodology and applied it to evaluate the effects of implant geometry and cup orientation on the range of motion.

METHODS

The parameters necessary to evaluate the PROM limits due to neck-liner impingement are the head-neck ratio of the implant, the orientation of the acetabular cup, and the relative position of the femoral implant with respect to the acetabular cup. The femoral neck can move without impingement within a conical space whose apex coincides with the femoral neck's center of rotation. In order to represent the allowable range of motion in two dimensions, we track the motion of the intersection of the neck axis with a plane P (Fig. 1). On this plane, its intersection with the cone defines an ellipse of allowable motion, and the trace of the neck axis defines a curve during leg motion.

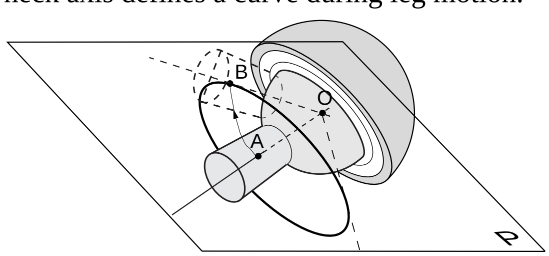

Figure 1. Impingement limits

The motion of the femoral neck is calculated based on the physiological motion described in terms of flexion, extension, internal and external rotation, adduction and abduction. The effects of the neck size and cup orientation were investigated using a geometry based on HGP II and Centralign hip replacement components (Zimmer, Inc.) with axisymmetric liner and 28 mm head. The neck sizes considered were short, medium and long. A series of ROM tests commonly used intra-operatively were simulated to assess the implant stability and impingement limits. The acetabular cup was placed in two different positions within a commonly accepted safe range, first at 40˚ of abduction and 15˚ of anteversion and then at 50˚ of abduction and 20˚ of anteversion.

RESULTS

Five clinically relevant tests were performed for each neck length and cup orientation. The simulation shows (Fig. 2) that a change of cup orientation within the "safe" zone can cause significant changes in the range of motion, that is, up to an increase of 13˚ for internal rotation in flexion (up to 21˚ when combined with the effect of neck size) and up to 10˚ (18˚) reduction of the external rotation.The change in the neck length from medium to long resulted in up to 12˚ of reduction of ROM because of a flange that increases the diameter of the long neck. In general, reorientation of the cup from 40˚/15˚ to 50˚/20˚ abduction/anteversion increased the range for internal rotation in flexion and decreased the range for external rotation in extension.

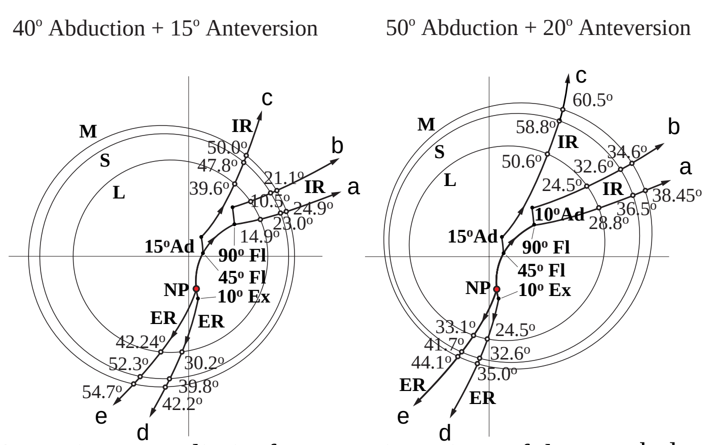

Figure 2. Impingement limits for two orientations of the acetabular cup

DISCUSSION

Both the reorientation of the cup within the commonly accepted "safe" range of cup orientations and the change of the femoral neck length can result in significant change of PROM. Impingement can cause dislocation, increased wear debris, increases in stress and micromotion at the bone-implant interfaces. Preoperative planning of the placement of the implant and precise positioning of the implant during surgery can minimize these complications and maximize safe range of motion.