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Comparison of Head Center Position and Screw Fixation Options Between a Jumbo Cup and an Offset Center of Rotation Cup in Revision Total Hip Arthroplasty: A Computer Simulation Study

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ABSTRACT

Jumbo acetabular cups are commonly used in revision total hip arthroplasty (THA). A straightforward reaming technique is used which is similar to primary THA. However, jumbo cups may also be associated with hip center elevation, limited screw fixation options, and anterior soft tissue impingement. A partially truncated hemispherical shell was designed with an offset center of rotation, thick superior rim, and beveled anterior and superior rims as an alternative to a conventional jumbo cup. A three dimensional computer simulation was used to assess head center position and safe screw trajectories. Results of this in vitro study indicate that a modified hemispherical implant geometry can reduce head center elevation while permitting favorable screw fixation trajectories into the pelvis in comparison to a conventional jumbo cup.

Large size jumbo acetabular cups are commonly used in revision hip arthroplasty. The successful fixation and durability of jumbo cup reconstruction are well documented [1–4]. In theory, the jumbo cup provides a large contact area with the host bone to allow for bone ingrowth, and a stable construct. The placement of a jumbo cup is performed using a surgical technique similar to that of a primary hip arthroplasty, making it a relatively straightforward procedure. Moreover, jumbo cups may be used to fill various sizes of bone defects, hence potentially reducing the need for augments and allografts. However, jumbo cups have also been associated with hip center elevation and instability [5–7]. Hip center elevation may potentially alter the post-op biomechanics and may also contribute to leg length discrepancy and sub-optimal clinical outcomes [8–10].

The jumbo cup requires the use of a cup diameter larger than the native acetabulum diameter. This may result in protrusion of the anterior edge of the cup beyond the anterior wall and removal of anterior column bone, potentially leading to iliopsoas impingement [11]. Iliopsoas tendonitis can cause groin pain after total hip arthroplasty due to soft tissue impingement against the anterior edge of the cup. Cups that are inadequately anteverted or lateralized have been associated with this problem more frequently while an anatomic implant having an anterior recess has been associated with a reduction in groin pain [11–13]. Odri et al found that cups more than 6 mm greater in diameter than the native acetabulum were associated with a significantly higher incidence of hip pain in comparison to cups closer to the anatomic size of the native acetabulum [14].

Although the jumbo cup is seated directly on host bone, initial fixation of the component frequently relies on the use of screws. However, screw fixation may be limited by poor pelvic bone stock, unsafe areas of screw fixation anteriorly, and implant screw hole locations which may restrict the trajectories of multiple screws into the posterior column of pelvic bone.

Alternatives to a jumbo cup include use of an augment above a smaller hemispherical shell or "bilobed" cup. However, both of these options require a more complex surgical technique in comparison to a jumbo cup which can limit their routine use [15]. We hypothesized that an asymmetric acetabular shell with offset center of rotation (COR), recessed anterior rim, and screw trajectories directed toward the posterior column may help address the potential for hip center elevation, soft tissue impingement, and issues with fixation of jumbo cups seen with conventional hemispherical designs, while still maintaining the surgical technique used with a conventional jumbo cup. The purpose of this study is to determine if the modified cup geometry could achieve more anatomic head center position and more favorable screw position into the posterior pelvic column than a conventional hemispherical jumbo cup.

Materials and Methods

Offset COR Acetabular Shell Design

The offset COR acetabular shell was developed with a partially truncated outer hemispherical geometry and the following unique features (Figs. 1 and 2):

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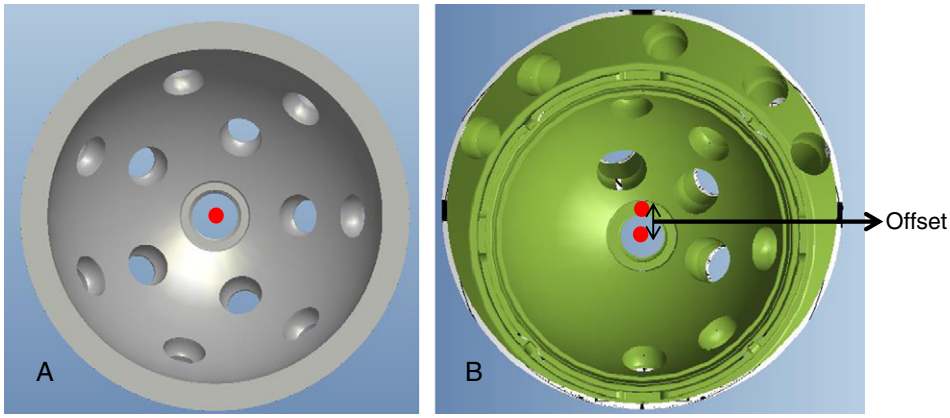

Fig. 1. (A) Illustration of a generic hemispherical shell with concentric inner and outer shell diameters. (B) Illustration of the offset COR shell.

1. Offset center of rotation that is designed to maintain the center of rotation closer to its anatomic position.
2. Thicker superior rim of the cup that is designed to permit the use of multiple peripheral screws directed into the posterior column of the pelvis.
3. Beveled anterior and superior rim of the cup designed to minimize soft tissue impingement.

A three dimensional computer simulation of pelvic reconstruction with a conventional jumbo cup and offset COR implant with the same external diameter was performed to assess the effects of the alternative implant design on head center position and safe screw trajectories into the posterior column. The trajectories of the screw holes were determined by using CT scans of pelvic bones obtained from a custom program, SOMA (Stryker Orthopaedics, Mahwah, NJ). The program, SOMA, contains a large database of CT scans [16]. Anatomic analysis and implant fitting tools are also integrated into the program and these tools have been used for prior population based anatomic studies [16].

Hip Center Elevation Study

A previous computer simulation of hemispherical jumbo cup reconstruction utilizing CT scans (265 pelvic scans consisting of 158 males and 107 females from the SOMA database) investigated the vertical and anterior reamer center shifts, as well as anterior column bone removal by simulating oversized reaming. The study found that the hip center shifted 0.27 mm superiorly and 0.02 mm anteriorly for every 1 mm increase in reamer diameter, simulating a revision THA [5]. In that prior study, anterior column bone removal increased 0.86 mm for every 1 mm increase in the reamer diameter. In the present investigation, the offset COR acetabular shell with an offset center of rotation was studied using the same method. The offset COR shell (diameter range 54–80 mm) was simulated at 45° inclination/20° anteversion, and the effective vertical hip center shift was then assessed with numerical analysis. To compare the generic jumbo shell to the offset COR shell, this study assumed a +6 mm minimum over-ream from the native acetabular diameter. This represents a relatively small amount of bone removal in a revision THA. The simulated reconstruction was assessed up to a +30 mm over-ream to determine the effect of larger bone defects. The vertical hip center shift, from a range of shells, was then compared to the prior study [5], to assess the net change in vertical shift distance (Fig. 3).

Screw Trajectory Optimization

265 CT scans of skeletally mature patients were available from the SOMA database to study a range of shell sizes from 54 to 80 mm. This

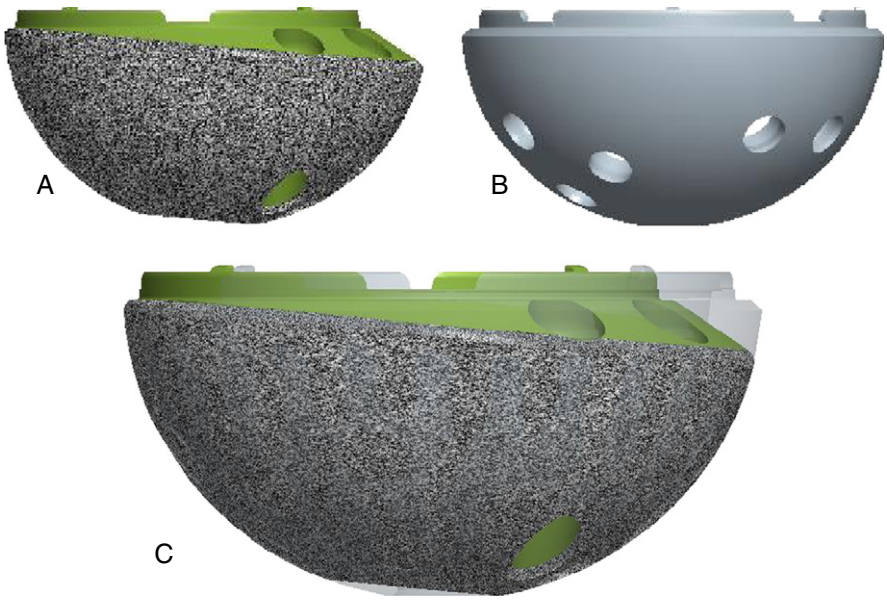

Fig. 2. (A) Illustration of the unique bevel shape in the anterior and superior regions of the offset COR acetabular shell. (B) Illustration of a hemispherical shell of the same diameter. (C) The conventional shell superimposed on the offset COR shell to demonstrate the differences introduced by the bevel.