Acetabular Loosening Using an Extended Offset Polyethylene Liner

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Abstract The use of extended offset femoral components and acetabular liners helps restore preoperative offset during hip arthroplasty. We report a relatively high acetabular component aseptic loosening rate with the use of offset polyethylene liners. We reviewed 1919 primary and 346 revision total hip arthroplasties (THAs). A 7-mm offset acetabular liner was used in 120 of the primary and 100 of the revision THAs. The aseptic loosening rate in the primary THA group was 0.12% in the standard offset and 4.2% in the extended offset groups at a minimum of 2 years (mean, 3.6 years; range, 2–9 years) followup. The aseptic loosening rate in the revision group was 1.7% in the standard and 7% in the extended offset groups at a mean of 4 years (range, 2–9 years) followup. Although extended offset acetabular liners help restore hip offset, torsional force applied to the implant-bone interface may have a detrimental effect on fixation. We found a relatively high failure rate in our primary and revision acetabular components used with an offset liner.

Level of Evidence: Level III, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

Restoring preoperative hip mechanics and soft tissue balance during primary and revision THA improves hip stability and joint function. Preoperative templating and the availability of multiple implant options have made this goal obtainable in most cases. If preoperative templating predicts a loss of hip offset with standard components, the use of extended offset components often becomes necessary to restore soft tissue tension without undue limb lengthening. Most hip arthroplasty manufacturers have extended offset polyethylene liners (4–10 mm) and extended offset femoral components available.

Extended offset polyethylene liners allow restoration of soft tissue tension by adding 4 to 10 mm of additional offset to the acetabular side. These devices translate the center of hip rotation laterally relative to the face of the acetabular component. For a well-positioned acetabular component, this provides a few millimeters of additional offset in the horizontal plane and a few millimeters of additional limb lengthening in the vertical plane. This lateral translation of the center of rotation, however, increases joint reaction forces and potentially increases polyethylene wear [3]. In addition, this translation of the center of rotation away from the geometric center of the acetabular metallic shell results in an eccentric loading pattern and increased torsional forces at the liner-shell interface and, more importantly, the bone-implant interface. These increased torsional forces may cause motion at the interface resulting in failure of ingrowth and early loosening. Limited literature is available with respect to these concerns [2, 6]. Both studies raised a similar concern, finding that the use of extended offset acetabular liners results in an increased torsional force at the bone-implant interface that can exceed that required to result in failure of initial fixation.

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Each author certifies that his or her institution has approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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The use of extended offset femoral components typically results in the addition of offset alone. That is, there is typically no additional limb lengthening with the use of extended femoral components. The additional offset on the femoral side results in a longer lever arm for the hip abductors and theoretically lower joint reaction force [3]. Like on the acetabular side, the longer femoral lever arm results in greater strains in the implant and at the bone-implant or implant-cement interface [3]. The potentially detrimental clinical effects of these elevated stresses are presently unknown.

Owing to these theoretical concerns, we hypothesized additional offset would result in an increased rate of acetabular loosening and reduced survivorship in primary and revision THA.

Materials and Methods

We retrospectively reviewed 1696 patients with 1919 primary THAs and 310 patients with 346 revision THAs performed between August 1997 and June 2005. In all cases, polyethylene acetabular inserts were used as the acetabular bearing. Several polyethylene implant options were available for use to restore loss of offset or alter stability. These options included standard liners, extended offset liners (7 mm of offset), and elevated rim liners (10° and 20°). In our practice, extended offset liners were used when preoperative templating predicted a loss in offset with the use of standard liners that could not be entirely restored using an offset femoral component. Because the intention of this evaluation was to compare standard liners and offset liners, we excluded from the evaluation 177 patients in whom other options were used (elevated rim liners or constrained liners). One hundred ninety cases of the 1919 primary THAs were excluded because we used liners other than standard or 7-mm extended offset leaving 1609 cases of standard polyethylene liners and 120 cases of offset liners. In the group of 346 revision THAs, we excluded cemented acetabular components, unidentified liners, elevated liners, and constrained liners. This left 115 cases of standard polyethylene liners and 100 cases of offset liners. We followed patients a minimum of 2 years (mean, 3.6 years; range, 2–9 years).

The primary hip arthroplasty group with standard polyethylene inserts was 39.8% male and 60.2% female. The mean age at index surgery in this group was 65 years (range, 15–96 years). Implants (all Zimmer, Warsaw, IN) used in this group included 782 Trilogy spiked, 654 Trilogy with cluster holes, 48 Trilogy with multiple holes, 37 Trabecular Metal Monoblock components, 84 Trabecular Metal with cluster holes, and three Trabecular Metal with multiple holes. In the components with screw holes (789),

the mean number of screws used was 2.2 (range, 1–5). The diagnoses included osteoarthritis (83.5%), rheumatoid arthritis (2.4%), posttraumatic arthritis (2.2%), developmental dysplasia (5.2%), osteonecrosis (5%), and 1.7% other. The type of polyethylene used in this group included 634 conventional and 975 highly crosslinked inserts.

The primary hip arthroplasty group with extended offset liners was 52% male and 48% female. The mean age at index surgery was 61.1 years (range, 19–86 years). Implants (all Zimmer) in this group included 82 Trilogy spiked, 26 Trilogy with cluster holes, and 12 Trilogy with multiple holes. In the components with screw holes (38), the mean number of screws used was 2.4 (range, 1–4). The diagnoses included osteoarthritis (76.7%), rheumatoid arthritis (1.7%), posttraumatic arthritis (4.2%), developmental dysplasia (10%), osteonecrosis (4.2%), and 3.2% other. The type of polyethylene used in this group included all conventional polyethylene because there is no offset liner manufactured with highly crosslinked polyethylene.

The revision hip arthroplasty group with standard liners was 65.2% male and 34.8% female. The mean age at the time of revision was 66.3 years (range, 30–93 years). Implants used in this group included two Trilogy spiked, nine Trilogy with cluster holes, one Trilogy without holes, and 37 Trilogy with multiple holes (Zimmer); two Osteonics Omnifit (Stryker Howmedica Osteonics, Mahway, NJ); 12 Harris-Galante II, six Harris-Galante I, 12 Trabecular Metal with cluster holes, and six Trabecular Metal with multiple holes (Zimmer); and 28 were liner exchanges only. The average number of screws used in the components with holes was three (range, 1–6). There were 46 conventional polyethylene liners used and 69 highly crosslinked liners used.

The revision hip arthroplasty group with extended offset liners was 64% male and 36% female. The mean age at the time of revision was 63.5 years (range, 29–87 years). Implants (all Zimmer) used in this group included five Trilogy Spiked, three Trilogy with cluster holes, one Trilogy with no holes, 71 Trilogy with multiple holes, one Trabecular Metal with cluster holes, seven Trabecular metal with multiple holes, and 12 liner exchanges only. The average number of screws used in the components with holes was 3.2 (range, 1–6). All liners were made with conventional polyethylene.

All acetabular components were implanted without cement. The ingrowth surface on the Trilogy components (Zimmer) is a titanium fiber metal mesh, whereas the ingrowth surface on the Trabecular Metal modular (Zimmer) components is porous tantalum.

We evaluated patients retrospectively using our clinical database for a minimum of 2 years postoperatively. One independent observer (TC) reviewed radiographs at an early postoperative interval (typically 6 weeks) for

component positioning at 6 months postoperatively and annually thereafter for any evidence of loosening or progressive radiolucencies. Radiographic evaluation included early postoperative and last followup. Followup radiographs included an anteroposterior view of the pelvis, an anteroposterior view of the hip, and a Lowenstein lateral view of the hip. Judet views were not obtained. Early postoperative radiographs were evaluated for initial positioning (abduction on the anteroposterior view and anteversion when groin lateral views were available), initial bone-prosthesis gaps (incomplete seating), and coverage. Latest followup radiographs were evaluated for incorporation of initial gaps, sclerotic lines (less than 1 mm), radiolucencies (defined as a lucency greater than 1 mm thick and involving over half the zone), osteolysis, screw lucencies, screw breakage, or change in position.

We performed Kaplan-Meier survivorship analysis on the four groups and compared survival using the Wilcoxon and log rank tests for equality of survival curves. These tests were both performed because the log rank test is sensitive to between-group differences in survival distributions late in followup, whereas the Wilcoxon test is sensitive to early differences in survival distributions [5].

Results

The survivorship of primary THA with extended offset liners was less than that of standard polyethylene liners at 6 years (test for equality of survival distributions: Wilcoxon $p < 0.01$, log rank $p < 0.01$). In the group of 1609 primary THAs performed with standard liners, we identified 16 revisions (1%). The cause of revision included nine for recurrent instability, four for sepsis, two for loosening (at a mean of 40 months), and one for polyethylene wear. Of the two that loosened, one was a spiked Trilogy component and one was a multiholed Trilogy component used with screws. In the group of 120 primary THAs performed with an extended offset liner, we identified 13 revisions. The cause of revision in these cases included five for loosening (at a mean 48 months), five for recurrent instability, two for sepsis, and one for polyethylene wear. Of the five that loosened in the offset liner group, the components used were three Trilogy spiked components and two holed Trilogy components used with screws (Figs. 1, 2). Radiographic review of all included primary THAs demonstrated an initial mean acetabular component position of 44° of abduction (range, 30° – 56°) and 25° of anteversion (range, 1° – 52°). The mean abduction angle in the five offset components that were revised for loosening was 51° (range, 36° – 70°). The mean abduction angle in the offset group not revised was 44° (range, 30° – 56°). Radiolucencies were identified in 47 of the cases with standard liners and in eight

Fig. 1 This radiograph demonstrates a primary THA with a 7-mm extended offset polyethylene liner.

Fig. 2 This is a radiograph of the same hip arthroplasty with early loosening of the acetabular component.

of the cases with extended offset liners. All radiolucencies in these cases were less than 1 mm in width and were nonprogressive. There were no cases of radiographically loose components that were not revised in either group. Therefore, the acetabular aseptic loosening rate was 0.12% (two of 1609) in the standard offset group and 4.2% (five of 120) in the extended offset group. Six-year survivorship of all primary THAs with any reoperation as the end point was 96% (95% confidence interval [CI], 94.76%–97.95%) (Fig. 3). Six-year survivorship with revision of the acetabular component for aseptic loosening as the end point of primary THA in patients with standard liners was 98% (95% CI, 96.7%–99.2%) and extended offset liners was 80.4% (95% CI, 69.6%–91.9%) (Fig. 4).

The survivorship of revision THA with extended offset liners was similar ($p = 0.09$) to that of cases with a standard polyethylene liner at 6 years (test for equality of

Fig. 3 This graph demonstrates 6-year survivorship of all primary hip arthroplasties with any reoperation as the end point.

Fig. 5 This graph demonstrates 6-year survivorship of all revision hip arthroplasties with any reoperation as the end point.

Fig. 4 This graph demonstrates 6-year survivorship of primary hip arthroplasties with acetabular revision for aseptic loosening as the end point. Hips with standard liners are indicated by the solid line, whereas hips with extended offset liners are indicated by the broken line.

Fig. 6 This graph demonstrates 6-year survivorship of revision hip arthroplasties with acetabular rerevision for aseptic loosening as the end point. Hips with standard liners are indicated by the solid line, whereas hips with extended offset liners are indicated by the broken line.

survival distributions: Wilcoxon $p = 0.27$, log rank $p = 0.09$). In the group of 115 revision THAs performed with standard liners, we identified five revisions. The cause of revision included four for sepsis and one for recurrent instability. In the group of 100 revision THAs performed with an extended offset liner, we identified 10 revisions. The cause of revision in these cases included six for loosening (at a mean of 31 months), three for recurrent instability, and one for sepsis. Of the six that loosened, all acetabular components used were holed Trilogy components with supplemental screws. Radiographic review demonstrated an initial mean acetabular component position of 44° of abduction (range, 30° – 67°) and 21° of anteversion (range, 0° – 62°). The abduction angle in the six offset components revised for loosening was on average 43° (range, 33° – 55°). The abduction angle in the remaining offset liners not revised was 44.3° (range, 30° – 67°).

Radiolucencies were identified in six cases with standard liners and in 13 of the cases with extended offset liners. All radiolucencies in these cases were less than 1 mm in width and were nonprogressive. There were three additional (not revised) cases of loosening identified radiographically (complete radiolucencies with change in component positioning). Two of these cases were in the standard liner group and one was in the offset liner group. Therefore, the acetabular loosening rate (revisions for aseptic loosening and radiographically loose but unrevised) was 1.7% (two of 115) in the standard offset group and 7% (seven of 100) in the extended offset group. Six-year survivorship of all revision THAs with any reoperation as the end point was 91.7% (95% CI, 86.6%–96.7%) (Fig. 5). Six-year survivorship of revision THA with revision of the acetabular component for aseptic loosening as the end point was 95.3% (95% CI, 90.7%–99.9%) in the standard offset

group and 86.4% (95% CI, 77.1%–95.8%) in the extended offset group (Fig. 6).

Discussion

The use of extended offset polyethylene acetabular liners provides improved soft tissue balancing and stability in certain clinical situations. However, translation of the center of rotation from the geometric center of the acetabular shell results in increased rotational torsion at the bone-implant interface with load application. The magnitude of this force is dependent on the position of the component with more vertically positioned components having greater torsional force. Patient factors such as body weight and activity level will affect these forces as well. Some concern has been raised that these increased torsional forces may result in a higher failure rate secondary to aseptic loosening. The purpose of this investigation was to perform a comparative retrospective review of our minimum 2-year results of 7-mm extended offset and standard polyethylene liners in primary and revision THA. Our hypothesis is this additional offset will result in an increased rate of acetabular loosening in both primary and revision THA.

This study has several important limitations. The series is a retrospective clinical review with potential biases in patient selection. In addition, the groups vary in size and with respect to demographics. There are a variety of implants (acetabular components) used in both the primary and revision setting and several surgeons were involved with varying techniques. The offset in this review is 7 mm and these findings may not necessarily apply to lesser degrees of offset. However, the study has the benefits of a relatively large patient volume with similar implant materials and ingrowth surfaces. The decision to use an extended offset liner was consistently based on preoperative templating and a sense of intraoperative stability. There is no reason to believe extended offset liners were used in cases with a reduced capacity for bony ingrowth (ie, poor bone support, poor bone quality). Although these limitations may compromise the strength of the relationship between extended offset liners and loosening, it establishes a clinical concern that has been theoretically raised previously.

At a minimum of 2 years followup, we identified a high acetabular aseptic loosening rate (acetabular revision for aseptic loosening and radiographically loose but not revised) of 4.2% in primary THAs performed with a 7-mm extended offset polyethylene liner; in contrast, the acetabular aseptic loosening rate in primary THAs performed with a standard (nonoffset) polyethylene liner was 0.12% at similar followup (Fig. 4). Similarly, we identified the

acetabular aseptic loosening rate of revision acetabular components in which an extended offset polyethylene liner was 7% in contrast to a 1.7% rate in standard liner cases. Although the 6-year survivorship curves were not statistically different, it demonstrated a trend toward inferior survival in the extended offset group. These findings support our hypothesis that the use of additional offset polyethylene liners resulted in a higher rate of acetabular mechanical failure. Other authors have raised a similar concern regarding these implants. Giori modeled this phenomenon [2] and reported a 70-kg person walking normally with a well-positioned acetabular component and a 4-mm offset polyethylene liner (lowest commercially available offset liner) will apply approximately 3.86 Nm of torsion on the implant with every step. A 10-mm offset liner (highest commercially available offset liner) increased the torsion to 9.65 Nm. He reported 20° of excessive abduction (65°) increased the torsion by 62% [2]. Curtis et al. [1] previously demonstrated an acetabular component of 52 mm diameter implanted with a 1-mm press-fit required approximately 9 Nm of torsion to cause failure of fixation. Underreaming by 2 mm increased this torsion to failure to approximately 28 Nm. Others have reported similar results [4]. Based on these calculations, depending on the patient's weight, activity level, component positioning, and amount of offset used, the torsional forces applied to the component could very well exceed that required to result in failure of initial fixation.

Limited clinical data are available to support this assertion. McGroory [6] reported on 18 acetabular revisions performed with a 7-mm extended offset polyethylene liner and identified three revisions for loosening and one radiographically loose. This rate of failure was greater in patients with a high abduction angle of acetabular implantation. They concluded the routine use of this component is not recommended in revision surgery with acetabular deficiencies.

There are many variables that have an effect on the likelihood of acetabular failure in primary and revision hip arthroplasty with the use of extended offset liners. Patient factors include weight and activity level. Technical factors at the time of surgery include position of implantation, amount of press-fit obtained, the shape of the reamed cavity, and the use of supplemental fixation such as screws or spikes. Finally, design factors include the frictional characteristics of the ingrowth surface, the amount of offset added, and the availability of supplemental fixation options.

Our data demonstrate a higher acetabular aseptic loosening rate in both the primary and revision settings with the use of a 7-mm offset polyethylene liner. We therefore make every effort intraoperatively to avoid the use of such implants. If additional offset is needed to restore soft tissue balance or stability, we will preferentially use an extended

offset femoral component. If a clinical scenario presents itself that necessitates the addition of acetabular offset, we confirm maximum bony support of the component, use supplemental screw fixation, and avoid excessive acetabular abduction.

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