Primary articulation of bipolar hemiarthroplasty systems is at the femoral head-liner interface. The purpose of this study was to compare observed damage modes on 36 retrieved bipolar systems with implant, demographic, intraoperative, and radiographic data to elucidate the effects of component design, specifically locking mechanism, on clinical performance.

Retrieved bipolar hip hemiarthroplasty systems of 3 different design types were obtained, disassembled, and evaluated macro- and microscopically for varying modes of wear, including abrasion, burnishing, embedding, scratching, and pitting. Clinical record review and radiographic analysis were performed by a senior orthopedic surgery resident. Average bipolar hip hemiarthroplasty system term of service was 46 months (range, 0.27-187 months). All devices contained wear debris captured within the articulating space between the femoral head and liner. In 31% of patients without infection, lucency was observed on immediate prerevision radiographs. The system with a leaf locking mechanism showed significantly increased radiographically observed osteolysis ($P<.03$) compared with a system with a stopper ring locking mechanism. In addition, implant design and observed damage modes, including pitting and third-body particle embedding, were significantly associated with radiographically observed osteolysis.

The authors are from the Department of Orthopaedic Surgery (MDH, LMK, PWG); and the Department of Orthopaedic Research (EAB, MRS, RTG), Beaumont Health System, Royal Oak, Michigan.

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This article is dedicated in memory of Harry N. Herkowitz, MD.

Correspondence should be addressed to: Lige M. Kaplan, MD, Department of Orthopaedic Surgery, Beaumont Health System, Royal Oak, Michigan 48073 (ligekaplan@yahoo.com).

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According to the American Academy of Orthopaedic Surgeons, 350,000 hospital admissions per year are due to hip fractures, a figure that is expected to double by the year 2050. Factors leading to this increase include rising rates of osteoporosis, an increase in the average lifespan, and an increase in the population of people older than 65 years. Depending on the fracture type and comorbidities, treatment options include open reduction and internal fixation with cephalomedullary devices and joint replacement.

Hemiarthroplasty is an accepted treatment option for displaced femoral neck fractures in elderly patients that decreases nonunion rates and eliminates avascular necrosis complications of the femoral head, both of which occur more frequently with internal fixation. However, hemiarthroplasty is associated with complications, including increased risks of infection, dislocation, fracture, acetabular cartilage erosion, and implant loosening. Acetabular cartilage erosion may lead to pain, component migration, acetabular protrusio, and eventually subsequent revision to total hip arthroplasty (THA).

The bipolar hip hemiarthroplasty (BHA) was developed to minimize acetabular wear, thereby reducing these complications. The BHA allowed 2 points of articulation, both between an outer shell and the acetabulum and between the inner femoral head and a polyethylene liner. The BHA device is composed of a cobalt-chromium-molybdenum (CoCrMo) alloy femoral head articulating against an ultra-high-molecular-weight polyethylene (UHMWPE) liner. The femoral head is subsequently “locked” into the liner, theoretically reducing the rate of dislocation. The liner is contained in a CoCrMo alloy shell that articulates with acetabular cartilage. The primary articulation of BHA devices is at the femoral head-liner interface, although in vivo evidence demonstrates motion between the CoCrMo alloy shell and acetabular cartilage. Motion at the metal-polyethylene articulation may lead to generation of particulate debris, potentially leading to polyethylene wear-induced osteolysis.

Although the CoCrMo-cartilage articulation is reduced in the BHA design, the constrained femoral head-liner articulation may promote polyethylene wear. Generation of polyethylene wear debris of a specific size range, morphology, and concentration is known to induce osteolysis, compromising the mechanical stability of implants. Coleman et al reported 31 consecutive BHAs converted to THAs, of which 56% showed radiographic evidence of osteolysis. Histologic investigation of tissues in these osteolytic zones demonstrated findings consistent with particle-induced osteolysis. Other studies have shown that embedded periarticular wear debris induces osteolysis and the progression of femoroacetabular joint degeneration. Despite numerous reported cases of osteolysis and subsequent loosening observed with BHA systems, no studies correlate radiographic findings and medical record review with ex vivo evaluation of implant damage. Hara et al performed an analysis of 23 retrieved BHA systems and reported mechanical damage and oxidation of the UHMWPE liners. Kusaba and Kuroki performed an in situ radiographic analysis of total UHMWPE wear in uncemented BHAs. The authors measured penetration of the femoral head into the acetabular liner but did not compare linear wear measurements to damage on retrieved device components. Kusaba and Kuroki also analyzed the surface roughness of 40 retrieved bipolar femoral heads and measured the associated polyethylene wear to determine changes in surface configuration. However, no studies have characterized damage modes of all BHA system components to understand the relationships between polyethylene and metallic damage and radiographic findings, patient demographics, and surgical data, which may lead to clinical failure.

The purpose of the current study was to compare damage modes observed on retrieved BHA components with implant design type and radiographic findings to elucidate the effects of component design (locking mechanism specifically) and material selection on clinical performance and failure.

Materials and Methods

Following institutional review board approval, 36 explanted BHA systems were obtained and disassembled between 2002 and 2010. Devices were obtained within 1 week of surgery and ultrasonically cleaned in a diluted Micro-90 solution (International Products Corporation, Burlington, New Jersey) for 5 minutes, followed by an ultrasonic bath in 85% (or greater) ethanol solution for 5 minutes. Devices were allowed to air dry and were vacuum-sealed to prevent oxidation, de-identified by labeling with an explant identification number, and entered into an electronic database.

The 36 retrieved explanted BHA systems included the following 3 design types: 9 Centrax (CX; Stryker Orthopaedics, Mahwah, New Jersey), 20 Self-Centering (SC; DePuy Orthopaedics, Inc, Warsaw, Indiana), and 7 MultiPolar (MP; Zimmer, Inc, Warsaw, Indiana) systems (Figure 1). Implant types differ mainly by the locking mechanism used to prevent dissociation of the femoral head from the UHMWPE liner. The CX design has a leaf locking mechanism, whereas the SC and MP designs have stopper ring locking mechanisms.

Individual components included 36 CoCrMo shells, 36 UHMWPE liners, 36
CoCr femoral heads, and 26 titanium or CoCr alloy femoral stems. Nineteen femoral stems were cemented and 17 were un cemented. One stem (MP) was designed as press-fit but was cemented at implantation. Little evidence exists implicating cement fixation with improved or deficient clinical outcomes compared with press-fit fixation of femoral stems.6 For all design types, the UHMWPE liner was composed of conventional UHMWPE, which was sterilized using gamma irradiation in an inert environment (eg, inert gas or vacuum). The UHMWPE was not subject to further cross-linking than the minimal amount that occurs during sterilization.

Retrieved BHA components were first evaluated visually for damage. Five damage modes were identified, including abrasion, burnishing, third-body particle embedding, pitting, and scratching/grooving.20 The components were also evaluated under light microscopy and scanning electron microscopy to further evaluate the extent of damage. Ultra-high-molecular-weight polyethylene components were sputter-coated with gold palladium prior to evaluation under scanning electron microscopy to improve electron conduction.

Medical record review was performed to collect pertinent clinical data, such as age at implantation and revision, body mass index (BMI), sex, implant term of service, and reason(s) for implantation and revision surgeries. Available serial radiographs were collected for the term of service of the implant (from immediately postimplantation to immediately prerevision) for analysis of device alignment, lucency, and the presence or absence of cement and/or metallic debris. Radiographic analyses were performed by a senior orthopedic surgery resident (M.D.H.). The location(s) of loosening, characterized radiographically as the presence of lucency, was defined by zone, as established by Gruen et al.21 Devices were further stratified by infected and noninfected cases to differentiate between septic vs aseptic loosening, and infected devices were excluded from radiographic analysis for osteolysis. Implant alignment was characterized as acceptable, varus, subsided, or retroverted.

Statistical analyses were performed with SigmaPlot version 11.0 statistical software (Systat Software, Inc, Chicago, Illinois) to understand the relationships between patient populations, damage mode and radiographic observations, and implant designs. First, Mann-Whitney rank sum analysis was performed to compare the patient populations in each design cohort. Second, chi-square analysis was used to compare the proportion of each observed damage mode in each design cohort. A Spearman rank order analysis was performed to ascertain any correlations between patient factors (eg, BMI, age at implantation) and implant designs. To explore relationships between observed damage modes, intraoperative observations, and radiographic data by design type, an analysis of variance analysis model (α=0.05) was performed for each component.

Finally, the designs were split into 2 groups, leaf locking and stopper ring locking mechanisms, and Spearman rank order analyses were performed to determine whether relationships between observed damage modes or radiographic data were associated with the locking mechanism. For the correlation analyses, correlation coefficients of 0.20 to 0.40 were considered weak, 0.40 to 0.60 were considered moderate, 0.60 to 0.80 were considered strong, and 0.80 to 1.00 were considered very strong.22 Cases of confirmed infection were removed when analyzing intraoperative and radiographic observational data.

RESULTS

Medical Record Review

Patient demographic data were collected (Table 1). Reasons for implantation were femoral neck fracture (n=35) and avascular necrosis (n=1). Average implant term of service for aseptic and septic devices were 68 months (range, 3-187 months)
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### Table 1
Patient Demographics of Bipolar Hip Hemiarthroplasty Revisions by Design Type and Locking Mechanism

<table>
<thead>
<tr>
<th>Demographic</th>
<th>All</th>
<th>SC</th>
<th>MP</th>
<th>CX: Leaf Locking</th>
<th>SC &amp; MP: Stopper Ring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient sex, No. F/M</td>
<td>25/11</td>
<td>14/6</td>
<td>1/6</td>
<td>5/4</td>
<td>15/12</td>
</tr>
<tr>
<td>Side, No. L/R</td>
<td>22/14</td>
<td>11/9</td>
<td>5/2</td>
<td>6/3</td>
<td>16/11</td>
</tr>
<tr>
<td>Mean BMI, kg/m²</td>
<td>26±5</td>
<td>26±5</td>
<td>30±8</td>
<td>24±3</td>
<td>27±6</td>
</tr>
<tr>
<td>(16-47)</td>
<td>(16-36)</td>
<td>(25-47)</td>
<td>(20-29)</td>
<td>(16-47)</td>
<td></td>
</tr>
<tr>
<td>Mean age at implant, y</td>
<td>72±12</td>
<td>72±12</td>
<td>74±12</td>
<td>71±11</td>
<td>73±12</td>
</tr>
<tr>
<td>(49-90)</td>
<td>(54-90)</td>
<td>(55-90)</td>
<td>(49-84)</td>
<td>(54-90)</td>
<td></td>
</tr>
<tr>
<td>Mean age at revision, y</td>
<td>77±11</td>
<td>76±11</td>
<td>78±13</td>
<td>80±9</td>
<td>76±11</td>
</tr>
<tr>
<td>(56-93)</td>
<td>(56-92)</td>
<td>(57-90)</td>
<td>(62-93)</td>
<td>(56-92)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; CX, Centrax (Stryker Orthopaedics, Mahwah, New Jersey); F, female; L, left; M, male; MP, MultiPolar (Zimmer, Inc, Warsaw, Indiana); R, right; SC, Self-Centering (DePuy Orthopaedics, Inc, Warsaw, Indiana).

### Table 2
Reasons for Revision of Bipolar Hip Hemiarthroplasty

<table>
<thead>
<tr>
<th>Reason for Revision</th>
<th>No. (%)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All</td>
<td>SC</td>
<td>MP</td>
<td>CX: Leaf Locking</td>
<td>SC &amp; MP: Stopper Ring</td>
</tr>
<tr>
<td>Dislocation</td>
<td>2 (6)</td>
<td>2 (10)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Fracture</td>
<td>3 (8)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>3 (33)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Infection</td>
<td>9 (25)</td>
<td>5 (25)</td>
<td>2 (29)</td>
<td>2 (22)</td>
<td>7 (26)</td>
</tr>
<tr>
<td>Instability</td>
<td>3 (8)</td>
<td>1 (5)</td>
<td>0 (0)</td>
<td>2 (22)</td>
<td>1 (4)</td>
</tr>
<tr>
<td>Leg-length discrepancy</td>
<td>1 (3)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (11)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Loosening</td>
<td>4 (11)</td>
<td>0 (0)</td>
<td>3 (43)</td>
<td>0 (0)</td>
<td>3 (11)</td>
</tr>
<tr>
<td>Pain</td>
<td>20 (56)</td>
<td>13 (65)</td>
<td>3 (43)</td>
<td>3 (33)</td>
<td>16 (59)</td>
</tr>
</tbody>
</table>

Abbreviations: CX, Centrax (Stryker Orthopaedics, Mahwah, New Jersey); MP, MultiPolar (Zimmer, Inc, Warsaw, Indiana); SC, Self-Centering (DePuy Orthopaedics, Inc, Warsaw, Indiana).

### Table 3
Intraoperative Observations at Bipolar Hip Hemiarthroplasty Revision

<table>
<thead>
<tr>
<th>Observation</th>
<th>No. (%)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All</td>
<td>SC</td>
<td>MP</td>
<td>CX: Leaf Locking</td>
<td>SC &amp; MP: Stopper Ring</td>
</tr>
<tr>
<td>Cemented</td>
<td>19 (53)</td>
<td>9 (45)</td>
<td>2 (29)</td>
<td>8 (89)</td>
<td>11 (41)</td>
</tr>
<tr>
<td>Infection</td>
<td>18 (50)</td>
<td>13 (65)</td>
<td>3 (43)</td>
<td>2 (22)</td>
<td>16 (59)</td>
</tr>
<tr>
<td>Instability</td>
<td>11 (31)</td>
<td>4 (20)</td>
<td>2 (29)</td>
<td>5 (56)</td>
<td>6 (22)</td>
</tr>
<tr>
<td>Aseptic loosening</td>
<td>12 (33)</td>
<td>3 (15)</td>
<td>2 (29)</td>
<td>7 (78)</td>
<td>5 (19)</td>
</tr>
<tr>
<td>Septic loosening</td>
<td>5 (14)</td>
<td>3 (15)</td>
<td>1 (14)</td>
<td>1 (11)</td>
<td>4 (15)</td>
</tr>
<tr>
<td>Pain</td>
<td>35 (97)</td>
<td>19 (95)</td>
<td>7 (100)</td>
<td>9 (100)</td>
<td>26 (96)</td>
</tr>
</tbody>
</table>

Abbreviations: CX, Centrax (Stryker Orthopaedics, Mahwah, New Jersey); MP, MultiPolar (Zimmer, Inc, Warsaw, Indiana); SC, Self-Centering (DePuy Orthopaedics, Inc, Warsaw, Indiana).

Radiographic analysis determined the presence or absence and location of osteolysis, septic loosening, and metallosis, as well as implant alignment. Fixation was not noted in any device. Femoral osteolysis was observed radiographically in 11 of 18 aseptic hips and categorized by Gruen zone. Acetabular osteolysis was observed medially in 1 MP device. Septic loosening was also observed in 5 of 18 infected hips and categorized by Gruen zone (Figure 2).

Metallosis was noted in 1 SC device. More than 64% of the implants demonstrated acceptable positioning (Table 4).

### Damage Mode Analysis

On disassembly, it was noted that biological or wear debris was captured within the articulation between the femoral head and UHMWPE liner, as well as between the UHMWPE liner and CoCrMo alloy shell, in all BHA devices, regardless of design and cleaning methodology (Figure 3).

None of the retrieved BHA components experienced catastrophic failure; however, laboratory analysis indicated both polyethylene and metallic components experienced damage, with 5 damage modes identified: abrasion, burnishing, embedding, pitting, and scratching/grooving (Figure 4).
scraping/grooving was observed on approximately 72% (n = 26) of liners. Of the observed damage modes, only 4 (grooving/scratching, burnishing, pitting, and embedding) were detected on the metallic components. Scanning electron microscopy revealed the extent of these damage modes on several explants (Figure 5).

Centrax UHMWPE liners demonstrated the highest incidence of pitting corrosion (n = 7 [77%]) and the lowest incidences of abrasion (n = 1 [11%]), burnishing (n = 2 [22%]), and scratching/grooving (n = 5 [56%]). Self-Centering UHMWPE liners exhibited the highest incidence of abrasion (n = 11 [55%]), burnishing (n = 10 [50%]), and embedding (n = 14 [70%]). MultiPolar UHMWPE liners showed the highest incidence of scratching/grooving (n = 7 [100%]) and the lowest incidences of embedding (n = 0 [0%]) and pitting corrosion (n = 2 [29%]).

MultiPolar metallic components (ie, femoral head, femoral stem, and shell) showed the highest incidences of scratching/grooving (n = 4 [57%], n = 5 [83%], and n = 4 [57%], respectively) and pitting corrosion (n = 5 [71%], n = 4 [67%], and n = 3 [43%], respectively) and the lowest incidences of burnishing (n = 1 [14%], n = 0 [0%], and n = 1 [14%], respectively) and embedding (n = 0 [0%] for all components). Self-Centering metallic components showed the highest incidence of burnishing (n = 11 [55%], n = 3 [27%], and n = 12 [60%], respectively).

Analysis of the nonarticulating surface of the UHMWPE liner, which is in contact with the metallic shell, revealed additional damage, with 13 UHMWPE liners showing evidence of impingement (CX, n = 1; SC, n = 9; MP, n = 3).

### Table 4

<table>
<thead>
<tr>
<th>Variable</th>
<th>All</th>
<th>SC</th>
<th>MP</th>
<th>CX: Leaf Locking</th>
<th>SC &amp; MP: Stopper Ring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metallosis</td>
<td>1 (3)</td>
<td>1 (5)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (4)</td>
</tr>
<tr>
<td>Osteolysis</td>
<td>11 (31)</td>
<td>2 (10)</td>
<td>3 (43)</td>
<td>6 (67)</td>
<td>5 (19)</td>
</tr>
<tr>
<td>Lucency (septic hip)</td>
<td>4 (11)</td>
<td>2 (10)</td>
<td>0 (0)</td>
<td>2 (22)</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Cement extrusion</td>
<td>2 (6)</td>
<td>2 (10)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Acceptable alignment</td>
<td>25 (69)</td>
<td>15 (75)</td>
<td>6 (86)</td>
<td>3 (33)</td>
<td>21 (78)</td>
</tr>
<tr>
<td>Varus alignment</td>
<td>10 (28)</td>
<td>3 (15)</td>
<td>1 (14)</td>
<td>6 (67)</td>
<td>4 (15)</td>
</tr>
<tr>
<td>Subsidence</td>
<td>1 (3)</td>
<td>1 (5)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (4)</td>
</tr>
<tr>
<td>Retroversion</td>
<td>1 (3)</td>
<td>1 (5)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (4)</td>
</tr>
</tbody>
</table>

**Abbreviations:** BHA, bipolar hip hemiarthroplasty; CX, Centrax (Stryker Orthopaedics, Mahwah, New Jersey); MP, MultiPolar (Zimmer, Inc, Warsaw, Indiana); SC, Self-Centering (DePuy Orthopaedics, Inc, Warsaw, Indiana).

### Statistical Analysis

Patient demographics and surgical factors, including BMI, age at implantation, age at revision, surgical side, implant term of service, sex, fixation (ie, cemented or uncemented), and implant head size, were compared for each implant design cohort using the Mann-Whitney rank sum test. The significant differences were a greater average BMI in the MP than in the CX designs (P = .03) and an increased rate of cemented fixation in the CX than in the SC designs.
Figure 3: Captured debris from retrieved bipolar hip hemiarthroplasty systems, including Centrax (Stryker Orthopaedics, Mahwah, New Jersey) (A, B), Self-Centering (DePuy Orthopaedics, Inc, Warsaw, Indiana) (C, D), and MultiPolar (Zimmer, Inc, Warsaw, Indiana) (E, F), showing differential sizes in polyethylene wear debris generated in vivo. Scale bar, millimeters.

Figure 4: Graphs showing damage mode analysis of retrieved bipolar hip hemiarthroplasty systems: all (A), Centrax (Stryker Orthopaedics, Mahwah, New Jersey) (B), Self-Centering (DePuy Orthopaedics, Inc, Warsaw, Indiana) (C), and MultiPolar (Zimmer, Inc, Warsaw, Indiana) (D) implant designs.
when comparing any of the other explants. Individual components were also analyzed to assess the relationship between component damage and radiographic observations. For the femoral head, damage modes of scratching/grooving (P = .01), burning (P = .01), and embedding (P < .001) were significantly associated with increased frequency of radiographically observed osteolysis in the CX vs the SC designs. For the UHMWPE liner, scratching/grooving (P < .01), burning (P = .01) and embedding (P < .01) were also significantly related to greater frequency of radiographically observed osteolysis in the CX vs the SC designs. Scratching/grooving (P < .01), burning (P < .001), pitting (P = .01) and embedding (P < .001) damage to the shell were associated with significantly greater frequency of radiographically observed osteolysis in the CX vs the SC designs.

Finally, Spearman rank order analyses correlated the observed damage modes and radiographic data, based on 2 cohorts delineated by locking mechanism (ie, leaf locking [CX] and stopper ring [SC, MP]). Liner abrasion damage was weakly correlated to stopper ring implants (P = .36; P = .03). Several damage modes were more likely to occur in concert. Liner abrasion and third-body embedding damage were positively weakly correlated (P = .33; P = .05). Embedding and burning on the shell were positively moderately correlated (P = .50; P < .01). On the stem, scratching and pitting were positively moderately correlated (P = .54; P = .01). No significant correlations existed between locking mechanism (leaf locking or stopper ring) and radiographically observed osteolysis, metallosis, or cement extrusion.

**DISCUSSION**

Understanding the mechanics and failure mechanisms of orthopedic devices is crucial to development of surgeon technique, patient treatment, and, ultimately, patient outcomes. Bipolar hemiarthroplasty is a viable treatment option for the growing number of femoral neck fractures in the elderly population. However, as with any metal-on-polyethylene articulation, polyethylene debris generation, subsequent osteolysis, and eventual loosening of the implant are potential detrimental consequences.

In the current study, damage modes and rates of osteolysis and aseptic loosening for this series of 36 retrieved bipolar systems were identified and defined. To the authors’ knowledge, this is the first retrieval-based design study for BHA that evaluated all components of each BHA system and related the retrieval analysis to clinical and radiographic data. Due to the retrieval-based nature of this study, a control has not been established to validate revision rates of BHA systems with regard to the observed damage modes; however, sta-
tistical analysis showed the demographics of the cohorts were approximately equivalent, with cemented fixation, implant size, and BMI as the only significantly different factors. A relationship between aseptic osteolysis and implant loosening has been established and is attributed to implant wear.²³,²⁴ Delaminated polyethylene third-body wear particles collected during disassembly of the components (Figure 3), in concert with the observed damage on all of the components, may be a strong predictor of accelerated wear to BHA components. Altered kinematics of the system due to component wear and impingement, as well as the presence of particulate debris, may initiate an inflammatory response.²⁵,²⁶ Microscopy confirmed the presence of bone cement particles and metallic wear debris embedded in numerous polyethylene liners. The accelerated wear by third-body particles may ultimately lead to early device failure or revision.²⁴

When infected cases were excluded, CX explants showed a significantly greater incidence of radiographically observed osteolysis (n=6 [86%]) compared with SC explants (n=2 [29%]). Damage to the CX liners was also significantly associated with radiographically observed osteolysis. The leaf locking mechanism and slotted design of the CX polyethylene liner may create increased surface area and sharp corners, which may then act as locations for stress concentrations, allowing crack initiation and, ultimately, damage and wear of the liner. A statistically significant relationship between radiographically observed osteolysis and implant design was not demonstrated with the stopper ring locking mechanism explants; however, no definitive conclusions can be drawn to implicate design type alone as a generator of increased wear, due to the retrospective nature of this study and the small sample size.

Kusaba and Kuroki²⁸ performed a radiographic wear analysis of 68 un cemented BHAs with Livermore’s method and found that linear wear averaged 1.4 mm in situ (range, 0.2-2.4 mm) and 0.17 mm per year (range, 0.03-0.32 mm/year). They observed deep rim abrasion in osteolytic hips, whereas the current study found scratching/grooving, burnishing, and embedding of debris into the liner to be significantly related to radiographically observed osteolysis. A retrieval analysis of 24 UHMWPE liners by Hara et al²⁷ found that 92% of liners showed signs of neck-cup impingement. Although burnished surfaces were observed on all of the retrieved liners, the authors reported no other localized damage modes. Thus, the authors concluded that the primary cause of osteolysis in their study population was a direct result of the observed impingement and not due to wear debris generated from the bearing surface. The current study observed neck-cup impingement in 13 of 36 retrievals (CX, n=1; SC, n=9; MP, n=3), only 3 of which showed evidence of osteolysis or aseptic loosening radiographically (SC, n=2; MP, n=1).

**CONCLUSION**

Clinical failure of BHA is a multifactorial issue in which the ultimate performance of the implant is affected by patient factors, surgical elements, and implant characteristics. Eventually, component wear may lead to third-body wear particles, resulting in an inflammatory and osteolytic environment, and these elements become contributory factors to clinical failure.²⁷ The current study found that implant design and associated damage modes were significantly associated with the incidence of radiographically observed osteolysis but did not significantly affect the implant term of service. In general, the BHA implants with a leaf locking mechanism exhibited greater incidences of radiographically observed osteolysis and intraoperatively observed loosening than did BHAs with a stopper ring locking mechanism; however, the explants with a stopper ring locking mechanism demonstrated an increased incidence of neck-cup impingement.

Bipolar hemiarthroplasty can provide satisfactory long-term results in the elderly patient population with femoral neck fractures. This study has shown that BHA systems are subject to both polyethylene and metallic component wear, which have been associated with inflammation and osteolysis. With polyethylene delamination encountered in all 3 implant designs, a role may exist for highly cross-linked polyethylene, which is associated with increased wear resistance and increased stability against oxidation, to reduce the wear and eventual migration of wear debris to the adjacent acetabular cartilage.²⁸²⁹ With currently available implants, consideration should be given to patient factors and implant design during hemiarthroplasty selection.

**REFERENCES**


