Abstract
A retrospective radiographic evaluation of 39 acetabularae reconstructed with Trilock™ press-fit components (Depuy, Warsaw, IN) without use of supplementary fixation was performed. The following radiographic criteria were evaluated: change in component inclination angle, migration, osteolytic areas, and radiolucent lines. Acetabular components were considered loose when there was migration greater than four millimeters, change in abduction angle greater than four degrees, or a concentric radiolucent line greater than two millimeters. The average length of follow-up was 12.6 years. Six of the 39 (15.4%) total hip arthroplasties were considered loose. Two (5.1%) of these were revised and four (10.4%) were asymptomatic at the time of latest follow-up. Significant areas of osteolysis were found in 15 hips (38.5%). We conclude that the Trilock™ acetabular component provides adequate fixation and satisfactory long-term results.

The use of cementless acetabular components has resulted in excellent long-term clinical results and is currently preferred for acetabular reconstruction. In studies of primary total hip arthroplasties with a minimum of ten-year follow-up, the survival rate of the press-fit acetabular component shells range from 83% to 98% and 82% to 92% for the liners. These clinical results compare favorably to those of cemented acetabular components, with reports of revision as high as 10% to 20% and loosening rates of 20% to 40% at long-term follow-up. Reports on the Trilock™/anatomic medullary locking (AML) cementless acetabular component have shown revision rates of 8% to 15% at greater than 10-year follow-up, with catastrophic polyethylene wear and osteolysis noted to be the primary modes of failure.

Prosthetic design, implant material, and degree of initial stability determine the extent of biological fixation and ingrowth that can occur with press-fit acetabular components. Initial stability is crucial (greater than 40 micrometers of micromotion can lead to formation of a fibrous membrane at the bone prostheses junction) for establishing bony ingrowth and can be achieved in several ways with pegs, screws, spikes, press-fit fixation, or with a combination of these modalities. Many of the previously noted studies employed supplemental fixation via screws or pegs to augment initial component stability. The porous coated Trilock™ acetabular components used in this study were press-fit and non-augmented.

We investigated this homogenous population of biologically fixed Trilock™ acetabular components to determine: 1. rates of revision, 2. rates of clinical and radiographic loosening, 3. and survivorship at long-term follow-up.

Materials and Methods
Our initial patient population consisted of 59 patients in whom 69 primary total hip arthroplasties were performed between 1983 and 1991. Only those patients with appropriate immediate postoperative and follow-up radiographs were included which resulted in the inclusion of 30 patients (39 hips). Twenty-eight of the remaining 29 patients (29 hips) were noted to have clinically
stable implants based on office notes and latest follow-up radiographs. However, these patients were lacking initial postoperative radiographs and determinations for radiographic loosening could not be performed accurately. Therefore, these patients were excluded from this study.

The mean age at the time of initial surgery was 55.7 years, with a range of 34 to 72 years. Three patients (four hips) were 38 years old or younger, 19 patients (26 hips) between 39 and 64 years old, and eight patients (nine hips) 65 years old or older. There were 18 females (23 hips) and 12 males (16 hips). Twenty total hip arthroplasties were performed on the right hip and 19 on the left hip. Nine bilateral primary joint arthroplasties were performed. The various disorders that led to degenerative joint disease are listed in Table 1. Surviving and non-reconstructed patients had an average length to follow-up of 12.6 years with a range of 9 to 16 years.

All patients had a porous coated, cobalt-chromium Trilock™ acetabular component without holes and a monoblock cobalt-chromium femoral component with a 32 mm femoral head (DePuy, Warsaw, IN) implanted without supplemental fixation. A single surgeon (N.N.T.) performed all surgeries via an anterolateral approach. Routine anti-staphylococcal antibiotics were provided perioperatively for each patient. Appropriate serial radiographs were found in 30 patients (39 hips). Radiographic evaluation consisted of an anteroposterior (AP) and lateral radiograph of the involved hip and an AP radiograph of the pelvis. All radiographs were evaluated for osteolysis, radiolucent lines, horizontal and vertical migration, acetabular inclination angle, and percent of component coverage. One member of the team (R.W.) performed all radiographic measurements and calculations (Fig. 1). These findings were corrected for magnification based on the known dimensions of the femoral head.

Radiographic measurements for cup migration were performed using currently accepted protocols. The perpendicular distance from the prosthetic center of rotation to a horizontal line drawn between the tips of the teardrops (or top of obturator foramen if unable to evaluate inter-teardrop line) was used to determine cup vertical migration. Horizontal migration was measured as the change in distance, from the tips of the teardrops to the perpendicular line from the center of rotation of the prosthesis (Fig. 1).

The cup inclination angle was measured in degrees as the angle formed by a line drawn along the bottom of the acetabular component intersecting with the horizontal inter-teardrop line. Acetabular coverage was measured as an estimate of the percentage of the shell that was covered with host bone as seen on AP pelvis and hip radiographs.

Radiolucent lines were defined as areas adjacent to the prosthesis of decreased radiodensity that appeared on follow-up radiographs that were not present on previous radiographs. Radiolucent lines were recorded in mil-

<table>
<thead>
<tr>
<th>Primary Diagnosis</th>
<th>Number of Patients</th>
<th>Number of Hips</th>
<th>Number of Hips Revised</th>
<th>Number of Hips Loose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osteoarthritis</td>
<td>20</td>
<td>25</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Rheumatoid Arthritis</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Osteonecrosis</td>
<td>8</td>
<td>11</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Posttraumatic OA</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Totals</td>
<td>30</td>
<td>39</td>
<td>2</td>
<td>4</td>
</tr>
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</table>

Figure 1 Schematic depicting technique used to measure acetabular inclination (A), cup height (B), component migration (C), percentage of cup coverage as well as areas of osteolytic lesions (based on the area of an ellipse).
limeters of thickness and were measured in each of the three zones described by Charnley and DeLee.\textsuperscript{21} Osteolysis was defined as any focal area of endosteal, intracortical, or cancellous bone loss greater than five millimeters and adjacent to the acetabular component.\textsuperscript{19,20,22} Using plain radiographs, areas of osteolysis were measured with calipers using the maximum diameter and the widest diameter perpendicular to this, for each of the three acetabular zones.\textsuperscript{23} These values were then used to calculate the area of an ellipse, which served as an estimate of the total area occupied by each osteolytic lesion.

Following the radiographic criteria of Yoder and colleagues,\textsuperscript{17} acetabular loosening was defined as migration of greater than 4 mm, an acetabular abduction angle change of greater than 4°, or a concentric radiolucent line greater than 2 mm around the entire cup. Final measurements were segregated into three categories: stable components, radiographically loose components, and revised components (Table 2). The Kaplan-Meier estimate of survival was used to generate survivorship curves for endpoints of revision and component loosening.\textsuperscript{24}

### Results

**Radiographic Analysis**

Table 2 represents a summation of radiographic analysis, dividing the results into three categories: stable, radiographically loose, and revised components. The average cup inclination was 46.5°, 54.8°, and 57.5° in those cups that were stable, radiographically loose, and revised, respectively. Change in the acetabular inclination angle was found to be higher in those cups revised (8.5°) and those considered loose (6.3°), compared to those patients with a stable component (1.4°).

Osteolytic lesions were found in 15 hips (38.5%) and classified in the zones of DeLee and Charnley.\textsuperscript{21} Four hips were found to have lesions in zone I, two of which underwent revision surgery. Osteolytic lesions in zone II were seen in two hips, one of which underwent revision. Zone III was the most common site for osteolytic lesions, occurring in 14 hips. In all radiographically loose or revised cases, osteolytic lesions were found in zone III. Three cases had osteolytic lesions affecting multiple zones, two hips with two zones and one hip with all three zones. The average area of osteolysis for stable implants was found to be 187 mm\textsuperscript{2}; while, measurements in those considered loose and those revised were 691 mm\textsuperscript{2} and 1470 mm\textsuperscript{2}, respectively.

Radiolucent lines were measured in four hips (10.2%). There were two cases involving continuous radiolucent lines involving all three DeLee and Charnley zones.\textsuperscript{21} One line was greater than 2 mm concentrically around the acetabular component and the hip was eventually revised. The second hip measured less than 2 mm and was associated with a hip considered radiographically loose. In total, three hips had radiolucent lines measured in zone I, two hips in zone II, and four hips in zone III. The percentage of acetabular coverage averaged 95% for all cases.

### Revision Cases

At a minimum follow-up of 9 years, two of 39 hips (5.1%) were revised. Table 3 highlights the details of these cases. Both cases displayed significant migration and change in component inclination at 13 and 11 years follow-up. The average time to revision was 12 years.

**Case 1.** A 54-year-old female presented with progressively worsening hip and groin pain 13 years after a primary total hip replacement. Plain radiographs at that time revealed evidence of aseptic loosening of the acetabular component (migration of 9 mm and change in inclination of 10°). At the time of surgery she was found to have gross loosening of the acetabular component and significant eccentric wear of the polyethylene liner. The patient underwent revision of the acetabulum and polyethylene liner and debridement of the cystic lesion.

### Table 2: Comparison of Radiographic Findings for Loose, Revised, and Stable Implants

<table>
<thead>
<tr>
<th></th>
<th>Average Change in Acetabular Inclination</th>
<th>Average Acetabular Migration</th>
<th>Average Change in Acetabular Height</th>
<th>Average Area of Osteolysis</th>
<th>Average Percent of Acetabular Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loose implants</td>
<td>6.3°</td>
<td>3.5 mm</td>
<td>2.3 mm</td>
<td>691 mm\textsuperscript{2}</td>
<td>100%</td>
</tr>
<tr>
<td>Revised implants</td>
<td>8.5°</td>
<td>4.5 mm</td>
<td>4.0 mm</td>
<td>1470 mm\textsuperscript{2}</td>
<td>100%</td>
</tr>
<tr>
<td>Stable implants</td>
<td>1.39°</td>
<td>1.2 mm</td>
<td>0.79 mm</td>
<td>187 mm\textsuperscript{2}</td>
<td>94%</td>
</tr>
</tbody>
</table>

### Table 3: Details of Revision Cases

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (years)</th>
<th>Gender</th>
<th>Primary Diagnosis</th>
<th>Time to Revision (years)</th>
<th>Reason for Revision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>54</td>
<td>Female</td>
<td>Osteoarthritis</td>
<td>13</td>
<td>Acetabular loosening – migration 9 mm, change in inclination 10° continuous radiolucent line, zone III osteolysis (24x4), and particulate debris.</td>
</tr>
<tr>
<td>2</td>
<td>51</td>
<td>Male</td>
<td>Osteoarthritis</td>
<td>11</td>
<td>Acetabular loosening – migration 5 mm, change in inclination 7°, zone III osteolysis 28x30.</td>
</tr>
</tbody>
</table>
without complication.

Case 2. A 51-year-old male with a history of primary osteoarthritis presented with hip pain 11 years after a primary total hip replacement. Radiographic evaluation revealed a well-fixed femoral component and acetabular loosening. Migration and change in inclination angle greater than 4 mm and 4° was noted, as well as a large, expansive area of osteolysis in zone III. At the time of revision surgery, the patient was noted to have a grossly loose acetabular component, significant polyethylene liner wear, and a large cystic lesion in zone III. He underwent revision of the acetabular component and liner with bone grafting of the lesion in zone III with morselized allograft.

According to the previously ascribed radiographic criteria, four (10.8%) of the remaining 37 hips were considered loose, but remained clinically asymptomatic at latest follow-up (Table 4). All four cases were noted to have a change in component inclination of greater than 4°. The average time to loosening for these cases was 11.8 years, with a range of 9 to 16 years. No demographic bias was noted for the cases requiring revision or those considered radiographically loose.

Kaplan-Meier Curves

Figure 2 represents the Kaplan-Meier estimates for survival of Trilock™ press-fit acetabular components implanted without supplemental fixation. The graphs include curves for both revision and loosening as endpoints.

Discussion

Biological fixation of the acetabular component in total hip arthroplasty has become the preferred operative method. While some component designs have enjoyed excellent long-term survival, others have been less successful. During many of these studies, supplemental fixation of the acetabular component with pegs or screws was performed. In this study, all patients received the same component, implanted by the senior surgeon (N.N.T.) via a uniform approach. In all cases, a press-fit of the acetabular component was achieved and no supplemental fixation was required. Survival results in this study are similar to previous studies at long-term follow-up, 100% and 95% survival rates of the acetabular components at 10 and 15 years, respectively. With radiographic loosening as the endpoint, cup survival rates decreased to 95% at 10 years and 91% at 15 years.

Osteolysis is the most common long-term complication of total hip surgery, with numbers that surpass the incidence of sepsis, dislocation, nerve injuries, and others. Significant rates of osteolysis have been found with the use of cementless acetabular components, ranging from 4% to 76% in primary total hip arthroplasties and 38.5% in this study. The development of osteolysis is multifactorial and is influenced by component design, position, femoral head size, polyethylene thickness, ster-
ilization techniques, and type of polyethylene. The correlation between osteolysis and component loosening is often difficult to ascertain.

Zicat and associates have shown that areas of osteolysis around press-fit acetabular components tend to be localized and expansive. These areas of bone loss portend a significant challenge at time of revision surgery and may constitute an indication for revision surgery itself. While such areas may appear expansive on pre-surgical radiographs, there always tends to be greater bone loss found intra-operatively. Despite these large osteolytic areas, patients are typically asymptomatic until component migration or fracture of the acetabulum occurs. In both revision cases and in all radiographically loose components in this study, large expansile areas of osteolysis were found. It is likely that these lesions were precursors to component migration and subsequent symptomatic aseptic loosening. The timing of revision surgery for these patients still remains a question. Do the risks and benefits of restoring acetabular bone stock with early surgical intervention outweigh those of operating on asymptomatic patients? Recent studies have shown that debridement and/or bone grafting of these lesions at the time of polyethylene liner exchange, resulted in resolution or arrest of the osteolytic process. This study supports the need for appropriate long-term follow-up and radiographic analysis to detect polyethylene wear and expanding areas of osteolysis before radiographic and in vivo evidence of component loosening occur.

Further studies with larger patient numbers are required to pinpoint the extent of osteolysis at which revision surgery should be performed. Some of the limitations in our study include relatively small patient numbers, use of hand instruments to perform our radiographic analysis, and a large number of patients that had to be excluded due to incomplete X-ray files. Twenty-eight of these 29 patients are known to be doing well clinically at latest follow-up and one underwent revision for loosening of both acetabular and femoral components. Inclusion of these patients would increase the survival rate of the Trilock™ cups, however, appropriate radiographic measurements could not be determined for this population and thus they were excluded. The high rate of osteolysis (38.5%) may be related to the relatively large femoral head (32 mm) used with these components. Lee and coworkers have shown that increasing femoral head size from 26 mm to 32 mm increased the incidence of osteolysis from 24% to 48% in primary total hip arthroplasty. Despite some of these limitations, the Trilock™ press-fit cup without supplemental fixation provided satisfactory long-term survival rates (Fig. 2).

In conclusion, the Trilock™ press-fit acetabular component provided good long-term survival rates. The concerning rate of osteolysis is consistent with past investigations of hip arthroplasties in which relatively large femoral heads were used. Changes in design, materials, and new pharmacotherapies are currently being studied to target these high levels of osteolysis associated with cementless primary total hip arthroplasty.

Acknowledgments
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References