Glenoid perforation does not affect the short-term outcomes of pegged all-polyethylene implants in total shoulder arthroplasty

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\textbf{Background:} The glenoid vault can be perforated during pegged glenoid preparation in total shoulder arthroplasty. The clinical implications of glenoid vault perforation, however, are unknown. The purpose of this study was to determine the effects of perforation of the glenoid during total shoulder arthroplasty on clinical and radiographic outcomes.

\textbf{Materials and methods:} Eighteen patients with known intraoperative glenoid perforations were prospectively identified and compared with 34 patients matched by age, gender, diagnosis, and arm dominance during the same period. Patients were evaluated with multiple outcome scores. Radiographs were evaluated for glenoid lucency immediately postoperatively and at final follow-up.

\textbf{Results:} Average follow-up was 28.1 months for the perforated group and 31.2 months for the matched controls. Both groups had significant improvements in outcome scores postoperatively. American Shoulder and Elbow Surgeons scores increased from 39.8 to 91.0 ($P < .001$) in the perforated group and from 36.9 to 82.6 ($P < .001$) in the control group. Constant scores increased from 24.4 to 77.4 ($P < .001$) in the perforated group and from 36.9 to 75.6 ($P < .001$) in the control group. Ninety-four percent of the perforated group and 80% of the matched controls were satisfied or very satisfied with their result ($P = .896$). The presence and number of perforations were not related to the American Shoulder and Elbow Surgeons score ($P = .549$), Constant score ($P = .154$), or radiographic lucency grade ($P = .584$).

\textbf{Conclusions:} Glenoid perforation during pegged glenoid preparation in total shoulder arthroplasty does not seem to have an adverse effect on clinical or radiographic outcomes at an average of 2 years of follow-up.

\textbf{Level of evidence:} Level III, Case Control Design, Treatment Study.
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\textbf{Keywords:} Glenoid perforation; total shoulder arthroplasty; pegged implants; outcomes

Hemiarthroplasty has been used to treat many shoulder conditions with success, but patient satisfaction has been shown to decrease over time.\textsuperscript{8} Several studies have suggested that total shoulder arthroplasty (TSA) yields better patient satisfaction and improved pain scores compared...
with hemiarthroplasty alone in patients with osteoarthritis. Furthermore, TSA has been shown to be more appropriate than hemiarthroplasty for inflammatory arthropathy as well. The drawbacks of TSA include the time and technical skill needed to prepare and to place the glenoid implant and the long-term failure of the construct due to glenoid implant wear and loosening. Achieving stable fixation of the glenoid component in TSA remains a key to long-term success.

Many studies have focused on the various factors necessary to achieve appropriate fixation. These include surgical technique, implant design, and cementing method. Containment of the prosthetic implant within the glenoid vault has also been thought to play a role in prosthetic longevity. Potential vault perforation during preparation of the glenoid component has been postulated to lead to early loosening by eliminating cement containment and by decreasing the cementing pressure necessary to achieve stable fixation. Clinical investigation has been undertaken in this area in an attempt to determine glenoid components that decrease the likelihood of perforation. Unfortunately, many glenoid perforations may go undetected at the time of surgery, which limits the ability to identify this as a definitive cause of early glenoid loosening. This study is the first of its kind and aims to demonstrate prospective outcomes of patients with known intraoperative glenoid vault perforations with comparisons to a cohort without perforations and presents data at 2 years’ follow-up.

**Materials and methods**

Between 2004 and 2007, a consecutive series of primary, anatomic TSAs by use of a single system were collected with documentation of any glenoid vault perforations. All glenoid components used in the study consisted of 4 peg holes in an inverse-T configuration. Intraoperatively, all glenoid peg holes were tested with a sounder to ensure that the drill hole was contained. All perforations were documented and detailed as to their location on the glenoid (anterior, posterior, superior, central). All glenoid morphology was also documented as described by Walch.

These perforation patients were observed prospectively with Constant and American Shoulder and Elbow Surgeons (ASES) scores and with serial radiographs. Our practice’s research database was searched for a cohort of patients who matched as closely as possible the perforation cohort for the following set of variables: age, sex, diagnosis, and arm dominance. This multiple-variable matching process provided for multiple comparison points per perforation patient, with the nearest match on the entire set of variables rather than on any single variable. Consequently, the groups differed slightly with respect to some of the specific matching variables but were similar on the multivariate aggregate. Use of several comparison cases for each perforation case, when available, improved the consistency and precision of the statistical estimates. Ultimately, the 18 patients with known glenoid perforations were matched with 34 patients without perforation and observed for an average of more than 2 years.

**Patient characteristics**

Women represented 12 of 18 (67%) patients in the perforation group and 14 of 34 (41%) in the control group. Ages were nearly identical (69.3 ± 6.8 years for the perforation group and 69.0 ± 8.3 years for the control group). Difference in body mass index was not significant between groups (30.7 ± 6.3 vs 29.4 ± 5.8; *P* = .527). Osteoarthritis represented the majority of cases (10 of 18 in the perforation group; 30 of 34 in the control group), followed by revision arthroplasty and rheumatoid arthritis.

**Patient evaluation**

All patients underwent a comprehensive history and physical examination, including range of motion, and standard shoulder radiographs (anterior-posterior, axillary lateral, and scapular lateral). Secondary imaging was also employed to better determine glenoid morphology by either computed tomographic arthrography or magnetic resonance imaging.

**Surgical technique**

All patients underwent a conventional TSA with a single system (Tornier, Bloomington, MN, USA) through a standard deltopectoral approach. The subscapularis was managed with a tenotomy, leaving a stump of tissue laterally to allow an end-to-end repair, and the glenohumeral ligaments and capsule surrounding the tendon were released to increase excursion. The humeral head was osteotomized at the level of the anatomic neck and the humerus was prepared for implantation of a press-fit prosthesis. An inferior capsular release was performed along the anterior and inferior portions of the glenoid neck to provide adequate visualization. Once the correct glenoid size was chosen, a central peg hole was drilled and then reamed with the aim to remove only articular cartilage and to provide a concentric backing for the glenoid component. Eccentric reaming was performed whenever appropriate (on the basis of preoperative imaging) to correct for the increased retroversion seen in some cases of osteoarthritis. A peripheral drill hole guide was used to place the holes for the pegged glenoid component. On completion of these drill holes, all 4 (superior, anterior, posterior, central) were carefully probed to ensure that there was bone containment throughout. The location of any breach was recorded. The glenoid was then irrigated, and the 4 peg holes were filled with methyl methacrylate under pressure by use of a tipped syringe and modern cementing techniques. No cement was placed on the back of the glenoid component. The glenoid was then impacted into place and held under pressure until the cement polymerized. The humeral component was then implanted, and glenohumeral mismatch was calculated on the basis of the size of the implants. The subscapularis was closed with multiple high-tensile, nonabsorbable sutures with both transtendinous and transosseous purchase, and a running, absorbable suture was placed over the top for reinforcement. The wound was irrigated and closed in layers. Postoperatively, patients were given a simple sling; at their 1-week follow-up appointment, aquatic physical therapy was prescribed with primary limitations aimed at protecting the subscapularis repair.
Follow-up outcomes assessment

All patients were assessed by Constant, WOOS, and ASES scores. Radiographic assessment of glenoid components was performed in a fashion similar to previously published studies at our institution.3,5 Radiographs were obtained 1 week postoperatively by fluoroscopic and magnification-controlled techniques to ensure that the beam was perpendicular to the bone-implant interface. Lucency about the glenoid component was graded according to Lazarus,7 which was a modification of the original classification proposed by Franklin et al.4 The images were viewed with a digital radiographic viewer (SwissVision Workstation; SwissRay, East Brunswick, NJ, USA), which allowed on-screen annotation as well as contrast modifications to ensure optimal visualization. These high-resolution images were viewed at a single viewing station under standard lighting conditions and employing the same radiographic protocol. Radiographs were evaluated by 2 raters who independently reviewed all images. As follow-up images were obtained, the 2 reviewers would review the new images on the same day, eliminating the ability for the reviewer to view previous patients’ images side by side.

Statistical analysis

Means and standard deviations were computed in both groups for all variables. The $\kappa$ statistic was used to evaluate interobserver agreement for the radiographic ratings. Preoperative to postoperative changes in outcome scores were compared between groups by a mixed linear model that accounted for the matched (clustered) design as well as repeated measures. The IBM SPSS Statistics (IBM Corporation, Armonk, NY, USA) statistical software application was used for data analysis. Statistical significance was set at $P < .05$.

Results

Average follow-up was 28.1 (12-60) months for the perforation group and 31.2 (12-72) months for the control group ($P = .354$). All patients regardless of group demonstrated statistically significant improvements in both ASES and Constant scores ($P < .001$). In comparison between groups, only the activity portion of the Constant score showed a statistically significant difference, with the perforated group performing better than the controls ($P = .036$). Both groups reported being satisfied or very satisfied with their functional outcome (79.4% of the controls and 94.4% of the perforated group ($P = .549$). No significant differences in glenoid morphology or glenohumeral mismatch were found ($P = .613$). Approximately half (56%) of the perforated glenoids took place in the setting of medium-sized components. Full outcomes data are seen in Table I.

Of 18 patients with perforations, 11 had only a single perforation; 6 patients had 2 perforations and 1 patient had 3 perforations. Perforations tended to be located superiorly.

<table>
<thead>
<tr>
<th>Table I</th>
<th>Preoperative and postoperative outcome data for both the perforated and control groups</th>
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<tbody>
<tr>
<td></td>
<td>Control group</td>
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<tr>
<td></td>
<td>Preoperative</td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant strength</td>
<td>4.3 ± 6.7</td>
</tr>
<tr>
<td>Constant pain</td>
<td>3.8 ± 2.8</td>
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<tr>
<td>Constant activity</td>
<td>8.1 ± 3.7</td>
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<tr>
<td>Constant mobility</td>
<td>10.7 ± 6.5</td>
</tr>
<tr>
<td>Constant total</td>
<td>36.9 ± 13.1</td>
</tr>
<tr>
<td>Constant adjusted</td>
<td>34.4 ± 16.1</td>
</tr>
<tr>
<td>ASES</td>
<td>36.9 ± 19.4</td>
</tr>
<tr>
<td>WOOS</td>
<td>68.7 ± 17.2</td>
</tr>
<tr>
<td>Forward flexion</td>
<td>81.3 ± 28.2</td>
</tr>
<tr>
<td>External rotation</td>
<td>14.6 ± 12.0</td>
</tr>
<tr>
<td>Abduction</td>
<td>76.0 ± 27.1</td>
</tr>
</tbody>
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ASES, American Shoulder and Elbow Surgeons score; WOOS, Western Ontario Osteoarthritis of the Shoulder index.

* Statistical significance.

Figure 1  Postoperative radiograph of a patient with glenoid perforation after TSA. Arrows indicate extruded cement from the center and superior holes.
analyzed various glenoid prosthetic designs using computer simulations that tested perforation tolerance in various degrees of anatomic version to determine distances before perforation. They concluded that knowledge of the tolerances of various glenoid prostheses will help surgeons prevent inadvertent perforations.

Perforations, however, may not always be preventable. Patients with excessive glenoid retroversion or medialization may not possess the necessary bone stock to prevent perforation during glenoid preparation. Furthermore, studies demonstrating superiority of pegged components over keels require that bone stock be present in the glenoid periphery to support the component. This inherently places an increased risk of peripheral perforation in glenoids that are small or possess significant bone loss. This study found that more than half of the perforations took place in medium-sized glenoids (i.e., a smaller glenoid face).

Our study demonstrates that at an average of 2 years of follow-up, there are no early deleterious effects of inadvertent glenoid perforation compared with a matched cohort in an unconstrained TSA when pegged glenoid components are used with modern cementing techniques. Both groups demonstrated significant improvement in shoulder scores, with no group showing superiority. Furthermore, radiographic evaluation for prosthetic radiolucency demonstrated no compromise in radiolucent line scoring. Whereas the long-term clinical consequences of glenoid prosthetic radiolucency remain unanswered, the short-term results of this study show no increase in radiolucency from perforation.

Strengths of this study include being the first of its kind to evaluate prospective outcomes in patients with glenoid perforation with an average of 2 years of follow-up. Each patient was evaluated intraoperatively to ensure the status of each glenoid and compared with patients without perforation. In addition to clinical outcomes, radiographs were also reviewed by use of previously published scoring systems to evaluate for radiolucent lines. Finally, by creating a matched cohort, we were better able to eliminate confounding variables to isolate the variables studied.

Whereas the collection of patients was performed prospectively in a consecutive series, the outcomes were studied retrospectively, which is prone to its inherent flaws. Because not all of the patients were treated for primary osteoarthritis, additional complicating factors may play a role, including biologic ones. Finally, given an average follow-up of more than 2 years, additional investigation will be necessary to determine the mid-term to long-term effects of glenoid perforation.

**Conclusion**

Clinical and radiographic outcomes of pegged glenoid components in the setting of glenoid vault perforation do

<table>
<thead>
<tr>
<th>Table II</th>
<th>Distribution of glenoid morphology</th>
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<tbody>
<tr>
<td>Glenoid morphology</td>
<td>Control (% within group)</td>
</tr>
<tr>
<td>A1</td>
<td>17 (50%)</td>
</tr>
<tr>
<td>A2</td>
<td>5 (14.7%)</td>
</tr>
<tr>
<td>B1</td>
<td>6 (17.6)</td>
</tr>
<tr>
<td>B2</td>
<td>5 (14.7)</td>
</tr>
<tr>
<td>C</td>
<td>1 (2.9)</td>
</tr>
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</table>

(13 patients), with an equal number (5) located anteriorly and posteriorly. Three perforations took place centrally. The number and location of perforations did not have any significant relation to ASES score \(P = .290\), Constant score \(P = .154\), or range of motion \(P \geq .100\). A radiograph demonstrating cement extrusion secondary to glenoid perforation is seen in Figure 1.

The immediate postoperative radiographs revealed only one glenoid component with radiolucency grade 1 in the perforated group; all other glenoids in both groups were rated grade 0. At latest follow-up, 28% of the perforated group showed grade 2 or higher radiolucency versus 35% in the control group \(P = .290\). Interobserver reliability between the 2 observers demonstrated a \(k\) coefficient of 0.65, defined as a moderate to high correlation. The reviewers were in complete agreement on the radiolucency grade 87% of the time, and all but 2 patients were within one category of each other. The number of perforations was unrelated to radiolucent grade \(P = .884\).

Glenoid morphology was noted to have an effect on Constant scores. The distribution of glenoid morphology is seen in Table II. B2 glenoids showed worse scores compared with A1s. B1 glenoids showed lower scores than A2s \(P = .039\). Morphology did not show any difference between perforation and control groups \(P = .222\).

**Discussion**

Implantation of a durable, stable glenoid component remains a challenge in unconstrained TSA. Recent advancements in surgical technique and implant technology continue to afford patients the potential for long-term success. Avoidance of perforation of the glenoid vault during preparation has been described as a technical aspect necessary to promote cement pressurization and interdigitation within the cancellous bone and the implant.\(^9\) Despite this, glenoid perforation does occasionally occur, and its implications have remained unknown. This study is the first of its kind to observe patients with known intraoperative perforations and provides data about their outcome.

Much of the work on glenoid perforation centers around glenoid 3-dimensional reconstructions or computer models with simulations of glenoid volumes. Ting and Poon\(^13\) analyzed various glenoid prosthetic designs using...
not show adverse effects at an average of 2 years of follow-up. Additional follow-up will be needed to ascertain longer term consequences.

Disclaimer

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