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Inferior Glenosphere Placement Reduces Scapular Notching in Reverse Total Shoulder Arthroplasty

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abstract

Scapular notching is a common complication after reverse shoulder arthroplasty and has been associated with poor clinical outcomes. Factors associated with notching include neck shaft angle and glenosphere position. The goal of this study was to evaluate the incidence of notching with an eccentric glenosphere that allows for inferior offset as well as its effect on clinical outcome. The charts of 82 patients who underwent reverse shoulder arthroplasty with this eccentric glenosphere were retrospectively reviewed. Scapular notching was assessed with standard anteroposterior radiographs of the glenohumeral joint according to the Nerot-Sirveaux classification system. Two experienced observers evaluated all radiographs. The presence of radiolucent lines was also evaluated. Both range of motion (ROM) and Constant-Murley scores were obtained. Average age was 74 years (range, 61-91 years), and follow-up was 26.3 months (range, 19-39 months). According to the Nerot-Sirveaux classification, 73 (89%) had no notching, 5 (6%) had grade I notching, 2 (2.5%) had grade II notching, and 2 (2.5%) had grade III notching. The overall presence of notching was 11% and correlated to the amount of inferior offset. No radiolucent lines were seen around the prosthesis. Both ROM and Constant-Murley scores (from 31.3 to 74.2) improved significantly in all patients from preoperative evaluation to final follow-up ($P<.05$). No significant differences in ROM and functional outcome were seen between the groups with and without notching. The inferior offset glenosphere created with this glenosphere base plate design reduced the incidence of scapular notching in reverse shoulder arthroplasty. This was particularly true when the glenosphere was maximally offset inferiorly. In the short term, notching does not affect ROM or functional outcome. [*Orthopedics*. 2015; 38(2):e88-e93.]

Figure: True anteroposterior plain radiograph of the Comprehensive Reverse Shoulder System (Biomet Inc, Warsaw, Indiana). Grade I notching is seen on the postoperative radiograph.

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Reverse total shoulder arthroplasty has become the standard of care for patients with disabling cuff tear arthropathy, failed total shoulder arthroplasty, and sequelae of trauma.[1-13] The reported clinical results have been satisfactory in these challenging pathologic cohorts. Recent advances in technology and surgical techniques have resulted in improved patient outcomes and subjective patient satisfaction.[12] This has led to expanded indications, including proximal humerus fractures in the elderly and reconstruction after tumor resection.[4,9] Unfortunately, there has also been a relatively high complication rate associated with reverse shoulder arthroplasty, and one of the most frequently reported complications is scapular notching.[13-23] Scapular notching was originally reported by Sirveaux et al[11] and is, by definition, erosion of the scapular neck secondary to impingement of the humeral component during adduction after reverse shoulder arthroplasty. It is a common complication after reverse shoulder arthroplasty, with a prevalence of 44% to 96%, as reported in the literature.[12,22,23] In a recent systematic analysis of complications in reverse shoulder arthroplasty, scapular notching accounted for 52% of all complications reported and was associated with medialization of the glenosphere component that is typically seen with the Grammont-style prosthesis.[13] Although the long-term clinical consequences are unclear, scapular notching appears to be associated with inferior mid-term clinical outcomes, especially after 5 years.[13,19,20,24] Several studies have also implicated scapular notching as a cause of glenosphere component loosening due to repetitive stress that resulted in poorer clinical outcomes.[3,11,25,26] Roche et al[27] further showed a correlation between severe notching and initial base plate stability in a cadaver biomechanical model.

The potential causes of scapular notching have been extensively evaluated both clinically and biomechanically. The causes appear to be related to component design, size, humeral neck shaft angle, positioning of the glenosphere, and surgical indications.[28] Lateral or inferior glenosphere offset and inferior tilt have been advocated to prevent or limit scapular notching in a number of recent studies.[11,18,22,28,29] Clearly, superior offset placement or superior tilt contributed to scapular notching in reverse shoulder arthroplasty, with disastrous clinical and radiographic effects.[5,20] In contrast to the studies noted earlier, Edwards et al[15] recently reported no significant decrease in the rate of notching with the glenosphere placed with an inferior tilt compared with the neutral position. Their study reported an incidence of notching in 75% vs 86% of patients when the inferior tilt was compared with the neutral position, respectively. Mulieri et al[10] reported that lateralization of the glenosphere decreased the notching rate to 13.4%. In response to these results, Boileau et al[28] advocated a biologic lateralizing technique with humeral head bone graft (BIO-RSA) (Tornier Aequalis Ascend Flex Reverse Shoulder Arthroplasty; Tornier, Bloomington, Minnesota). With this technique, their scapular notching rate was reduced to less than 19%.

The goal of the study was to identify the effect of a component design that allows eccentric positioning of the glenosphere on scapular notching with a minimum of 12 months of follow-up (Comprehensive Reverse Shoulder System; Biomet Inc, Warsaw, Indiana). This system is designed to allow multiple lateral and inferior offset options as well as inferior tilt of the glenosphere. Specifically, the eccentricity of the glenosphere allows the surgeon to adjust inferior offset according to patient anatomy at multiple increments in millimeters (**Figure 1**). The authors hypothesized that the rate of radiographic scapular notching would be reduced according to the amount of inferior glenosphere offset and that notching would not affect clinical outcome at short-term follow-up.

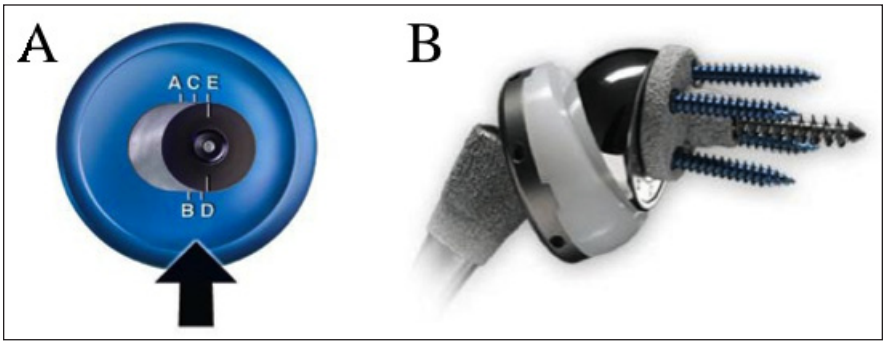

Figure 1: Eccentric glenosphere trial component of the Comprehensive Reverse Shoulder System (Biomet Inc, Warsaw, Indiana) (A). Settings A to E represent the different increments in millimeters. The eccentric glenoid is seen on the final implant (B). The amount of inferior offset is determined with rotation of the glenosphere onto the metaglene.

Materials and Methods

A retrospective radiographic study was performed within a prospective follow-up of reverse shoulder arthroplasty procedures performed with the Comprehensive Reverse Shoulder System. The study was approved by the institutional review board. The authors reviewed the charts of the first 100 patients who underwent reverse shoulder arthroplasty with the prosthesis described earlier. Of this group, 82 were available for a minimum of 12 months of follow-up. Four experienced shoulder surgeons performed all procedures (J.S.D., R.F.W., E.V.C., and D.M.D.). The study group included 50 women and 32 men. The initial indication for surgery was cuff tear arthropathy in 63 patients, acute and chronic trauma in 5 patients, and revision total shoulder arthroplasty in 14 patients. Inferior scapular notching was assessed with true

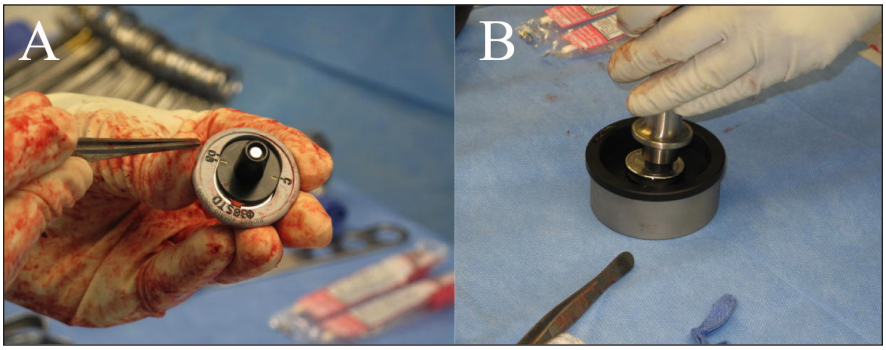

Figure 2: The trial glenosphere component size is determined intraoperatively. The different settings (A-E) are seen on the side of the trial component (A). The final glenosphere component is assembled in the eccentric offset position according to the size determined with the trial components (B).

Figure 3: True anteroposterior plain radiograph of the Comprehensive Reverse Shoulder System (Biomet Inc, Warsaw, Indiana). Grade I notching is seen on the postoperative radiograph.

anteroposterior radiographs in the plane of the scapula (Grashey view) of the glenohumeral joint using the Nerot-Sirveaux classification.[11] This classification system is divided into 5 grades. Grade zero is no notching. Grade I notching is a defect within the inferior pillar of the scapular neck that does not extend to the inferior screw. Grade II is erosion of the notching to the level of the most inferior fixation screw. Grade III is extension of the notching or erosion past the inferior screw. The last and most severe grade is grade IV, which is described as extension of the notching to the undersurface of the base plate or instability. Two experienced orthopedic surgeons (X.L., J.S.D.) reviewed all of the radiographs. If they disagreed in their assessment, a third experienced orthopedic surgeon (D.M.D.) reviewed the radiograph to assist in the final grading. The authors evaluated the amount and degree of inferior glenosphere offset or inferior tilt in these patients on the latest follow-up radiograph. They evaluated the dial setting of the glenosphere component (A-E) as well as the relationship of the glenosphere to the metaglene. The presence of radiolucent lines and base plate loosening was also evaluated. Furthermore, range of motion (ROM) and Constant scores were recorded during the preoperative visit and at final follow-up. Statistical analysis was performed with Student's *t* test, with significance set at $P<.05$.

The base plate and glenosphere (36 mm or 40 mm) of this particular reverse shoulder arthroplasty system is an eccentric design that can be dialed to 5 different settings (A-E). Position A corresponds to an inferior offset of 0.5 mm, B corresponds to 1.5 mm, C corresponds to 2.5 mm, D corresponds to 3.5 mm, and E corresponds to 4.5 mm. In the standard glenosphere (36 mm), the offset range is 1.5 to 3.5 mm (B-D). Once the correct inferior offset position is determined intraoperatively, the taper adaptor of the final implant is aligned to the setting (A-E) as indicated on the undersurface of the glenosphere (**Figure 2**). The humeral stem of this prosthesis has a neck shaft angle of 135° and the liner has an angle of 12°, giving the final assembled prosthesis an angle of 147°.

Results

Average patient age was 74 years (range, 61-91 years), and average follow-up was 26.3 months (range, 19-39 months). According to the Nerot-Sirveaux classification,[11] 73 (89%) of patients had no notching, 5 (6%) had grade 1 notching (**Figure 3**), 2 (2.5%) had grade II notching, and 2 (2.5%) had grade III notching. The overall presence of notching was 11%. In 37 patients with the maximum inferior offset of 2 to 4 mm, no radiographic notching was observed. Of the 33 patients with 0 to 2 mm of minimal inferior offset, 2 showed evidence of grade III notching and 4 had grade 1 notching. In the 3 patients with no inferior offset (0 mm), 1 had grade I notching and 2 had grade II notching (**Table**). Most of these patients also had some degree of inferior tilt. The patient with grade III notching, a 76-year-

Table

Grade of Scapular Notching Versus Amount of Inferior Offset of the Glenosphere

Scapular Notching	Inferior Offset 0 mm (3 Patients)	Inferior Offset 0-2 mm (33 Patients)	Inferior Offset 2-4 mm (37 Patients)
Grade I	1	4	0
Grade II	2	0	0
Grade III	0	2	0

old man with metastatic prostate cancer to the glenoid that was not recognized preoperatively, also had evidence of loosening of the base plate (**Figure 4**). No other patient showed any sign of base plate lucency or loosening.

Both ROM (forward elevation, from 59° to 121°, $P<.05$; abduction, from 70° to 108°, $P<.05$; and external rotation, from 12° to 31°, $P<.05$) and Constant-Murley scores significantly improved in all patients from the preoperative examination (31.3) to final follow-up (74.2) ($P<.05$). No significant differences in ROM and functional outcome were seen between the groups with and without notching ($P>.05$). No intraoperative complications were associated with implantation of the glenosphere in the inferior offset with this glenosphere using a dialed mechanism (A-E settings). Of the 36 patients who were available for 2 or more years of follow-up, only 1 had progression of notching from grade I to grade II.

Discussion

Scapular notching is a well-reported finding in many clinical series evaluating the results of reverse shoulder arthroplasty.[2,6,11,13,14,19,20,22,23,27,28,30-33] This finding was first described by Sirveaux et al[11] and confirmed in a recent systematic literature review that reported an incidence of 44% to 96% with the use of the Grammont-style reverse prosthesis with medialization of the glenosphere center of rotation.[22] Radiographic evidence of scapular notching tends to appear early in the postoperative period, with inferior scapular neck erosion typically seen 6 weeks to 14 months after reverse shoulder arthroplasty.[22,34] The severity of notching has been reported to progress over time.[20,35] However, the clinical significance of this phenomenon has been debated, with several studies reporting no adverse effect and no correlation of notching with any objective or subjective clinical results.[1,12] In contrast, other studies have shown loss of function and pain relief at approximately 5 to 6 years in patients who had scapular notching.[12,20,22,24,27,30] Further, in a small series, Delloye et al[36] reported that progression of scapular notching after reverse shoulder arthroplasty resulted in glenosphere loosening that necessitated revision in 2 patients. In this short-term follow-up study, no significant difference was found in improvement in ROM and Constant-Murley scores between the groups with and without scapular notching. However, most of the patients reported by Delloye et al[36] had a lower grade of notching (grade II or II), whereas Sirveaux et al[11] reported a direct correlation between the severity of notching (grade III or IV) and lower postoperative Constant-Murley scores. Length of follow-up may also contribute to the ability to correlate or detect functional outcome with scapular notching. In a series of 60 patients who underwent reverse shoulder arthroplasty (DePuy Delta Prosthesis; DePuy, Warsaw, Indiana), Sadoghi et al[33] reported no correlation between notching and clinical outcome at mid-term follow-up of 24 to 60 months; however, at final follow-up of more than 60 months, a positive correlation was seen between inferior scapular notching and Constant-Murley pain scores and a decrease in active ROM.

The position of the glenosphere base plate in relation to the native glenoid is an important contributing factor to inferior scapular notching. Simovitch et al[23] reported that the craniocaudal position of the glenosphere significantly correlated with inferior notching. Recent studies also showed a decrease in the incidence of scapular notching in implants placed with inferior offset.[18,19,28,29,37] Additionally, several authors advocated lateralized offset of the glenosphere to decrease the incidence of scapular notching.[5,6,28] In a computer simulation model, Gutierrez et al[38] evaluated the effect of glenosphere position and implant design on the range of impingement-free abduction and adduction deficit after reverse shoulder arthroplasty. The most important factor for increased ROM was lateralization of the center of rotation, followed by inferior placement of the glenosphere. Increased humeral neck shaft angle was also associated with increased adduction deficit. Thus, a neck shaft angle of 135° on the humeral prosthesis is associated with greater ROM in adduction before inferior scapula impingement compared with a prosthesis that has a neck shaft angle of 155°.[17] The humeral prosthesis used in this study (Comprehensive Reverse Shoulder System) has a neck shaft angle of 135° plus a 12° liner, which equates to a final neck shaft angle of 147°. Having a neck shaft angle that is 8° lower than the traditional 155° for the humeral prosthesis would contribute to the lower incidence of notching reported in this study. However, the authors' primary focus was to evaluate the effect of inferior notching with inferior or eccentric glenosphere offset. The overall incidence of scapular notching in the current study was 11% and well below the values reported previously.[22,23] The potential to customize inferior offset via an eccentric glenosphere with or without inferior tilt played a significant role in the lower rate of notching in this study. In 37

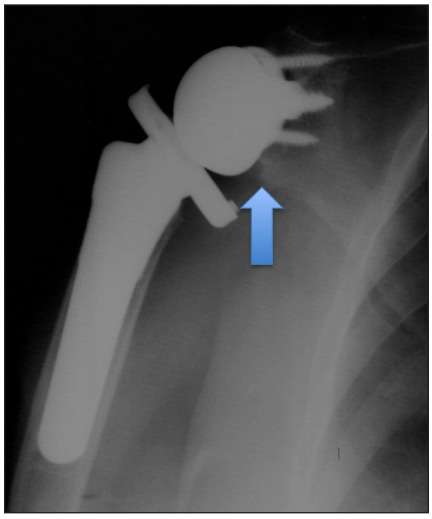

Figure 4: Grade III scapular notching in a patient with metastatic prostate cancer to the glenoid (arrow). The glenosphere base plate ultimately became loose and required revision to hemiarthroplasty.

patients with a maximum offset of 2 to 4 mm, the authors found no evidence of scapular notching. By comparison, scapular notching was found (grade I=1 and grade II=2) in all 3 patients with glenospheres that had no inferior offset (0 mm). In the group with minimal inferior offset of 0 to 2 mm, 6 patients had notching (grade I=4 and grade III=2), for an incidence of 18% within this group.

The authors' findings are supported by a recent clinical trial comparing the clinical outcome and incidence of notching in patients implanted with a concentric vs eccentric glenosphere (Systema Multiplana Randelli-SMR Prosthesis; Systema Multiplana Randelli, Lima-LTO, Italy). Patients with the eccentric glenosphere showed no scapular notching (concentric glenosphere, 42% notching) and better clinical outcome as measured by both Constant-Murley scores and anterior elevation.[39] Mizuno et al[40] also reported a significant decrease in the severity of radiographic notching with an eccentric glenosphere compared with Grammont-style reverse shoulder arthroplasty. Roche et al[41] also recommended inferior positioning of the base plate with greater overhang of the glenosphere to decrease the incidence of scapular notching and inferior osteophyte formation. Biomechanical studies reported increased shear forces at the surface of the base plate and native glenoid when the glenosphere is placed inferiorly and thus advocated a slight inferior tilt (15°) to increase compressive forces while decreasing micro motion.[16,32,42] Although their study did not evaluate the effect of inferior tilt on scapular notching, in a prospective clinical trial, Edwards et al[15] reported that inferior tilt of the glenosphere did not significantly decrease the incidence of scapular notching (humeral stem neck shaft angle, 155°). In their study, notching was seen in 75% vs 86% of patients in the inferior tilt and control groups, respectively. Another important factor in scapular notching is lateralization of the glenosphere. Using a bony increased offset reverse shoulder arthroplasty, Boileau et al[28] reported a low rate of inferior scapular notching in 19% of patients (N=42) at final follow-up of 28 months. Valenti et al[43] also reported improved external and internal rotation in 76 patients with a mean follow-up of 44 months using a less medialized center of rotation reverse shoulder arthroplasty.

Using the Comprehensive Reverse Total Shoulder System, the rate of scapular notching in the current study was low (11%) at short-term follow-up. In this short-term series, inferior offset had a favorable effect on the incidence of scapular notching; however, the authors cannot discount the other advantages of this system (lower humeral neck shaft angle, 147°) that may have contributed to this result. These advantages include previously reported characteristics, such as lateralization of the center of rotation and neck shaft angle of the humeral component.

Limitations

This preliminary study had many inherent limitations. It was a retrospective study, and 18 of the 100 patients (18%) were lost to follow-up. In addition, although the anteroposterior radiographs in the plane of the scapula (Grashey view) were reviewed by two experienced surgeons, the reliability of standardization of the "true" anteroposterior views could be questioned. Further, interobserver reliability was not assessed. In addition, the effect of inferior glenosphere tilt and the humeral component design of this reverse shoulder arthroplasty system was not considered. Furthermore, the authors did not evaluate the incidence of anterior or posterior notching, which correlates with impingement with internal and external ROM. However, in a biomechanical cadaver model, Li et al[44] showed that, with inferior translation of the glenosphere, humeral internal and external ROM to impingement was significantly increased, further supporting the advantages of an eccentric dial glenosphere that can customize the inferior glenosphere translation. With these limitations considered, the lower scapular notching rates seen in this series were significantly better than those reported in other clinical series. The use of this particular implant, with all of the features described earlier, resulted in a comparatively lower rate of scapular notching.

Conclusion

The inferior offset glenosphere created with this glenosphere and base plate design reduced the incidence of scapular notching in reverse shoulder arthroplasty, especially when the glenosphere was maximally offset inferiorly. In the short term, notching did not influence ROM or functional outcome.

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