The effect of radial mismatch on radiographic glenoid loosening

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Background: The ideal glenohumeral radial mismatch following anatomic total shoulder arthroplasty (TSA) remains ill defined, with biomechanical and clinical studies recommending a range between 4 and 10 mm. This study evaluates the effect of radial mismatch on the formation of radiolucent lines after TSA.
Methods: We evaluated 451 TSAs at a mean follow-up of 5.4 years. All TSAs were performed using a single implant system that allows radial mismatch between 3.4 and 7.7 mm. Shoulders were retrospectively evaluated for radiographic glenoid loosening according to the Lazarus score. Shoulders were evaluated according to radial mismatch: 3.4 mm in 23, 4.3 mm in 154, 5.1 mm in 72, 5.9 mm in 81, 6.7 mm in 103, and 7.7 mm in 18. Clinical outcome measures included range of motion and American Shoulder and Elbow Surgeons, University of California, Los Angeles, and Shoulder Pain and Disability Index scores.
Results: At similar follow-up times, all groups demonstrated a similar incidence of glenoid radiolucencies and similar mean Lazarus scores. Shoulders in female patients were more commonly treated with implant combinations resulting in 4.3, 5.9, and 7.7 mm of radial mismatch ($P < .001$). Improvements in range of motion and American Shoulder and Elbow Surgeons, University of California, Los Angeles, and Shoulder Pain and Disability Index scores were similar among all groups. Rates of reoperation secondary to glenoid loosening were similar among groups ($P = .57$). Moreover, the incidence of radiographic loosening (Lazarus grade 4 or 5) was similar among the groups ($P = .22$).
Discussion: Variation in mismatch between 3.4 and 7.7 mm did not affect the incidence of glenoid lucent lines or Lazarus score. This finding suggests that optimal radial mismatch may extend below 5.5 mm, as previously recommended by Walch et al, without affecting the incidence and grade of glenoid lucencies.

Anatomic shoulder arthroplasty designs continue to exhibit variations in radial mismatch between 1 and 38 mm.[27] The first anatomic shoulder arthroplasty, designed by Neer in 1952, had a radial mismatch of 0 mm, with the humeral head and glenoid face having equal radii of curvature.[21] Biomechanical studies have suggested maintaining a mismatch between 4 and 10 mm to limit contact stresses at the bone-cement interface in an effort to improve implant longevity.[2,11,12,24] Increased contact stresses may play a role in the development of periglenoid lucencies, which have been shown to progress over time.[7,9,20] At mid-term follow-up, 60% of shoulders have documented lucencies about the glenoid component.[4,15,19] Of these, 33% have been documented to be loose, as defined by a complete radiolucent line and/or shift in component position.[4,19] As demand continues to increase, surgeons must continue to identify modifiable risk factors for glenoid component loosening. Clinical work by Walch et al[33] documented lower rates of radiolucent lines with radial mismatch between 6 and 10 mm. However, other studies have been unable to confirm a relationship between radial mismatch and component loosening and/or component revision.[28,36]

The primary purpose of this study was to evaluate the effect of radial mismatch on the formation of radiolucent lines following anatomic shoulder arthroplasty. Secondary outcome measures

Table I
Demographic information by radial mismatch

Demographic	Radial mismatch of 3.4 mm	Radial mismatch of 4.3 mm	Radial mismatch of 5.1 mm	Radial mismatch of 5.9 mm	Radial mismatch of 6.7 mm	Radial mismatch of 7.7 mm	P value
n	23	154	72	81	103	18	
Pegged/keeled, n	22/1	91/63	59/13	42/39	62/41	7/11	
Age, mean (SD), yr	66.4 (7.9)	67.8 (8.9)	65.9 (8.6)	69.0 (9.1)	65.1 (9.0)	63.8 (8.7)	.062
Sex: M/F, n	21/2	21/133	68/4	5/76	75/28	0/18	<.001
BMI, mean (SD)	31.2 (5.2)	29.9 (7.4)	30.0 (6.2)	28.4 (6.0)	30.7 (6.4)	29.4 (5.4)	.90
Prior surgery, %	9	16	18	9	12	6	.34
Injection, %	13	40	29	27	32	22	.080
Follow-up, mean (SD), yr	5.7 (2.1)	5.3 (2.3)	5.3 (2.2)	5.2 (2.3)	5.6 (2.4)	4.7 (2.5)	.87

SD, standard deviation; *M*, male; *F*, female; *BMI*, body mass index.

included functional outcomes, patient-reported outcomes, complications, and reoperation rates. On the basis of the study by Walch et al,[33] we hypothesized that radiolucent lines would be more common with a radial mismatch below 6 mm.

Materials and methods

Using an international shoulder arthroplasty database, we conducted a retrospective review of all primary anatomic total shoulder arthroplasties (TSAs) over a 10.5-year period (April 2005−September 2016). All surgeons participating in the database are fellowship-trained high-volume shoulder surgeons. Sixteen surgeons provided patients included in this study. Revision shoulder arthroplasty surgery, metallic caged glenoid components, augmented components, and shoulders with a preoperative diagnosis of infection were eliminated. All shoulders with a minimum 2-year clinical and radiographic follow-up were included. This left 451 TSAs for analysis. There were 261 female and 369 male patients with a mean age of 66 years at the time of index arthroplasty (range, 36-90 years). Shoulders were retrospectively evaluated at a minimum 2-year follow-up (mean, 5.4 years; range, 2-12 years).

All TSAs were performed using the Equinoxe system (Exactech, Gainesville, FL, USA). This implant system offers both pegged and keeled components, both of which are placed in a cemented fashion within the glenoid vault. This system allows for a radial mismatch between 3.4 and 7.7 mm. Shoulders were evaluated according to the amount of radial mismatch: 3.4 mm in 23, 4.3 mm in 154, 5.1 mm in 72, 5.9 mm in 81, 6.7 mm in 103, and 7.7 mm in 18. Demographic information for each group is shown in Table I. At the time of final follow-up, Grashey and axillary lateral radiographs were reviewed by the performing surgeon for radiographic glenoid loosening according to the Lazarus score.[17] Humeral lines were assessed according to Sanchez-Sotelo et al[25,26] (Fig. 1). Clinical outcome measures included active abduction, forward elevation, external rotation, and internal rotation. Internal rotation was assessed according to the level reached by the thumb and grouped as previously described by Flurin.[3] On the basis of this scale, no internal rotation is rated as 0; hip, 1; buttocks, 2; sacrum, 3; L5 to L4, 4; L3 to L1, 5; T12 to T8, 6; and T7 or higher, 7. Patient-reported outcomes were collected at follow-up and included the American Shoulder and Elbow Surgeons score; Constant score; Simple Shoulder Test score; University of California, Los Angeles score; and Shoulder Pain and Disability Index score.

Statistical analysis

Statistical analyses were performed using SPSS software (version 17.0; IBM, Armonk, NY, USA) and the R package (version 3.5.1; R Foundation for Statistical Computing, Vienna, Austria). TSAs were evaluated in groups according to mismatch. Categorical data were evaluated using χ^2 analysis. Continuous variables were assessed using 1-way analysis of variance and Tukey post hoc tests. The α level for statistical significance was set at .05.
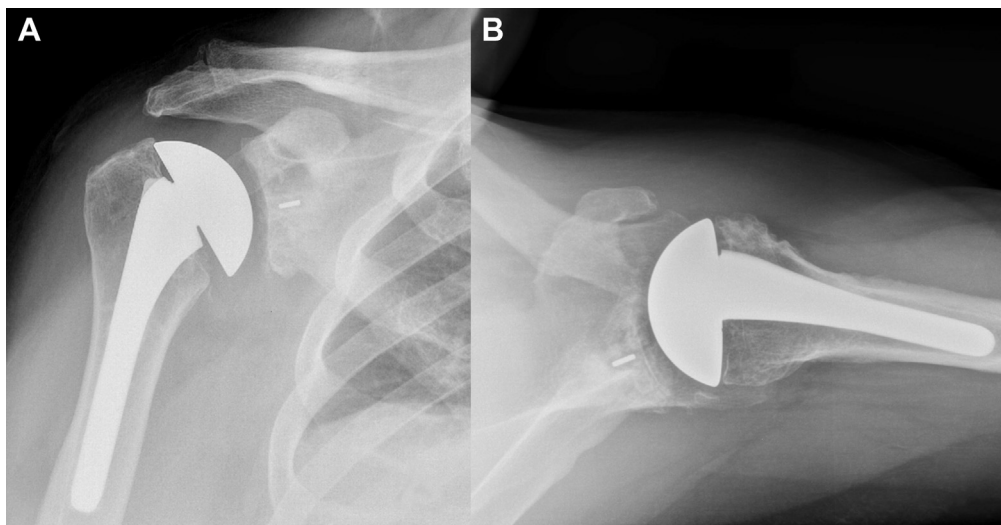

Figure 1 Grashey (**A**) and axillary lateral (**B**) radiographs showing a well-seated anatomic total shoulder arthroplasty 2 years postoperatively without evidence of periprosthetic loosening.

Table II
Radiographic comparison by radial mismatch

Radiographic finding	Radial mismatch of 3.4 mm	Radial mismatch of 4.3 mm	Radial mismatch of 5.1 mm	Radial mismatch of 5.9 mm	Radial mismatch of 6.7 mm	Radial mismatch of 7.7 mm	P value
Glenoid lines present, %	35	38	43	43	39	50	.84
Lazarus grade, n							.67
0	15	96	41	46	63	9	
1	3	19	11	11	14	1	
2	0	12	10	10	15	2	
3	3	11	6	8	5	2	
4	0	7	2	4	1	2	
5	2	9	2	2	5	2	
Grade 4 or 5 lucent lines, %	9	10	6	7	6	22	.22
Humeral lines present, %	9	11	7	14	9	17	.70

Results

Shoulders were evaluated at a mean follow-up of 5.4 years (range, 2-12 years). Groups were similar regarding body mass index, prior surgery, and prior injections. Follow-up was also similar across all groups (Table I). Shoulders in female patients were more commonly treated with implant combinations resulting in 4.3, 5.9, and 7.7 mm of mismatch ($P < .001$).

Radiographic outcomes

At final follow-up, 40% of shoulders demonstrated radiolucencies about the glenoid component, with a mean grade of 1.0. The Lazarus score was grade 0 in 270 shoulders, grade 1 in 58, grade 2 in 49, grade 3 in 35, grade 4 in 16, and grade 5 in 22. The incidence of glenoid radiolucent lines and the average Lazarus scores were similar among all mismatch subgroups (Table II, Fig. 2). When we evaluated the incidence of grade 4 and 5 periglenoid lucencies, all groups demonstrated similar rates of clinically significant radiolucencies ($P = .22$). Humeral loosening was also statistically similar regardless of mismatch ($P = .7$).

Clinical outcomes

Improvement in range-of-motion (ROM) measures, as well as American Shoulder and Elbow Surgeons, University of California, Los Angeles, and Shoulder Pain and Disability Index scores, was similar among all groups (Table III). Complications were similar

among all groups ($P = .35$). Rates of reoperation were significantly different among groups, with the 3.4-mm mismatch group having a revision rate of 22% ($P = .028$). However, when we evaluated the incidence of revision for aseptic glenoid loosening, all groups demonstrated similar rates of revision surgery ($P > .999$).

Discussion

Glenoid lucencies result in decreased shoulder function following anatomic TSA.[30] Optimizing radial mismatch decreases shear forces at the bone-cement interface and theoretically decreases component loosening. Clinical studies have recommended an optimal radial mismatch between 6 and 10 mm.[33] Despite the theoretical advantages, no single TSA design has demonstrated clinical superiority in glenoid component loosening at mid-term follow-up.[1,4,13,16,19,22] At a mean radiographic follow-up of 5.4 years, similar rates of glenoid component lucencies were identified in shoulders with a radial mismatch between 3.4 and 7.7 mm. Thus, the study hypothesis was rejected.

The first anatomic shoulder arthroplasty, as designed by Neer,[21] used a conforming glenohumeral articulation with a radial mismatch of 0 mm. Although a congruent joint decreases contact stresses with a stable center of rotation, the glenohumeral joint has been shown to translate across the face of the glenoid with active ROM.[6,18] Translation in the setting of a more congruent glenohumeral joint leads to edge loading of the prosthesis, which can mimic the rocking-horse effect, as described by Franklin et al.[5,35] Biomechanical studies have shown TSA with a radial mismatch of 4 mm to most closely mimic native shoulder translations with simulated active elevation.[12] As the center of the head translates away from the center of the glenoid, bone-cement contact forces increase, theoretically increasing the risk of component loosening. Biomechanically, these forces lead to significantly greater micromotion with a radial mismatch that exceeds 10 mm, with catastrophic failures occurring at a mismatch of 14 mm.[24]

In a clinical study, Nho et al[23] showed higher rates of component loosening with conforming glenoid components. This finding is in contrast to the findings of Schoch et al,[28] who showed similar rates of glenoid loosening and/or component shift among 3 generations of TSA with varying amounts of glenohumeral mismatch (0-2 mm). Because of concerns with implant loosening, modern shoulder prostheses have expanded the radial mismatch options in the design, which ranges from 1 to 38 mm.[27]

Walch et al[33] evaluated the effect of radial mismatch on the presence of postoperative periglenoid lucencies. In their study of 319 shoulders, mismatch ranged from 2.5 to 10 mm. At a mean follow-up of 4.5 years, a significantly lower radiolucency score was shown in shoulders with a mismatch above 5.5 mm. Therefore, they recommended glenohumeral mismatch between 6 and 10 mm for future designs. This finding is in contrast to the results of our study,
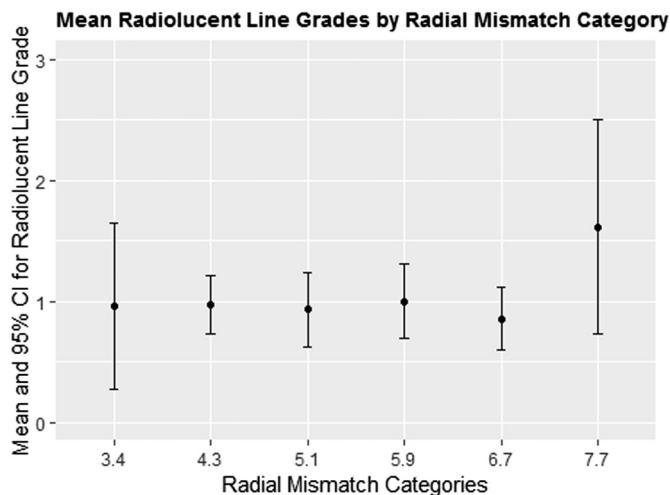

Figure 2 Relationship between radial mismatch (in millimeters) and Lazarus score with 95% confidence interval *(CI)*.

Table III
Clinical outcome comparison by radial mismatch

	Radial mismatch of 3.4 mm	Radial mismatch of 4.3 mm	Radial mismatch of 5.1 mm	Radial mismatch of 5.9 mm	Radial mismatch of 6.7 mm	Radial mismatch of 7.7 mm	*P* value
n	23	154	72	81	103	18	
Abduction, mean (SD), °	36 (32.3)	43 (38.6)	32 (43.8)	47 (41.3)	42 (37.5)	40 (55.0)	.50
Forward elevation, mean (SD), °	34 (36.7)	50 (36.7)	33 (42.8)	51 (43.1)	46 (39.8)	36 (53.0)	.066
IR, mean (SD)	1.3 (2.4)	2.1 (2.0)	1.8 (1.9)	2.3 (2.0)	1.6 (2.4)	2.4 (1.8)	.25
ER, mean (SD), °	28 (19.9)	34 (22.3)	25 (20.1)	36 (22.3)	30 (19.9)	31 (22.3)	.07
ASES score, mean (SD)	48.3 (23.2)	44.7 (24.8)	40.2 (26.3)	41.2 (25.0)	47.8 (24.2)	41.8 (31.0)	.62
UCLA score, mean (SD)	16.5 (4.5)	15.9 (7.2)	13.9 (7.6)	16.0 (7.7)	16.7 (6.2)	14.8 (10.0)	.48
SPADI score, mean (SD)	49.1 (25.7)	66.3 (28.7)	54.1 (35.7)	59.3 (30.2)	66.5 (31.2)	52.7 (37.7)	.12
Complications, n (%)	5 (22)	19 (12)	7 (10)	7 (9)	8 (8)	3 (17)	.38
Reoperations, n (%)	5 (22)	14 (9)	7 (10)	5 (6)	3 (3)	0 (0)	.028
Aseptic glenoid loosening, n (%)	1 (4)	8 (5)	5 (6)	3 (4)	2 (3)	0 (0)	.57
Aseptic humeral loosening, n	1	3	1	0	0	0	
Rotator cuff tear, n	1	2	0	2	1	0	
Infection, n	2	1	1	0	0	0	

SD, standard deviation; *IR*, internal rotation; *ER*, external rotation; *ASES*, American Shoulder and Elbow Surgeons; *UCLA*, University of California, Los Angeles; *SPADI*, Shoulder Pain and Disability Index.

which shows similar grades of glenoid component lucencies with a radial mismatch ranging from 3.4 to 7.7 mm. Our results are similar to those of Young et al,[36] who found no correlation of radiolucent line score and radial mismatch (mean, 5.5 ± 1.5 mm) in 217 primary TSAs performed for primary osteoarthritis. Thus, the optimal range of mismatch to minimize clinical glenoid lucencies may extend below the 6-mm limit initially indicated by Walch et al.

In the same study, Walch et al[33] also reported greater external rotation with a mismatch between 4.5 and 7 mm. However, we did not identify any greater improvement in ROM with a specific glenohumeral mismatch, including groups with below 4.5 mm and above 7 mm of radial mismatch. Furthermore, the clinical significance of the differences in the study of Walch et al remains unclear as external rotation values were not reported in the article.[33] Similarly to Walch et al, we demonstrated similar forward elevation, internal rotation, and complications regardless of mismatch.

The reoperation rate for all shoulders in this study was 7.5% at a mean follow-up of 5.4 years. This finding is similar to findings of previous large studies on anatomic TSA.[14,29,32] The most common reason for reoperation in this study was aseptic glenoid loosening (4%). This finding is similar to the results of Somerson et al,[31] who reported glenoid component failure to be the most common cause of failure after anatomic TSA between 2012 and 2016. However, we are unaware of any study evaluating the effect of glenoid mismatch on the reoperation rate after TSA. On the basis of the results of this study, reoperations were significantly more common in shoulders with a mismatch of 3.4 mm when compared with the other groups. This finding is likely related to the small sample size. When we evaluated the causes of reoperation within this subgroup, only 1 reoperation was caused by glenoid loosening whereas 2 reoperations were caused by infection. When comparing reoperations caused by glenoid component loosening between groups, we noted no differences.

This study represents the largest cohort of shoulders used to evaluate the effect of glenohumeral mismatch on both radiographic and clinical outcomes. However, our study has multiple limitations. Most important, radiographs were evaluated by the performing surgeon, which introduces self-evaluation bias. Preoperative imaging was not routinely captured within the database; therefore, we were unable to assess the distribution of glenoid morphology between groups and its impact on the formation of radiolucent lines.[34] A second limitation is that both pegged and keeled components were used. The choice to combine these implants into a single group was made based on prior studies that have reported similar rates of peri-implant lucencies for both types of

components.[4,16,19] A third limitation is that postoperative radiographic evaluations were performed using radiographs, which may under-report lucencies compared with computed tomography scans.[8] Because of this limitation, we were unable to accurately assess postoperative retroversion or subluxation, which may have affected the formation of radiolucencies.[10,24] However, given the large sample size and similar evaluation techniques among all groups, we believe that the comparison among groups remains valid.

Conclusion

Variation in mismatch between 3.4 and 7.7 mm did not affect the incidence of glenoid lucent lines or the mean Lazarus score. This finding suggests that optimal radial mismatch may extend below 5.5 mm, as previously recommended by Walch et al,[33] without affecting glenoid loosening.

Disclaimer

Bradley S. Schoch is a paid speaker for DJO.

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