



Humeral stem lucencies correlate with clinical outcomes in anatomic total shoulder arthroplasty



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Background: Humeral stem lucencies are uncommon after uncemented anatomic total shoulder arthroplasty (aTSA), and their clinical significance is unknown. This study compares clinical outcomes of aTSA with and without humeral stem lucencies.

Methods: Two-hundred eighty aTSAs using an uncemented grit-blasted metaphyseal-fit humeral stem between 2005 and 2013 were retrospectively evaluated for radiographic humeral stem lucencies. All shoulders were evaluated at a minimum 5-year follow-up from a multicenter database. Clinical outcomes included range of motion (ROM) and American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES) score, Constant score, University of California–Los Angeles Shoulder Score (UCLA), Simple Shoulder Test (SST), and Shoulder Pain and Disability Index (SPADI) scores. Postoperative radiographs were evaluated and complications were recorded.

Results: Two-hundred forty-three humeral stems showed no radiolucent lines. Among the 37 humeral stems with lucent lines, lines were most common in zones 8, 4, 7, and 3. Preoperative ROM and functional outcomes were similar between groups. Postoperative change in outcomes exceeded the minimal clinically important difference (MCID) for all ROM and outcomes in both groups. Postoperative change between groups showed no significant difference in ROM or outcome scores, but improved mean abduction exceeded the MCID in the patients without humeral lines. The complication rate after omitting patients with humeral loosening was higher in patients with humeral lucencies, as was the revision rate. There was also a higher glenoid-loosening rate in patients with humeral lucencies.

Conclusion: Humeral lucent lines after uncemented stemmed aTSA have a small negative effect on ROM and functional outcomes compared with patients without lucent humeral lines, which may not be clinically significant. The complication and revision rates were significantly higher in patients with humeral lucencies.

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Anatomic total shoulder arthroplasty (aTSA) is a reliable surgical option for patients with glenohumeral joint osteoarthritis with an intact rotator cuff.^{2,15,18,22,29} Good long-term results have been reported for aTSA, with survival rates around 90% at 10 years.^{1–3,8,11,23,27}

Rates of complications in aTSA have been quoted around 4.3%–9.4%,^{1,3,4,6,29–31} with some long-term studies showing even higher rates.⁷ The most common complication remains glenoid loosening,

with high rates reported at mid- to long-term follow-up.^{12,16,18,22} The presence of glenoid lucencies has been associated with decreased forward elevation and patient-reported outcome measures (PROMs).^{12,24} Studies evaluating the effects of humeral stem loosening remain limited. Godeneche et al¹³ found only 20 studies over a 20-year period in a meta-analysis that reported on revision rates and radiographic findings after uncemented aTSA including a variety of humeral designs with many studies reporting on short-term outcomes, making it difficult to draw conclusions.

The purpose of this study is to assess the prevalence of humeral lucent lines in uncemented aTSA and to evaluate the impact of humeral lines on postoperative range of motion (ROM) and PROM at midterm follow-up.

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Materials and methods

A retrospective review of all primary anatomic total shoulder arthroplasties between March 2005 and May 2013 was performed using a prospectively collected multicenter research database. All shoulders with a press-fit uncemented humeral stem, adequate radiographic data, preoperative and postoperative ROM, and PROMs with a minimum 5-year follow-up were included.

All arthroplasties were performed using a single shoulder arthroplasty system (Equinox; Exactech, Inc., Gainesville, FL, USA). This system uses a platform press-fit, metaphyseal, grit-blasted humeral stem that is between 100 and 125 mm long depending on stem diameter. All operations were performed by fellowship-trained surgeons from 14 different centers across the world. The deltopectoral approach was used in all cases. Exclusion criteria included revision shoulder arthroplasty, rheumatoid arthritis, and post-traumatic arthritis.

All shoulders were evaluated by the operating surgeon using a standardized follow-up protocol. Radiographic follow-up included a minimum of 2 views (Grashey and axillary lateral views). Humeral stem lines were evaluated according to their presence or absence, location, and thickness using a standardized multicenter protocol. Location was categorized according to the Sanchez-Sotelo radiographic zones.^{20,21} Glenoid periprosthetic lines were graded according to the Lazarus Scale.¹⁴ Shoulders were then separated based on the presence or absence of peri-implant humeral component lucencies, and their data were compared.

Demographic data were evaluated, including age, sex, and body mass index. Data were collected on the history of administration of a prior corticosteroid injection to and prior surgery of the operative shoulder. The performing surgeons and/or their research assistants examined patients independently both prior to and following primary shoulder arthroplasty using a standardized protocol. Shoulders were evaluated clinically for active ROM, including abduction, forward elevation, external rotation with the arm at the side, and internal rotation. Abduction, forward elevation, and external rotation were measured in degrees. Internal rotation was measured according to the level reached by the thumb. This value was categorized as described by Flurin et al.¹⁰ At the time of clinical follow-up, outcome scores were obtained, including American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES) score, Simple Shoulder Test (SST), Constant score, University of California–Los Angeles Shoulder Score, and Shoulder Pain and Disability Index (SPADI). The minimal clinically important difference (MCID) for ROM and outcome scores was used as defined by Simovitch et al.²⁶ for aTSA. Postoperative follow-up was performed at regular intervals, with ROM and outcome scores obtained at each visit. Complications and reoperations were recorded. Shoulders undergoing revision surgery were included in clinical analysis using the most recent data before revision surgery. Subanalysis was also performed to evaluate the effect of stress shielding where the patients with humeral lines in zone 8 were compared to the other patients with humeral lucent lines, excluding patients revised for humeral loosening. In this subanalysis, patients were included in the stress shielding group if they had lines in zone 8 (isolated) or lines in zones 8 and 7 (within the proximal grit-blasted portion of the stem) but were excluded if they had lines in any other zone to try to distinguish between stress shielding (loss of bone proximal to the area of ongrowth) and osteolysis (which should theoretically have lucent lines in other zones).

Statistical analysis

Continuous variables were evaluated using Welch 2-sample *t* test or 1-way analysis of variance with Tukey honestly significant

difference post hoc test for multiple comparisons of means. Categorical variables were analyzed using a χ^2 test or Fisher exact test, based on sample size. The alpha level for significance was set at $P < .05$. SPSS, version 17.0 (SPSS, Chicago, IL, USA), and R, version 3.5.1 (R Foundation for Statistical Computing, Vienna, Austria), were used for statistical analyses. The patients with humeral lucent lines present were directly compared to those without any lines.

Results

Two hundred eighty aTSAs (137 males, 143 females) were evaluated at a mean follow-up of 6.6 years (range, 5.0–12.0 years). This group was from a total of 559 aTSAs performed during the study period, with 279 being excluded (50%) because of missing preoperative or postoperative data points at a minimum 5-year follow-up. Follow-up for the humeral line group (7.4 years) was longer than shoulders without humeral lines (6.5 years; $P = .003$). At the most recent follow-up, 243 (86.8%) showed no humeral lucent lines and 37 (13.2%) showed 1 or more peri-implant humeral lucencies. Humeral lucent lines were more prevalent in zone 8 (21/37, 57%), zone 4 (15/37, 41%), zone 7 (12/37, 32%), and zone 3 (11/37, 30%). See Figure 1 for complete details. Both groups were similar in age, sex, body mass index, history of prior surgery, estimated blood loss, and comorbidities. See Table I for demographic data.

Range of motion

Both the humeral lucent line group and those shoulders without humeral lines demonstrated similar preoperative ROM. Postoperatively, shoulders with humeral lucent lines had statistically worse forward elevation (125° vs. 142°, $P = .002$) and abduction (110° vs. 122°, $P = .03$). There was no significant difference in internal (L3 vs. L3) or external rotation (43° vs. 48°) between the 2 groups (Table II). The mean change in ROM preoperatively to postoperatively was higher in shoulders without humeral lucent lines, but these were not statistically different, and only mean abduction was above the MCID (Table II).

Clinical results

Similar to ROM, shoulders with and without humeral lines demonstrated similar preoperative PROMs. At follow-up, outcome scores were significantly worse in shoulders with humeral lucent lines compared to those without lines in all of the outcome scores studied (Table II). However, none of these postoperative differences exceeded the MCID for aTSA (Table II). Additionally, the change in preoperative to postoperative values did not show any clinically significant differences between the shoulders with humeral lucent lines and those without humeral lucent lines (Table II).

Complications

Gross humeral loosening was noted in 4 of the 37 patients in the humeral lucent line group (11%). One patient experienced humeral lucent lines with an impending pathologic fracture and underwent revision surgery. One patient sustained rotator cuff failure that led to particulate debris and ultimately to humeral and glenoid loosening and revision surgery. Another patient had significant glenoid wear, and eventually humeral loosening, also requiring revision surgery. The last patient had humeral loosening confirmed by computed tomographic scan, and revision was planned at the time of data collection.

Other complications besides humeral loosening were more common in the humeral lucent line group (21% vs. 8%; Table III). The



Figure 1 The 8 radiographic zones of Sanchez-Sotelo for assessment of lines around the humeral component.

need for any revision excluding the patients revised for humeral loosening was higher in the humeral lucent line group (18% vs. 4%). Glenoid loosening was also higher in the humeral lucent line group (12% vs. 3%). All complications are presented in Table III.

A subanalysis was performed to assess the effect of stress shielding (lucency in zone 8) compared to other shoulders with humeral lucent lines. All mean ROM changes evaluated were worse for the patients with stress shielding except internal rotation (Table IV). Mean difference in forward elevation and abduction improvements were above the MCID, but were not statistically significant between groups. When evaluating change in outcome scores preoperatively to postoperatively, patients with stress shielding (lines in zone 8) had less improvement in all outcome scores compared to patients with humeral lines in other zones. The mean difference in the SST score was above the MCID and the mean difference in the SPADI score change approached the MCID in favor of the patients with lines in other zones.

Table 1
Demographics

	No humeral lucent lines	Humeral lucent lines	P value
Number of aTSAs	243	37	
Sex, F/M, n	122/121	21/16	.45
BMI, mean	30.2	30.3	.96
Prior surgery	31 (7.8)	6 (16.2)	.60
Age, yr, mean	65.9	65.1	.62
Follow-up, yr, mean	6.5	7.4	.003
Diabetes, n (%)	21 (8.7)	2 (5.4)	.75
Heart disease, n (%)	28 (11.5)	6 (16.2)	.42

aTSAs, anatomic total shoulder arthroplasties; F, female; M, male; BMI, body mass index.

Discussion

Anatomic total shoulder arthroplasty has proven to be a reliable surgical option for treatment of glenohumeral osteoarthritis with significant improvements in patient-reported outcomes. With the elderly population staying healthier, more active, and living longer, there has been an increased rate of shoulder arthroplasty being performed as an option to return to or maintain an active lifestyle.^{17,25} Component lucent lines after anatomic shoulder arthroplasty, glenoid more commonly than humeral lines, remain a familiar complication that may result in declining shoulder function without undergoing revision surgery, but little is reported on the effect of humeral lucent lines on outcomes. This study shows that the presence of periprosthetic humeral lucent lines is associated with small decreases in both ROM and PROMs.

Recent studies have demonstrated that periprosthetic glenoid loosening with both pegged and keeled components is a major cause of failure of aTSA, especially in the long term.^{7,8,11,12,16–18,22,27} The presence of peri-implant glenoid lucencies has been shown to correlate with worsening PROMs.^{12,24} The majority of this effect has been shown to occur with higher-grade lucencies (Lazarus 5). Schoch et al²⁴ also demonstrated worse overhead ROM in shoulders with a glenoid lucency score exceeding grade 2. This is similar to our study, where overhead ROM was worse in shoulders with humeral lines. The effect on PROMs was similarly not significantly different.

Although many studies mention a low rate of humeral stem loosening and discuss glenoid lucencies, the incidence of humeral lucent lines is less commonly reported. A radiographic study of 151 stemmed TSAs reported a 14.6% incidence of humeral lucent lines at a mean follow-up of 8 years.¹¹ This is similar to the rate of humeral lines in this study (13.2%). Although the authors report the incidence of humeral lines, Fox et al¹¹ does not evaluate the effect of humeral lines on outcomes. Other studies have reported an incidence of humeral lines between 0% and 39% for uncemented humeral stems used for aTSA. However, similar to Fox et al,¹¹ none of these studies have evaluated the effect of humeral lines on clinical outcomes. One systematic review of radiographic outcomes following uncemented humeral stems in aTSA showed a humeral lucent line rate of 0% for long coated stems (1 study included) and 8%–25% for long uncoated stems (3 studies included).¹³ One study evaluating short press-fit humeral stems showed a 8.2% humeral lucent line rate using a grit-blasted stem.²⁹ Romeo et al¹⁹ reported on 64 short-stem aTSAs demonstrating a humeral lucent line rate of 39% at mean 25-month follow-up. Throckmorton et al³⁰ showed a decreased humeral lucent line rate of 7% at early minimum 2-year follow-up with the addition of a porous coated metaphyseal area in the Cofield-2 prosthesis (Smith & Nephew, Memphis, TN, USA). None of these studies correlated the presence of humeral lines to clinical outcomes.

Table II
Postoperative and change from preoperative values of range of motion and outcome scores

	Postoperative			Change from preoperative to postoperative			MCID for aTSA ²⁶
	No humeral lucent lines	Humeral lucent lines	P value	No humeral lucent lines	Humeral lucent lines	P value	
FE	142°	125°	.002	+47°	+32°	.068	23.1°
Abduction	122°	110°	.03	+40°	+25°	.081	13.9°
ER	48°	43°	.12	+34°	+25°	.31	14.5°
IR	L3	L3	.27	+ 2 levels	+ 2 levels	.78	–
ASES	80.8	69.6	.004	+44.2	+37.7	.28	17.0
Constant	69	60.8	.003	+21.2	+29.4	.58	12.8
SST	10	8.7	.006	+6.4	+6.5	.92	1.8
SPADI	22.3	37.0	.002	–61.5	–54.3	.30	21.3
UCLA	29.5	26.2	.005	+15.5	+15.7	.58	10.5

FE, forward elevation; ER, external rotation; IR, internal rotation; ASES, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form; SST, Simple Shoulder Test; SPADI, Shoulder Pain and Disability Index; UCLA, University of California–Los Angeles Shoulder Score; MCID, minimal clinically important difference; aTSA, anatomic total shoulder arthroplasty.

P values in bold indicate significance (<.05).

Smaller effects on PROMs were seen in shoulders with 1 or more peri-implant humeral lucent lines at a minimum of 5 years after aTSA. Although both groups showed improvements exceeding the MCID for all PROMs, improvements were statistically similar regardless of humeral lucencies. These similarities are reflected in the fact that ASES and SPADI improvements were slightly higher in shoulders without lines, whereas Constant score improvements were slightly higher in shoulders with a humeral line. Improvements in both SST and University of California–Los Angeles Shoulder scores were essentially equivalent between groups. As a group, improvements in PROMs were similar to other published reports on aTSA, including ASES,^{5,6,18} SST,^{15,17,19} Constant,^{7,12,17,27,28} and SPADI scores.²⁸

ROM improvements in this study were similar to other reports on aTSA.^{5,7,12,15,17–19,22,30} When evaluating the effect of humeral lucent lines, postoperative forward flexion and abduction were significantly decreased in shoulders with 1 or more humeral lucent lines; however, these did not exceed the MCID. When evaluating improvements in motion, forward flexion and abduction were much better than preoperative values in the patients without humeral lucent lines, with the mean abduction exceeding the MCID.

Within the humeral line group in this study, stress shielding was shown to be associated with worse improvements in ROM and PROMs compared to patients with humeral lucencies in other zones. This suggests that stress shielding after aTSA has a detrimental effect on shoulder function. The cause of stress shielding is unknown, but does appear to be multifactorial and related to stiffer implants, cortical contact, and polyethylene-associated bony reaction.⁶ One study evaluating bone resorption in a standard-length, tapered rectangular humeral stem reported a 17% rate of complete proximal bony resorption at 5-year follow-up.²⁸ Spormann

et al²⁸ did not show any outcome differences using the Constant, SPADI, and DASH scores in patients with and without bone resorption. A recent study of 171 aTSAs compared patients with and without medial calcar bone resorption and did not show a difference in outcomes or radiographic loosening in patients with medial calcar resorption.⁹ These studies are in contrast to this study, which showed slightly better improvements in ROM and PROMs in shoulders without humeral lucencies; and the subgroup analysis showed that shoulders with stress shielding had the lowest improvement in outcome scores.

Despite improvements in techniques and implants, complications such as rotator cuff failure and implant loosening still remain a problem for aTSA. In one recent aTSA meta-analysis, component loosening was the most common complication.^{1,3} Although glenoid component loosening is a common complication of aTSA, less is known about humeral stem loosening. The meta-analysis reported a humeral stem loosening rate of 1.1% at 5.3 years.³ One radiographic study of 151 stemmed aTSAs reported a 3% rate of humeral stem loosening.¹¹ No humeral loosening was seen at early minimum 2-year follow-up of the proximally porous-coated Cofield-2 prosthesis.³⁰ A recent systematic review of minimum 2-year follow-up studies demonstrated that uncemented humeral loosening after aTSA was 2.9% for short coated stems, 8.7%–20.6% for short uncoated stems, and 0%–6% for long stems, with the revision rates for loosening often being lower.¹³ One study of 118 short press-fit humeral stems showed a 2.5% humeral loosening rate, which was attributed to females with osteoporosis.²⁹ Similar loosening rates were seen between short stems (1.8%) and traditional-length stems (1.7%), with the same metaphyseal geometry and metaphyseal grit-blast finish at a minimum 2-year follow-up.⁵ Our study demonstrated a similar frequency of humeral stem loosening (1.4%) as is reported in the literature.

Our study found that complications other than humeral loosening were significantly higher in patients with peri-implant humeral stem lucencies. Additionally, there was a higher rate of associated glenoid loosening and a higher rate of revision surgery. To our knowledge, no other study has associated an increased complication rate with patients with humeral stem lucencies in aTSA.

This study has multiple limitations. The main limitation is its retrospective design; however, a prospectively collected database was used to provide the data. The operations were performed by multiple surgeons at different centers. This contributed to inherent variation in surgical techniques and postoperative protocols. This also, however, increases the generalizability of the study findings toward a diverse population and allows us to have a large number of patients with adequate follow-up. Radiographs were analyzed by

Table III
Complications not including the 4 patients with gross humeral loosening

	No humeral lucent lines, n (%) (n = 243)	Humeral lucent lines, n (%) (n = 33)	P value
Patients with any complication	19 (8)	7 (21)	.02
Any revision	9 (4)	6 (18)	.004
Glenoid loosening	7 (3)	4 (12)	.03
Cuff insufficiency/instability	7 (3)	1 (3)	.64
Brachial plexopathy	2 (0.8)	0	>.99
Subacromial bursitis/cuff tendonitis	2 (0.8)	1 (3)	.32
Unexplained pain	2 (0.8)	0	>.99
Infection	1 (0.4)	0	>.99
Periprosthetic fracture	1 (0.4)	0	>.99

Table IV
Change in ROM and PROMs based on the location of humeral lucent lines

	Change from preoperative to postoperative			MCID for aTSA ²⁶
	Lucent lines in zones 8	Humeral lines in all other zones	<i>P</i> value	
Number of aTSAs	19	14	—	—
FE	+27°	+70°	.066	23.1°
Abduction	+20°	+43°	.37	13.9°
ER	+25°	+38°	.37	14.5°
IR	+ 2.2 levels	+ 1.0 levels	.26	—
ASES score	+38.6	+41.2	.20	17.0
Constant score	+27.8	+36.3	.45	12.8
SST	+6.0	+8.0	.27	1.8
SPADI	−54.7	−74.5	.32	21.3
UCLA	+15.7	+17.8	.65	10.5

ROM, range of motion; PROMs, patient-reported outcome measures; FE, forward elevation; ER, external rotation; IR, internal rotation; ASES, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form; SST, Simple Shoulder Test; SPADI, Shoulder Pain and Disability Index; UCLA, University of California—Los Angeles Shoulder Score; MCID, minimal clinically important difference; aTSA, anatomic total shoulder arthroplasty.

Italics indicates approached significance.

the surgeon performing the procedure, introducing possible self-assessment bias. Additionally, although radiographs were taken using a standardized protocol, variability in x-ray technicians and positioning was likely present and could have affected the grading of humeral lucencies. The relatively small number of patients with humeral lucent lines in this study makes subanalysis difficult. Further studies are needed to confirm the effect of humeral lucencies on aTSA clinical outcomes.

Conclusion

The presence of peri-implant lucencies about the humeral component following anatomic shoulder arthroplasty appears to have a small negative affect on ROM and PROMs compared with shoulders without humeral lines, which may not be clinically significant. This effect appears to be greater in shoulders with stress shielding (zone 8 lucency). Additionally, the overall complication and reoperation rate was significantly higher in patients with radiographic humeral stem lucencies.

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