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Humeral bone resorption after reverse shoulder arthroplasty using uncemented stem

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Background: Humeral stem loosening has gained attention as it has been identified as a cause of revision surgery in reverse shoulder arthroplasty (RSA). In RSA, humeral stem revision is very difficult if there is humeral bone loss because of stress shielding. Some studies of humeral bone resorption after anatomic shoulder arthroplasty have been published, but there are few detailed reports of humeral bone resorption after RSA. This study aimed to investigate the prevalence of humeral bone resorption after RSA procedures and to evaluate the risk factors for bone resorption.

Methods: This study included 48 shoulders that underwent RSA with an uncemented humeral stem from July 2014 to May 2017 and were followed up for more than 1 year. The prevalence of humeral bone resorption and risk factors were investigated. Logistic, multiple logistic, and multivariate logistic regression analyses were performed to evaluate the data.

Results: Grade 0 bone resorption, the most advanced grade, occurred in 8 shoulders (16.7%); grade 1, in 0 (0%); grade 2, in 17 (35.4%); grade 3, in 14 (29.2%); and grade 4, in 9 (18.8%). A high occurrence of bone absorption was observed in zones 1, 2, and 7. Grade 4 bone resorption did not occur in zones 3, 5, and 6. Female sex and an onlay-type stem were significant independent risk factors for grade 4 bone resorption.

Conclusions: Bone resorption was frequently observed in the greater tuberosity, lateral diaphysis, and calcar region. Significant risk factors included female sex and an onlay-type stem.

Recently, some reports have shown that loosening and complications were more frequent on the humeral side than on the glenoid side.[3,4] Loosening of the humeral stem has received attention because humeral stem loosening was identified as a cause of revision surgery in reverse shoulder arthroplasty (RSA). In RSA, humeral stem revision is very difficult if there is humeral bone loss because of stress shielding. Some studies of humeral bone resorption after anatomic shoulder arthroplasty have been published,[5–7,11,12,15,16,18,19,21–24] but there are few reports of humeral bone resorption after RSA.[1,10,13,14,20]

Therefore, this study aimed to investigate the prevalence of humeral bone resorption after different RSA procedures and to evaluate the risk factors for bone resorption.

Materials and methods

Study design and patients

We conducted a retrospective case-series study to assess humeral bone resorption in patients who have undergone RSA. Overall, 48 shoulders that underwent RSA with an uncemented humeral stem from July 2014 to May 2017 were included in this

The Hokushin Hospital Ethics Review Board approved this study (study no. 1901).

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study. Patients who underwent RSA with a short stem or stemless RSA were excluded from this study.

Data collection

By use of postoperative anteroposterior radiographs, the location and grade of humeral bone resorption were evaluated at 1, 2, 3, 6, 12, 18, and 24 months postoperatively and at final follow-up. The location of bone resorption was divided into 7 zones: zone 1, greater tuberosity; zone 2, lateral diaphysis; zone 3, lateral diaphysis beyond the deltoid tuberosity; zone 4, tip of the stem; zone 5, medial diaphysis beyond the deltoid tuberosity; zone 6, medial diaphysis; and zone 7, calcar region (Fig. 1).[11] The degree of bone resorption was classified from grades 0 to 4: grade 0, no bone resorption; grade 1, decrease in the cortical bone density; grade 2, thinning of the cortical bone comprising less than one-half of the original thickness; grade 3, thinning of the cortical bone comprising more than one-half of the original thickness; and grade 4, complete disappearance of the cortical bone.[11]

The appearance rates of bone resorption for each implant model (Trabecular Metal Reverse Shoulder System [Zimmer, Warsaw, IN, USA]; Comprehensive Reverse Shoulder System [Biomet, Warsaw, IN, USA]; SMR system [Lima, San Daniele, Italy]; and Delta Extend Reverse Shoulder System [DePuy, Warsaw, IN, USA]) were also compared. Six factors were analyzed as risk factors of bone resorption and included (1) age, (2) sex, (3) type of stem coating (on-growth or ingrowth), (4) stem shape (onlay or inlay type), (5) type of fixation of the stem (proximal or distal fixation), and (6) intramedullary occupation ratio of the implant. The Comprehensive Reverse Shoulder System used an onlay-type stem, whereas the Trabecular Metal, Comprehensive, and Delta Extend Reverse Shoulder Systems used inlay-type stems. The proximal-fixation type was used for the Trabecular Metal, Comprehensive, and Delta Extend Reverse Shoulder Systems, whereas the distal-fixation type was used for the SMR system. The SMR system and Delta Extend Reverse Shoulder System used on-growth–type coated stems, whereas the Trabecular Metal and Comprehensive Reverse Shoulder Systems used ingrowth-type coated stems. The intramedullary occupation ratio of the implant was measured at the narrowest part of the humerus on anteroposterior and lateral radiographs (Fig. 2).

Statistical analysis

Logistic regression analysis was performed to evaluate the differences in bone resorption in each zone and the differences in each implant model. $P < .05$ was considered statistically significant. For risk factors, multiple logistic regression analysis was performed to compare the relative impact of variables. Values were compared using the χ^2 test and Mann-Whitney U test on univariate analysis. To assess predictors of bone resorption, multivariate logistic regression analysis was performed using variables with $P < .20$ on univariate analysis. $P < .05$ was considered significant on multivariate analysis. All statistical analyses were performed with JMP software (version 9.0.0; SAS Institute, Cary, NC, USA).

Results

The subjects included 16 men and 22 women. The mean age at surgery was 76.5 years (range, 70-88 years). Patients were followed up for a mean duration of 18.5 months (range, 12-31 months). Arthroplasty was performed because of intractable pain and functional disability due to cuff tear arthropathy (CTA) in 39 shoulders, retear after cuff repair in 4, malunion after proximal humeral fractures in 2, primary osteoarthritis in 2, and conversion from humeral head replacement in 1. The Trabecular Metal Reverse Shoulder System was used in 22 shoulders; Comprehensive Reverse Shoulder System, 11; SMR system, 10; and Delta Extend Reverse Shoulder System, 5.

Grade of bone resorption

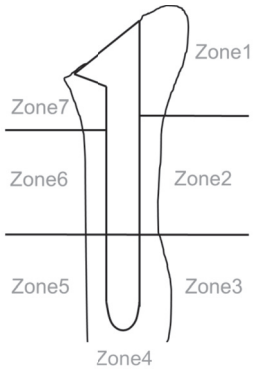
Grade 0 bone resorption, the most advanced grade, occurred in 8 shoulders (16.7%); grade 1, in 0 (0%); grade 2, in 17 (35.4%); grade 3, in 14 (29.2%); and grade 4, in 9 (18.8%). The first appearance of bone resorption occurred, on average, at 7.6 months (range, 4-12 months) postoperatively.

Location of bone resorption

The locations of bone resorption of each grade and statistical analysis findings of the appearance rates between zones are shown in Table I. A high appearance rate of bone absorption was observed in zones 1, 2, and 7. Grade 4 bone resorption did not occur in zones 3, 5, and 6.

Implant models

Bone resorption of grade 3 or higher occurred in 8 shoulders (36.4%) with the Trabecular Metal Reverse Shoulder System, 7 (63.6%) with the Comprehensive Reverse Shoulder System, 6 (60.0%) with the SMR system, and 2 (40.0%) with the Delta



Zone 1	Greater tuberosity
Zone 2	Lateral diaphysis
Zone 3	Lateral beyond deltoid tuberosity
Zone 4	Tip of stem
Zone 5	Medial beyond deltoid tuberosity
Zone 6	Medial diaphysis
Zone 7	Calcar region

Figure 1 Locations of bone resorption.

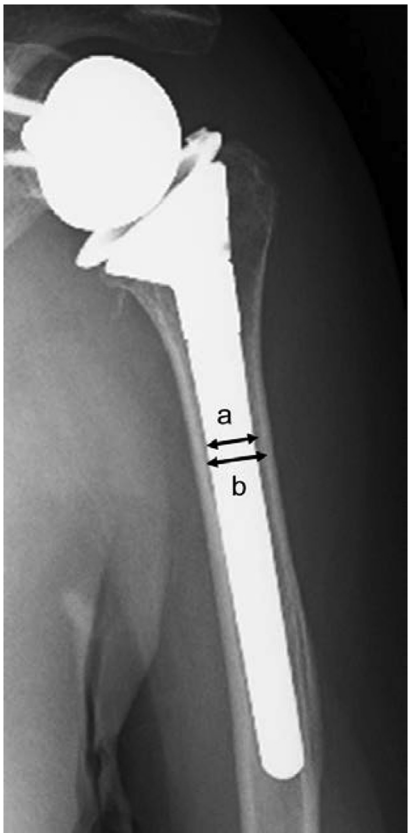


Figure 2 The intramedullary occupation ratio of the implant is calculated as the ratio of the transverse diameter of the stem (*a*) to the intramedullary diameter (*b*).

Extend Reverse Shoulder System; no statistically significant differences were found between the implant models. Grade 4 bone resorption occurred in 2 shoulders (9.1%) with the Trabecular Metal Reverse Shoulder System, 6 (54.5%) with the Comprehensive Reverse Shoulder System, 1 (10.0%) with the SMR system, and 0 (0%) with the Delta Extend Reverse Shoulder System. Bone resorption was more frequently found with the Comprehensive Reverse Shoulder System than with the Trabecular Metal Reverse Shoulder System, SMR system, and Delta Extend Reverse Shoulder System.

Multivariate logistic regression analysis

Variables analyzed as dependent variables on univariate analysis were sex and the stem shape (onlay or inlay type) in patients with bone resorption of grade 3 or higher (Table II) and were sex, type of stem coating (on-growth or ingrowth), stem shape (onlay or inlay type), and intramedullary occupation ratio of the implant in patients with grade 4 bone resorption (Table III). The analysis revealed that no variable was a significant independent risk factor for grade 3 bone resorption (Table IV) and that female sex ($P = .0316$; odds ratio, 9.95; 95% confidence interval, 0.09-2.72) and an onlay-type stem ($P = .0146$; odds ratio, 10.6; 95% confidence interval, −2.33 to −0.23) were significant independent risk factors for grade 4 bone resorption (Table V).

Case presentation

Figures 3 and 4 present examples of bone resorption in 2 patients. In case 1, onlay-type RSA with latissimus dorsi

Table I
Locations of bone resorption of greater tuberosity

Zone	Grade 1<			Grade 2<			Grade 3<			Grade 4		
	Location		*P* value	Location		*P* value	Location		*P* value	Location		*P* value
1 > 3			<.001			<.001			<.001			.007
1 > 5			<.001			<.001			<.001			.007
1 > 6			<.001			<.001			<.001			.007
2 > 3	77.1%		<.001	70.8%		<.001	33.3%		<.001	8.3%		.007
2 > 5			<.001			<.001			<.001			.007
2 > 6	33.3%		.008	18.8%		<.001	3.8%		.001	0%		.007
6 > 3			.006			.020			—			—
6 > 5			.001			<.001			—			—
7 > 3			<.001			<.001			<.001			.017
7 > 5	6.3%		<.001	0%		<.001	0%		<.001	0%		.017
7 > 6			<.001			<.001			<.001			.017

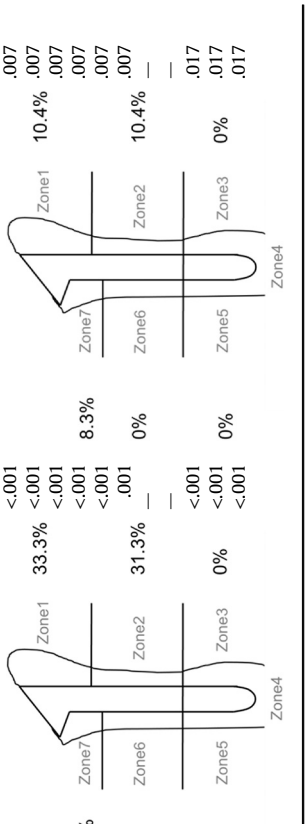


Table II
Results of univariate analysis of bone resorption of grade 3 or higher

	Resorption (n = 23)	Nonresorption (n = 25)	*P* value
Age, yr	76.0 ± 4.5	77.0 ± 5.3	.419
Sex	8 M and 15 F	15 M and 10 F	.072
Stem coating	8 on-growth type and 15 ingrowth type	7 on-growth type and 18 ingrowth type	.422
Stem shape	7 onlay type and 16 inlay type	4 onlay type and 21 inlay type	.199
Fixation concept of stem	17 proximal and 6 distal	21 proximal and 4 distal	.307
Occupation ratio, %	93.3 ± 5.3	92.1 ± 6.3	.513

M, male; *F*, female.
Data are presented as mean ± standard deviation or number of shoulders.

transfer for CTA was performed in a 72-year-old woman. Bone resorption in zones 1, 2, and 7 appeared at 6 months postoperatively and progressed thereafter. Grade 4 bone resorption in zones 1, 2, and 7 was observed at 1 year postoperatively (Fig. 3).

In case 2, inlay-type RSA was performed for CTA in a 71-year-old woman. At 11 months postoperatively, bone resorption in zone 1 appeared. Grade 4 bone resorption in zone 1 was observed at 2 years postoperatively (Fig. 4).

Discussion

Rates of humeral loosening from 0.61% to 1.4% have been reported,[2,3,9,25] and a high rate of humeral loosening was found with a longer follow-up time.[9] Humeral loosening is one of the causes of RSA revision. Boileau et al[3,4] reported humeral loosening as the cause of RSA revision in 10%-17% of cases. Melis et al[13] and Boileau[3] suggested that compared with anatomic total shoulder arthroplasty, the constraints associated with Grammont RSA are predominantly located on the humeral side rather than on the glenoid side, which is protected by medialization of the glenoid implant. In humeral component revision of RSA, it is difficult to replace a humeral component if there is obvious humeral bone resorption. Thus, humeral bone resorption is a very important problem after RSA.

Bone resorption around the humeral stem after anatomic total shoulder arthroplasty and hemiarthroplasty has been reported since the 1980s.[5–7,11,12,15,16,19,18,21–24] Yet, few previous studies have assessed humeral bone resorption after RSA.[1,10,13,14,20] Melis et al[13] assessed 34 shoulders after Grammont RSA and reported greater tuberosity resorption in all 34 shoulders (100%), lesser tuberosity resorption in 26 (76%), and cortical thinning in 16 (47%). Al-Hadithy et al[1] assessed 41 shoulders after RSA for CTA and reported that 4 patients (10%) had medial proximal stress shielding. Harmsen and Norris[10] reported no bone resorption after Grammont-type RSA. Schnetzke et al[20] assessed 19 shoulders after onlay, curved, short-stem RSA and reported proximal bone resorption on the medial side in 8 shoulders (42.1%) and on the lateral side in 8 (42.1%). Merolla et al[14] compared 36 Grammont RSA and onlay, curved, short-stem RSA cases; they reported that Grammont-type RSA showed greater tuberosity resorption in 10 shoulders (28%), lesser tuberosity resorption in 2 (5%), and cortical thinning in 21 (58%) whereas onlay, curved, short-stem RSA showed greater tuberosity resorption in 2 (5%), lesser tuberosity resorption in 2 (5%), and cortical thinning in 10 (26%). In our study, bone resorption was observed in 40 shoulders (83.3%), and full-thickness cortical bone resorption occurred in 9 (18.8%). Bone resorption was frequently observed at the greater tuberosity, lateral diaphysis, and calcar region (zones 1, 2, and 7). The location of bone resorption in our study was similar to that reported in previous studies, whereas the appearance rates were inconsistent with those previously reported. In addition, the location of bone resorption in our RSA study was similar to that in our previous anatomic arthroplasty study.[11]

In past reports on anatomic shoulder arthroplasty, there was no correlation between bone resorption and the clinical results.[12,16,18,21] Melis et al[13] showed no correlation between bone resorption and the clinical results in RSA. Deltoid wrapping contributes to joint compression and stability of RSA.[8,17] If there is obvious bone resorption at the greater tuberosity, the effect of deltoid wrapping would be diminished, and instability might occur after RSA.

Age, secondary osteoarthritis, a high occupation ratio of the implant, low bone density, a large implant size, on-growth–type stem coating, and hemiarthroplasty with rotator cuff tear were reported as risk factors for humeral bone resorption after anatomic shoulder arthroplasty.[11,15,22] A large filling ratio was reported as a risk factor for revision after RSA.[20] In this study, risk factors for humeral bone resorption were female sex and an onlay-type stem. Female sex being a risk factor suggests a stronger relationship of outcomes with low bone quality and density because of osteoporosis. The proximal shape of the inlay-type stem may lead to proximal fixation and contribute to a low rate of bone resorption.

There are some limitations to this study. First, this study was a preliminary analysis that aimed to investigate the prevalence of and tendency for humeral bone resorption in patients after RSA as a first step in determining the entire spectrum of factors

Table III
Results of univariate analysis of grade 4 bone resorption

	Resorption (n = 9)	Nonresorption (n = 39)	*P* value
Age, yr	76.7 ± 5.7	76.5 ± 4.8	.926
Sex	1 M and 8 F	22 M and 17 F	.016
Stem coating	1 on-growth type and 8 ingrowth type	14 on-growth type and 25 ingrowth type	.147
Stem shape	6 onlay type and 3 inlay type	5 onlay type and 34 inlay type	.002
Fixation concept of stem	8 proximal and 1 distal	30 proximal and 9 distal	.389
Occupation ratio, %	95.2 ± 5.2	92.1 ± 5.8	.099

M, male; *F*, female.
Data are presented as mean ± standard deviation or number of shoulders.

Table IV
Results of multivariate analysis of bone resorption of grade 3 or higher

	P value	Odds ratio (95% CI)
Sex (M vs. F)	.124	2.54 (0.78-8.42)
Stem shape (onlay type vs. inlay type)	.401	1.85 (0.44-8.42)

CI, confidence interval; *M*, male; *F*, female.

Table V
Results of multivariate analysis of grade 4 bone resorption

	P value	Odds ratio (95% CI)
Sex (M vs. F)	.031	9.95 (1.20-229.20)
Stem coating (on-growth type vs. ingrowth type)	.834	1.34 (0.05-19.44)
Stem shape (onlay type vs. inlay type)	.014	10.58 (1.56-105.64)
Occupation ratio	.349	1.10 (0.90-1.38)

CI, confidence interval; *M*, male; *F*, female.

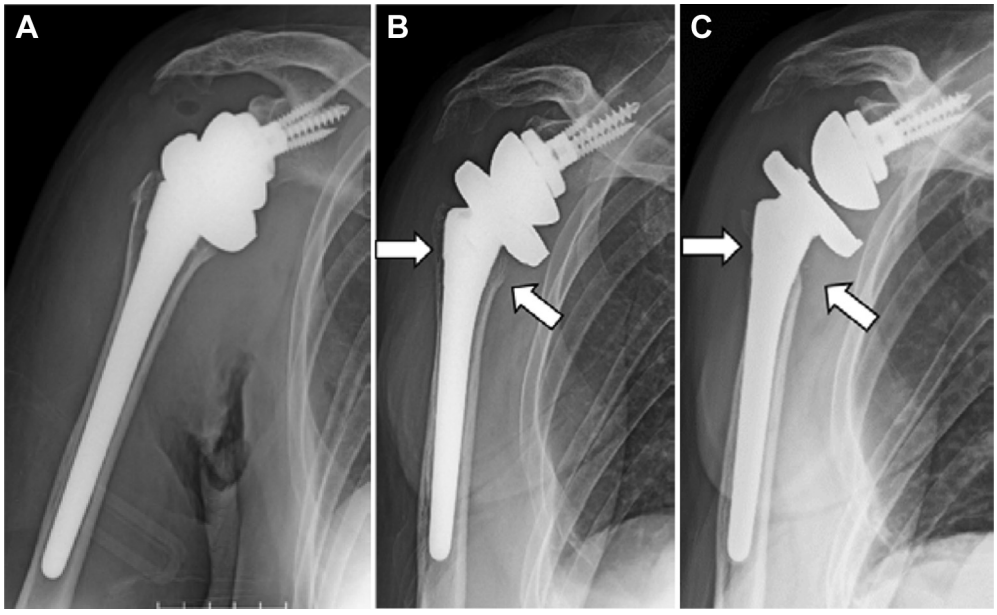


Figure 3 Radiographs obtained immediately (**A**), at 6 months (**B**), and at 1 year (**C**) postoperatively. *White arrow*, bone resorption area.

underlying this issue. In many cases, the progression of bone resorption was observed during the follow-up period. Al-Hadithy et al[1] suggested that there might be a correlation between medial cortex bone resorption and the scapular notch. The mechanism of bone resorption after RSA may be not only stress shielding but also polyethylene wear. Therefore, it is important to continue longitudinal observation and to clarify whether the bone resorption finally progresses to stem loosening. Second, preoperative bone mineral density and bone quality were not measured. To further discuss osteoporosis as a related factor, it is necessary to investigate the general status of bone quality prior to surgery. Third, bone resorption was only defined by findings from plain radiography. A 3-dimensional investigation using computed tomography should provide a more detailed location of the bone resorption.

Conclusion

Bone resorption was frequently observed at the greater tuberosity, lateral diaphysis, and calcar region (zones 1, 2, and 7). Risk factors for bone resorption included female sex and an onlay-type stem.

Disclaimer

The authors, their immediate families, and any research foundations with which they are affiliated have not received any

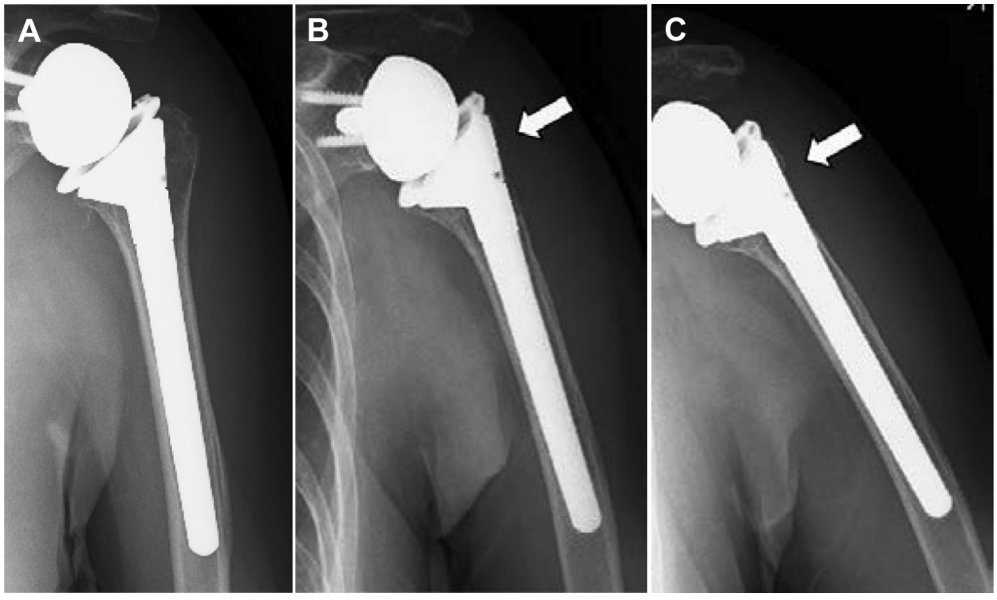


Figure 4 Radiographs obtained immediately (**A**), at 11 months (**B**), and at 2 years (**C**) postoperatively. *White arrow*, bone resorption area.

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