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Clinical results of reverse shoulder arthroplasty for comminuted proximal humerus fractures in elderly patients: a comparison between nonporous stems versus trabecular metal stems

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Background: This study compared the clinical results for nonporous stems vs. trabecular metal (TM) stems used in reverse shoulder arthroplasty (RSA) for comminuted proximal humeral fractures (CPHFs) in elderly patients.

Methods: In this retrospective study, a total of 41 shoulders (39 women) of patients with CPHF aged >70 years who underwent RSA were investigated. The minimum follow-up period was 2 years. A total of 15 shoulders were treated with Grammont-style RSA using nonporous stems (the G-RSA group), and 26 shoulders were treated with RSA combining TM stems (the FR-RSA group). The American Shoulder and Elbow Surgeons (ASES) shoulder score, Constant score, shoulder joint range of motion (ROM), and radiographic findings were compared between the 2 groups.

Results: ASES scores and Constant scores were significantly higher in the FR-RSA group than in the G-RSA group. External rotation at the side in the FR-RSA group was significantly higher than that in the G-RSA group. In the FR-RSA and G-RSA groups, the union rates at the greater tuberosity (GT) were 88.5% and 46.7%, respectively, and scapular notching rates were 20% and 7.7%, respectively. Based on a sub-analysis, the age was lower, body mass index was higher, and ASES scores, Constant scores, and external rotation ROM were higher in the GT union group than in the GT nonunion group.

Conclusion: GT bone union rates were high, and external rotation ROM of the shoulder joint were more improved for RSA using TM stems than those for RSA using nonporous stems in elderly patients with CPHF.

Proximal humeral fracture (PHF) is the third most common fracture followed by hip fracture and distal radius fracture in the elderly.[3] PHF treatment is decided based on age, sex, fracture type, and activity of the patient; comminuted PHF may be treated with surgery for the purpose of pain relief and functional improvement.[16,22,24] Implant surgery is indicated especially in comminuted proximal humerus fractures (CHPFs) in the elderly.[6] It has been reported that although humeral head replacement provides favorable clinical outcomes if greater tuberosity (GT) bone union is achieved, GT nonunion would lead to poor clinical outcomes.[2,6,7]

Reverse shoulder arthroplasty (RSA) has been reported to have stable outcomes in patients with cuff deficiency and is increasingly used for CHPF in the elderly worldwide.[7,21,26] Favorable outcomes with RSA were reported as compared with conservative therapy such as open reduction internal fixation and humeral head replacement.[7,9,18]

The Grammont-type cemented stem (invented by Paul Grammont in Dijon, France, in 1985) was introduced to Japan in 2014, allowing the use of this implant for comminuted proximal humeral fracture (CPHF) in the elderly. After that, the RSA system with the trabecular metal (TM) stem became available. TM materials have recently been used in hip and knee arthroplasties to facilitate bone ingrowth.[14,19] To date, there have been no reports comparing the outcomes between these 2 types of bone fracture treatments in Asian people who have smaller shoulder joints.[20]

The purpose of this study was to compare clinical results between these 2 types for CPHF in the elderly. We hypothesized that GT bone union rates would be higher and that shoulder joint ranges

Institutional review board approval was received from Jichi Medical University Hospital (A17-174).

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of motion (ROMs) and clinical scores would be superior for RSA using TM stems.

Materials and methods

This research has been approved by the institutional review board of the authors' affiliated institutions. This was a retrospective case-control single-center study that included 46 elderly patients with acute CHPF who underwent RSA between May 2014 and February 2018. The inclusion criteria were 70 years of age or older at the time of surgery; 3-part or 4-part fractures based on the Neer classification,[23] including dislocation fractures; having surgery within 3 weeks after injury; and availability of 2-year or longer follow-up assessment. The exclusion criteria were previous shoulder surgical history and neurologic disorders. Four patients were lost during the follow-up, and 2 patients received surgeries 4 weeks after the surgery, leading to 41 shoulders finally analyzed. A total of 37 shoulders were from females. The mean age was 78 ± 6.4 (70-88) years. For the fracture types, there were 5 shoulders with 3-part fractures, 29 shoulders with 4-part fractures, and 7 shoulders with 4-dislocation fractures based on the Neer classification. The mean follow-up period was 29 (24-49) months.

From May 2014 to May 2016, the Grammont-style RSA (Aequalis II; Wright Medical, Memphis, TN, USA) with a humeral component to the cemented stem was used (G-RSA group: Figs. 1, *A*, and 2). From June 2016 to April 2018, the TM stem (TM Reverse Stem; Zimmer Biomet, Warsaw, IN, USA) was used as the humeral component, whereas the lateralized glenosphere (Comprehensive Reverse Shoulder Glenoid Baseplate; Zimmer Biomet) was used as the glenoid component (the FR-RSA group; Figs. 1, *B*, and 3).

Functional assessments

The functional evaluation included a pain score on the numeric rating scale, American Shoulder and Elbow Surgeons (ASES) shoulder score, Constant score, active ROM of anterior elevation (AE), abduction, external rotation (ER) at the side, and internal rotation (IR). IR was measured by assessing how far up the spine the patient could reach with the thumb. An independent examiner blinded to the group was assigned at each institute to evaluate shoulder function and active ROM.

Radiologic assessments

Anteroposterior views in the neutral position at the final follow-up were analyzed to determine the status of the GT and classify the patients into 2 categories: union and nonunion.

Union was defined as GT healing where the GT was visible on the lateral part of the stem, at or below the level (no more than 5 mm) of the prosthetic head, and in continuity with the diaphysis (Fig. 2, *B*). Nonunion was defined as GT failed healing or resorption (Fig. 3, *B*).

The acromiohumeral distance (AHD) was calculated starting from the most lateral part of the undersurface of the acromion and running perpendicular to a line parallel to the top of the GT.[28] The distance from the perpendicular AHD line to the most lateral portion of the GT determined the lateral humeral offset.[29] The Nerot-Sirveaux classification was used as the evaluation of the scapular notching.[27]

Surgical procedures

All surgeries were performed by the authors. The deltopectoral approach was selected for all patients. Around the point of insertion of the pectoralis major muscle in the upper arm, we found the long head biceps tendon and partitioned it into the smaller tuberosity and the GT using the intertubercular sulcus as a landmark. The supraspinatus tendon was temporarily detached from the GT. The fracture part was exposed, and the humeral head was removed. After the glenoid was exposed, we set a base plate of 25 mm in

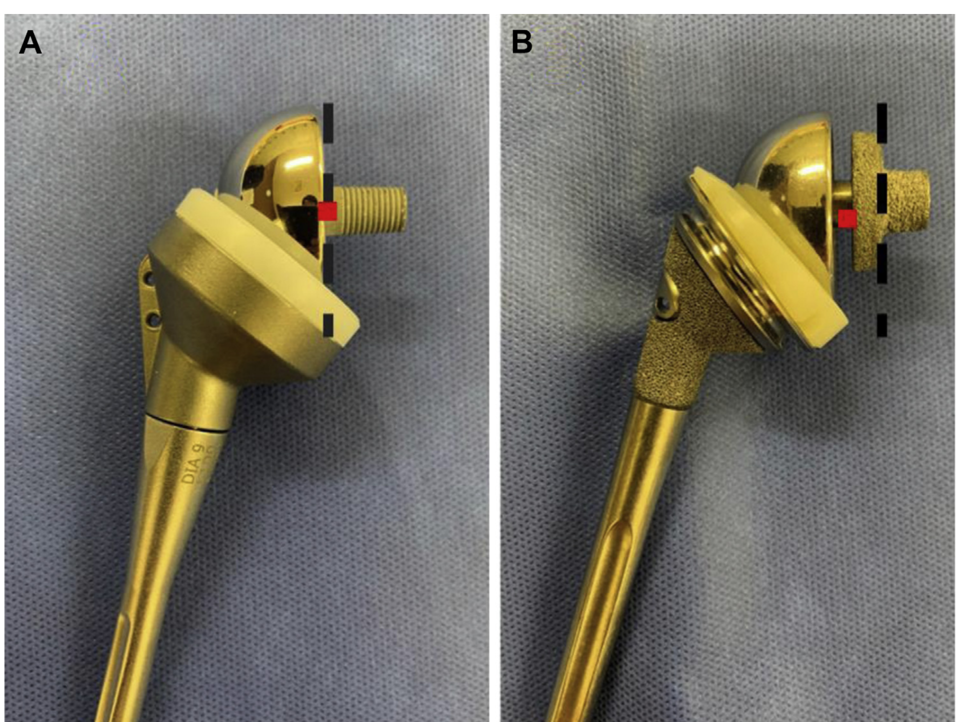

Figure 1 (**A**) Grammont style reverse shoulder arthroplasty (G-RSA group). (**B**) Trabecular metal stem and lateralized glenosphere (FR-RSA group); glenosphere was designed with 1 mm inferior offset and 5.9 mm laterally from the baseline (- - - -: black line). ■, center of rotation.

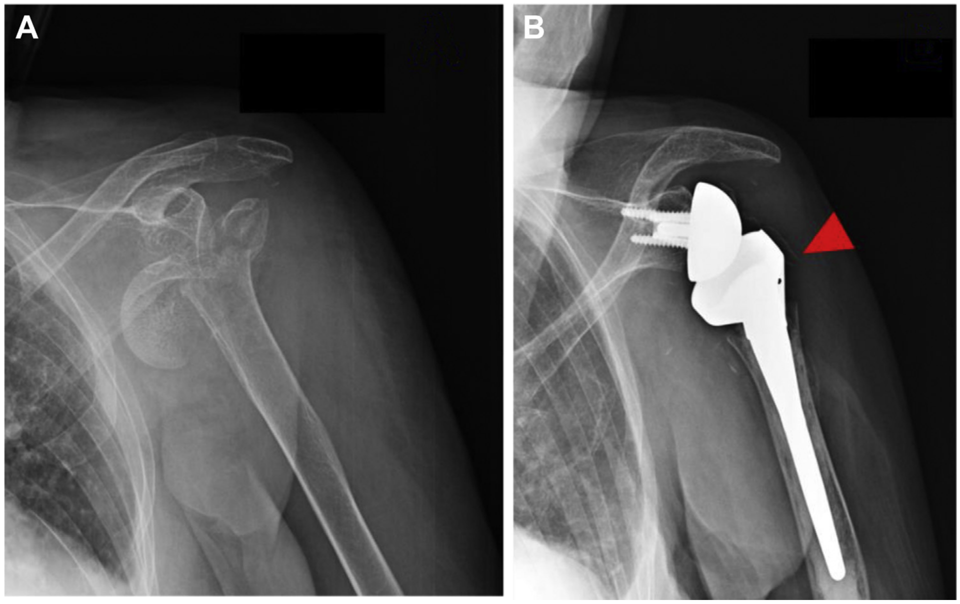

Figure 2 (**A**) Eighty-two-year-old woman, 4-part dislocated fracture (left shoulder). (**B**) X-ray 2 years after operation (Grammont-style RSA using the cemented stem), resorbed tuberosity (▲) on the anteroposterior view. *RSA*, reverse shoulder arthroplasty.

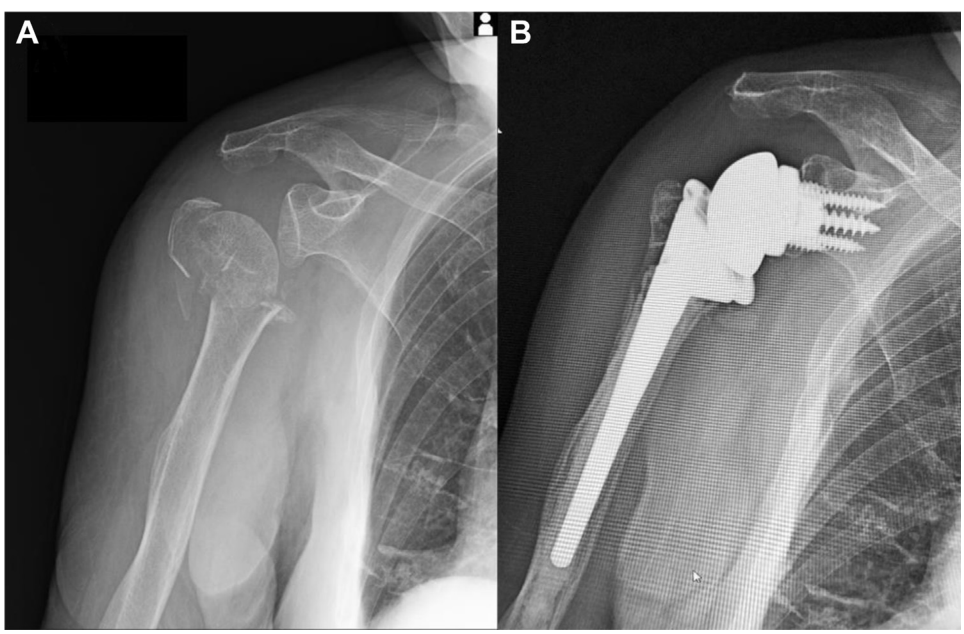

Figure 3 (**A**) Seventy-eight-year-old female, 4-part fracture (right shoulder). (**B**) X-ray 2 years after operation (RSA using the trabecular metal stem and lateralized glenosphere; FR-RSA), healed tuberosity on the anteroposterior view. *RSA*, reverse shoulder arthroplasty.

diameter and placed it with an inferior tilt of 10° in all patients. Glenospheres of diameter 36 mm were used in both groups. We determined the insertion height of the humerus stem so that the deltoid muscle and the conjoined tendon could have proper tension during test repositioning and that both tuberosities could be repaired well. After 4 high-strength threads were put through holes created in the diaphyseal region of the bone, the stems in both groups were fixed to the shafts with cement (Cobalt Bone Cement; Zimmer Biomet) at a retroversion angle of 25°. The thinnest inserts were used in all patients. After stem repositioning, cancellous bone obtained from the humeral head was grafted to the proximal part of the stem as much as possible (Fig. 4). The GT was repaired by suturing between the tuberosities and between each tuberosity and the diaphyseal region with high-No. 2 strength threads (Fig. 5). The cut end of the supraspinatus tendon was sutured to the infraspinatus tendon. A drain was inserted, and the surgical incision was closed.

Postoperative rehabilitation

The affected arm was kept in a sling for 4 weeks; during this period, pendulum and self-assisted circumduction exercises were encouraged. Four weeks after surgery, self-assisted passive ROM exercises were started, such as AE in the supine position and table

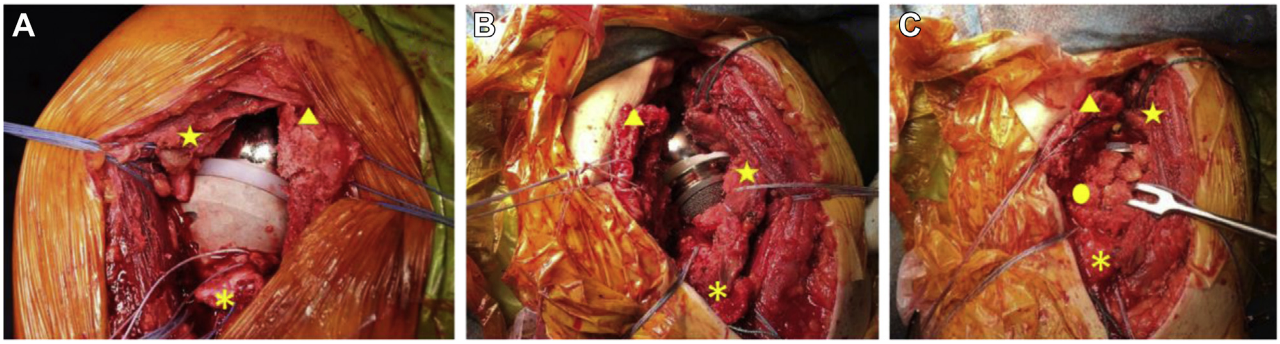

Figure 4 (**A**) G-RSA group (right shoulder). (**B**) FR-RSA group (left shoulder). (**C**) Bone graft to the metaphysis of proximal humerus. ▲, lesser tuberosity; ★, greater tuberosity; ✱, diaphysis; ●, bone graft from the humeral head.

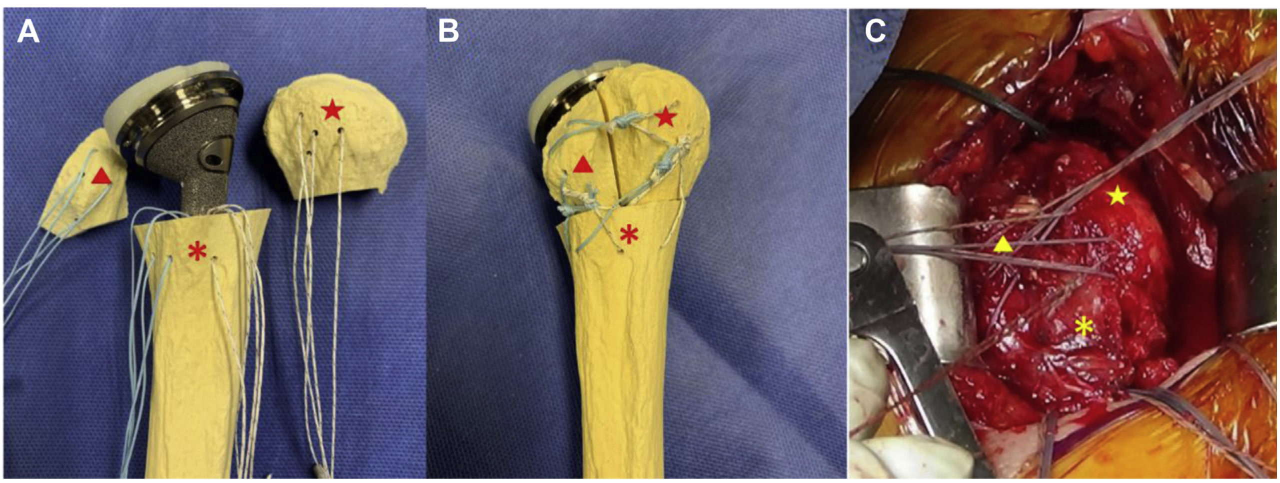

Figure 5 Technique of tuberosity repair. (**A**, **B**) Schema by a bone model. (**C**) Left shoulder. ▲, lesser tuberosity; ★, greater tuberosity; ✱, diaphysis.

sliding/stretching exercise, preferably during or after a hot bath or shower. After 4 weeks, self-assisted active exercises were started. Isotonic strengthening exercises using an elastic band were started 2 months postoperatively. Three months after surgery, the patients were allowed to gradually return to their daily activities.

Clinical outcomes and radiographic findings 2 years after surgery were compared between the G-RSA group and the FR-RSA group. As a subanalysis, clinical outcomes were compared between the GT union group and the GT nonunion group. Finally, the clinical outcomes of patients with GT unions were compared between the G-RSA group and the FR-RSA group.

Statistical analysis

A statistical analysis was performed using the Mann-Whitney *U* test for continuous variables and the χ^2 test or Fisher's exact test for categorical variables. The level of statistical significance was set at $P < .05$. Calculations were performed with SPSS 20 software (IBM, Armonk, NY, USA).

Results

There were no differences between the 2 groups in patient demographics, including age, sex, dominant side, period from injury to surgery, fracture type, medical complications, and the American Society of Anesthesiologists physical status (Table I).

ASES scores and Constant scores 2 years after surgery were significantly higher in the FR-RSA group than in the G-RSA group (Table II). The ER in the FR-RSA group was significantly higher than that in the G-RSA group. There were no significant differences in AE, abduction, and IR. According to radiographic evaluation performed 2 years after surgery, GT bone union rates were 46.7% (7 of 15) in the G-RSA group compared with 88.5% (23 of 26) in the FR-RSA group ($P = .0082$, Table III). Scapular notching rates were 20% (3 shoulders) in the G-RSA group and 7.7% (2 shoulders) in the FR-RSA

Table I
Study population and demographics

	G-RSA (n = 15)	FR-RSA (n = 26)	*P* value
Sex (male/female)	1/14	3/23	>.99
Age (yr)	79.2 ± 6.3	79.4 ± 6.6	.944
BMI (kg/m^2)	23.0 ± 3.1	24.2 ± 3.1	.451
Dominant arm involvement (%)	71.4 (11/4)	58.3 (12/14)	.173
Interval between injury and surgery (d)	5.0 ± 2.4	4.6 ± 1.9	.437
Neer classification			.95
3-part	3	2	
4-part	10	19	
Dislocation fracture	2	5	
Comorbidities			
Smoker	0	2	>.99
Diabetes	5	11	.81
Osteoporosis	6	15	.685
Malignoma	2	3	>.99
ASA physical status (class II/III)	11/4	21/5	.28

BMI, body mass index; *ASA*, American Society of Anesthesiologists.

Table II
Clinical comparison between the Grammont-style RSA and fractured RSA

	G-RSA (n = 15)	FR-RSA (n = 26)	*P* value
Numeric rating score	1.4 ± 1.2	0.88 ± 0.68	.107
ASES score	68.7 ± 18.2	77.3 ± 15.1	.012
Constant score	70.1 ± 17.7	79.7 ± 11.6	.044
Anterior elevation	112 ± 26	122 ± 18.7	.217
Abduction	106 ± 31	119 ± 36	.325
External rotation at side	16 ± 16	28 ± 12	.0057
Internal rotation	L4	L4	.153

ASES, American Shoulder and Elbow Surgeons.

Table III
Radiologic outcomes between the Grammont-style RSA and fractured RSA

	G-RSA (n = 15)	FR-RSA (n = 26)	*P* value
Radiologic outcome	7 (46.7)	23 (88.5)	.0082
Union of GT	5 (33.3)	2 (7.7)	
Nonunion of GT, displaced absorption	3 (20)	1 (3.8)	
Scapular notching	3 (20)	2 (7.7)	.248

GT, greater tuberosity.
Data are presented as n (%).

group (*P* = .248). All of them in both groups were classified to grade 1.

As for postoperative complications at the final examination, postoperative infection, dislocation, fractures around the implant, and reoperation were not reported in either group.

Patients with GT union (n = 30) were younger at the time of surgery and had a higher body mass index (BMI) compared with patients with GT nonunion (n = 11). In addition, ASES scores, Constant score, and ER were significantly higher (Table IV).

When only patients with GT union were compared between the G-RSA group and the FR-RSA group, there were no differences in numeric rating scale scores, ASES scores, Constant scores, and shoulder joint ROM (Table V). According to postoperative radiographic evaluations, lateral humeral offset was significantly higher in the FR-RSA group; there were no differences in AHD.

Discussion

This research showed that for elderly patients with CPHF, RSA using the TM stem had a higher GT bone union rate, significant improvements in the clinical scores, and better ER ROM compared with RSA using the nonporous stem.

Several experts have reported favorable outcomes using RSA in elderly patients with CPHF. Chun et al[5] reported a visual analog scale pain score of 1.5, an ASES score of 72, a Constant score of 65, an AE of 125°, and an ER of 17° by using the same stem type as our G-RSA group, whereas Wright et al[30] reported a visual analog scale score of 0-1, an ASES score of 82, an AE of 130°, and an ER of 32° for RSA using TM stems. The surgical procedures differed; however, the results were similar to ours.

Regarding complications, the multicenter retrospective review for 422 patients by Gallinet et al[10] revealed a 12.5% overall complication rate and 5% revision rate, of which 50% were caused by instability. The report showed a 6% mortality rate, 12.5% overall complication rate, and 5% revision rate at 1 year.[10] Among the 2-year postoperative complications in our study, dislocation, infection, acromion fracture, and periprosthetic fracture did not occur, which indicates that the postoperative courses of our patients were uneventful.

Clinical outcomes for RSA in elderly patients with CPHF are affected by GT bone union.[9,11,12,15] Jain et al[15] reported in their meta-analysis that AE, ER, and the Constant score were higher in the GT bone union group than in the GT bone nonunion group. Our results showed that ASES and Constant scores and ROM for ER at the side were higher in the GT union group. Age was younger and BMI was higher in the GT bone union group than in the GT bone nonunion group. Generally, there exists a negative correlation between bone union capacity and age, and a positive correlation between BMI and bone density.[28] In addition to the design of RSA, age and BMI could have an effect on GT bone union.

Although bone-compatible designs have been adopted for stems and GT repair procedures have improved,[8,25] GT bone union rates varied from 37% to 100%.[7,20] Chun et al[5] reported that GT union rates were 36.8% (14 of 38) for nonporous cement stems of the Grammont style, whereas Chivot et al[4] reported that GT bone union rates using TM stems were 89%. The results were similar to ours. It is highly likely that the structure of porous tantalum coating in the proximal part of the TM stem[1] affects this difference in the bone union rates. As the volume of the proximal part of the TM stem is small, the back and lateral side of the stem can be fully filled with cancellous bone transplanted from the epiphysis, which seems to affect bone union (Fig. 4, *C*). Meanwhile, the bone union rates for the Grammont-type RSA were low possibly because the implant was made of a nonporous cobalt-chromium alloy and the large metaphysis raised the stem higher, whereby excessive traction force was applied to the repaired GT.

Lateralization of the glenoid components and humerus components in RSA prevents scapular notching and improves ER ROM.[13,17] Jain et al[15] reported in their meta-analysis that scapular notching occurred in 26% of elderly patients who underwent RSA

Table IV
Clinical comparison between the greater tuberosity (GT) union group and the GT nonunion group

	Union (n = 30)	Nonunion (n = 11)	*P* value
Sex (male/female)	28/2	10/1	>.99
Age (yr)	77.1 ± 6.3	83.8 ± 4.5	.023
BMI (kg/m^2)	23.3 ± 3.7	19.2 ± 3.2	.033
Implant (G-RSA/FR-RSA)	23/7	3/8	.0082
Numeric rating score	0.87 ± 1.1	1 ± 1	.521
ASES score	75.5 ± 14.6	66.1 ± 7.5	.043
Constant score	79.1 ± 15.1	68.4 ± 15.1	.013
Anterior elevation	123 ± 22	112 ± 33	.375
Abduction	120 ± 26.3	103 ± 43.9	.329
External rotation at side	29 ± 14.5	10 ± 9.5	.001
Internal rotation	L4	L4	.256

BMI, body mass index; *ASES*, American Shoulder and Elbow Surgeons.

Table V
Clinical comparison of patients with greater tuberosity union between the G-RSA group and the FR-RSA group

	G-RSA (n = 7)	FR-RSA (n = 23)	*P* value
Sex (male/female)	0/7	1/22	>.99
Age (yr)	75.8 ± 5	77.4 ± 6.7	.431
BMI (kg/m^2)	23.5 ± 3.7	23.3 ± 3.8	.919
Postoperative			
Numeric rating score	1.5 ± 1.7	0.65 ± 1.2	.286
ASES score	70.5 ± 21.3	80.9 ± 11	.201
Constant score	76.3 ± 22.5	80.1 ± 12.3	.563
Anterior elevation	122 ± 29.7	128.9 ± 19.1	.973
Abduction	114 ± 30	120 ± 25.7	.865
External rotation at side	21.6 ± 17.5	26.1 ± 13.9	.473
Internal rotation	L3	L3	.431
Postoperative X-ray evaluation			
AHD (mm)	23.5 ± 5.8	24.2 ± 6.8	.91
LHO (mm)	0.8 ± 1.5	4.2 ± 3.3	.037

BMI, body mass index; *ASES*, American Shoulder and Elbow Surgeons; *AHD*, acromiohumeral distance; *LHO*, lateral humeral offset.

with CHPF. According to the results of the joint research study among various institutions conducted by Lignel et al,[17] scapular notching occurred in 44% of the cases, of which 7% were severe (grades 3 and 4). In a comprehensive stem, the hemisphere is lateralized, whereby scapular notching may be prevented. In this research, scapular notching rates in the FR-RSA group (7.7%) seemed to be lower than those in the G-RSA group (20%). Further long-term follow-up might be needed for evaluating attribution to the effects of the lateralization. In an analysis of GT bone union in both groups, lateralization of GT in X-ray was greater in the FR-RSA group; however, there were no differences in clinical outcomes, including ER. This result could not demonstrate that lateralization of GT bone union improved the ER angle.

This research was subject to several limitations. First, this was a retrospective study. Although it was performed by a single surgeon at the same facility with the same procedure, it was possible that biases were present. Second, the number of patients was small with a minimum follow-up period of 2 years. Intermediate and long-term follow-up is desirable. Third, as the stem design and the glenoid design were different between the 2 groups, it was impossible to analyze whether the stem side or the glenoid side contributed to improvements in the clinical outcomes in the FR-RSA group. Fourth, preoperative bone strength and physical activity levels in both groups were not evaluated. It was likely that bone fragility had effects on the surgical procedures or GT bone union; therefore, the possibility that preoperative bone strength and physical activity levels had effects on postoperative clinical outcomes could not be ruled out.

Conclusion

GT bone union rates were high and ER ROM of the shoulder joint were more improved for RSA using TM stems than those for Grammont-style cemented RSA in elderly patients with CPHF.

Disclaimer

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