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ORTHOPAEDIC SURGERY

Non-fracture stem vs fracture stem of reverse total shoulder arthroplasty in complex proximal humeral fracture of asian elderly

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Abstract

Purpose Fracture stem of the reverse total shoulder arthroplasty (RTSA) was designed for better tuberosity bone healing for the proximal bone defect of complex proximal humeral fractures (PHF). Our purpose was to compare the clinical and radiological outcomes of patients using fracture stem vs non-fracture (conventional) stem of RTSA in complex PHF of elderly patients.

Methods Between 2008 March and 2017 June, 48 patients who had undergone an RTSA with non-fracture or fracture stem for complex PHF with a minimum 18 months of follow-up were evaluated. Finally, total 45 patients with a mean age of 80 ± 7 years (65–92 years) were enrolled because three patients were excluded due to age related mortality. We divided them into two groups: 25 patients using non-fracture stem (non-fracture stem group) in the early period of this study, and consecutive 20 patients using fracture stem (fracture stem group) in the later period. Between two groups, we compared clinical and radiologic outcomes such as tuberosity failure, heterotopic ossification (HO), dislocation, acromion fracture, notching, loosening and periprosthetic fracture.

Results In all patients, clinical outcomes were improved significantly and tuberosity failure was found in 62% (28/45). Between two groups, there were no statistically significant differences on clinical outcomes and radiologic outcomes except UCLA score. As complications, two humeral stem revision was performed due to tuberosity failure related HO and stem loosening with subsequent periprosthetic fracture in non-fracture stem group.

Conclusions Compared to non-fracture stem, fracture stem usage of RTSA in complex PHF of elderly patients has no significant different impact on clinical and radiological outcomes. However, tuberosity failure related secondary HO of non-fracture stem might be responsible for stem loosening and periprosthetic fracture in the RTSA for complex PHF of elderly patients.

Level of evidence Level IV, case series study.

Keywords Complex proximal humeral fractures · Reverse total shoulder arthroplasty · Fracture stem · Non-fracture (conventional) stem · Stem loosening

Introduction

Proximal humeral fractures (PHF) are the third most common fracture in elderly patients, accounting for 10% of all fractures [1]. Treatment of complex PHF in the elderly patients remains highly controversial. Minimally displaced fractures are usually treated non-surgically [2], but displaced fractures generally require operative intervention [3]. Improved fixation devices such as proximal humeral anatomical locking plates and nails have enhanced the possibility to provide stable fixation following open reduction of these fractures [4]. However, despite improved device and surgical techniques, adequate treatment of complex PHF in elderly osteoporotic patients remains a challenging task for

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orthopedic surgeons [5]. Two treatment options are available in these situations: Hemiarthroplasty (HA) and Reverse total shoulder arthroplasty (RTSA). HA for the treatment of complex PHF is a gold standard treatment previously, but technically challenging procedure. Clinical outcomes of HA for fracture highly depends on the fate of the tuberosity healing. With HA, pain relief is often acceptable, but functional outcomes are variable [6]. Currently, the use of RTSA is being increased for the treatment of complex PHF in elderly patients. In addition, when the rotator cuff is not functioning properly due to tuberosity fracture, RTSA has been used with predictable results. Several case series have reported the outcome of RTSA for acute fracture [7, 8]. But few data exist comparing the results of non-fracture stem vs fracture stem of RTSA in complex PHF of elderly patients.

The problem of tuberosity failure is important for functional or radiological outcomes after RTSA [9, 10]. Specific conclusions as yet are difficult to reach in Korean elderly population because it was introduced in late 2007, and also these were a few clinical studies of the RTSA of these complex PHF in elderly patients. Fracture stem of the RTSA was designed for better bone healing for the proximal bone defect of complex PHF. This fracture stem was introduced in late 2014 in Korea, so that, there was a little clinical outcomes or comparison study between two stems until now.

The purpose of this study was to compare the clinical and radiological outcomes of RTSA using non-fracture (conventional) stem vs fracture stem for treatment of complex PHF in elderly patients. The hypothesis was that RTSA using fracture stem provide better radiological outcomes (especially tuberosity healing) and less complications.

Method

Between 2008, March to 2017, June, forty-eight patients who had undergone an RTSA with non-fracture (conventional) stem) or fracture stem for treatment of complex PHF in elderly patients were evaluated. A minimum follow-up periods were 18 months. Among them, three patients were excluded due to age-related mortality and finally, total 45 patients were enrolled in this study. Compared to the non-fracture (conventional) stem, the introduction time of fracture-specific stem (Aequalis® Fracture Stem; Tornier, Minneapolis, MN) was different in Korea (non-fracture stem in 2007 and fracture stem in 2014). We used non-fracture stem and fracture stem consecutively for RTSA treatment of complex PHF in elderly patients. Out of 45 patients, 8 were male and 37 were female, with a mean age 80 ± 7 years (65–92 years). Mean follow-up period was 3.4 ± 2.8 years (1.5–6 years). 25 patients treated with non-fracture stem in the early period of this study (non-fracture stem group) (Fig. 1), and consecutively twenty patients treated with fracture stem in the later period (fracture stem group) were enrolled (Fig. 2).

Demographic and clinical data of these patients were presented in Table 1. Fracture type of PHF were assessed according to the Neer classification. Especially, in two patients with chronic locked dislocation, duration of dislocation was 4 months and 1 year, respectively, one patient showed complete loss of rotator cuff tendon, the other showed tuberosity failure with malunion with rotator cuff tear. Postoperative radiologic evaluation included scapular notching grade by Sirveaux et al. [11]., the presence of tuberosity tuberosity failure, heterotopic ossification (HO), glenosphere or stem loosening, dislocation, acromial fracture and periprosthetic fracture. Radiologically, tuberosity failure was defined as migration or absorption of tuberosity fracture fragments and tuberosity healing was defined as identification of the tuberosity on a plain anteroposterior (AP) radiograph at follow-up periods [24].

All surgeries were performed by a senior author, using a standard deltopectoral approach, and all humeral implants used were cemented non-fracture stem or fracture stem of RTSA with a medialized center of rotation: Aequalis Reversed (Tornier, Edina, Minnesota). The tuberosity of complex PHF was reattached as described by Boileau et al. [12], with circlage sutures and suture tension bands to fix the tuberosities to each other, the prosthesis, and the shaft. Postoperatively, the patients were immobilized in abduction brace and started on passive range of motion (ROM) exercises on postoperative 6 weeks. At postoperative 6 weeks, the abduction brace was removed, and patients were encouraged to perform deltoid activation exercises and activities as tolerated. Progressive passive and active ROM exercises were performed and then gradual strengthening exercise was started.

All patient's charts were reviewed and outcomes assessed included shoulder range of motion (ROM), clinical scores, tuberosity failure and its' complications. Follow-up radiologic findings were reviewed for the complication such as tuberosity failure and implant loosening, dislocation, periprosthetic fracture and acromion fracture, etc. Subjective clinical outcome variables included American Shoulder and Elbow Surgeons (ASES), University of California, Los Angeles (UCLA) and Simple shoulder test (SST) scores. ASES, UCLA, and SST scores were used to assess satisfaction, function, and general well-being. At final follow-up, shoulder ROM in terms of forward flexion, abduction, external rotation at side and internal rotation at back was measured with a goniometer by the same author.

Statistical analysis

All statistical analyses were performed by SPSS software (Version 19, SPSS, Inc., Chicago, IL).

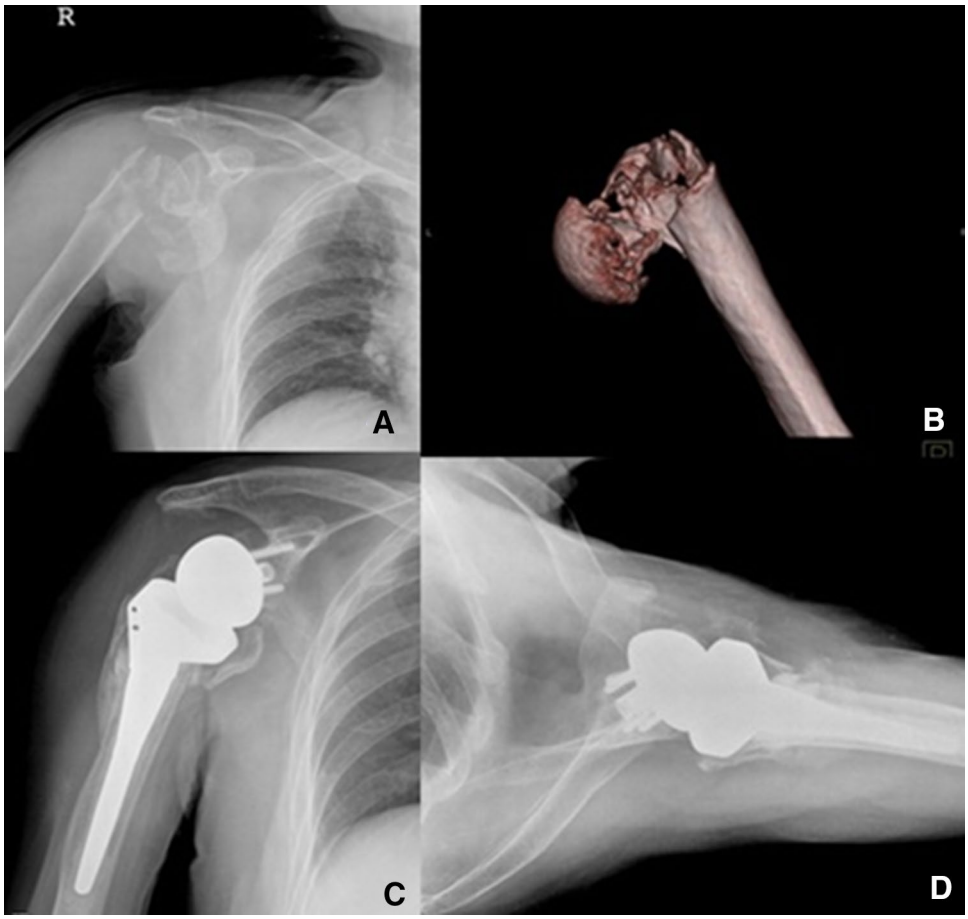

Fig. 1 **a**, **b** A 79-year old male had a 4 part fracture-dislocation on left proximal humerus after falling down injury. **c**, **d** Reverse total shoulder arthroplasty with conventional stem was performed and the greater tuberosity was reattached. We found a well healed greater tuberosity and satisfactory clinical outcomes at the final follow-up

Because of the small sample size, continuous measures were analysed using Wilcoxon Rank Sum tests. Between patients with non-fracture humeral stem or fracture humeral stem, Mann–Whitney test was used for notching, tuberosity failure, heterotopic ossification, stem loosening and periprosthetic fracture. p values < 0.05 were considered significant.

Results

Clinical outcomes

At the last follow-up, both groups showed significant improvement on pain VAS, ASES, UCLA and SST scores. However, there were no significant statistical differences of preoperative and postoperative clinical outcomes among two groups ($p > 0.05$). Pain VAS, ASES, UCLA and SST scores improved significantly to post-operative mean of 2, 68, 23 and 5. Mean ROM (forward flexion, abduction, external rotation and internal rotation) were 108°, 107°, 21° and L4, respectively (Table 2).

Radiologic outcomes

Radiologically, tuberosity failure was found in 62% (28/45) among all patients (Table 3) (Figs. 3, 4). Between two groups, tuberosity failure was higher in non-fracture stem group. As complications, two stem loosening, four periprosthetic fractures and seven HO were found in non-fracture stem group, and five HO was found in fracture stem group. Between two groups, there were no significant differences statistically on HO, glenosphere loosening, dislocation, acromion fracture and notching except tuberosity failure, stem loosening and periprosthetic fracture.

In non-fracture stem group, four periprosthetic fractures were developed. Among them, plate fixation was performed in two periprosthetic fractures (Vancouver type C) and two humeral stem revision was performed due to HO related stem loosening and subsequent periprosthetic fracture. Correlation between stem loosening and periprosthetic fracture was significant at the 0.01 level. In two humeral stem revision, the migration of non-healed tuberosity fracture fragments might cause HO (Fig. 5). The pattern of these secondary HO was resulted from the migration of tuberosity fracture fragments, and secondary new bone formation was developed

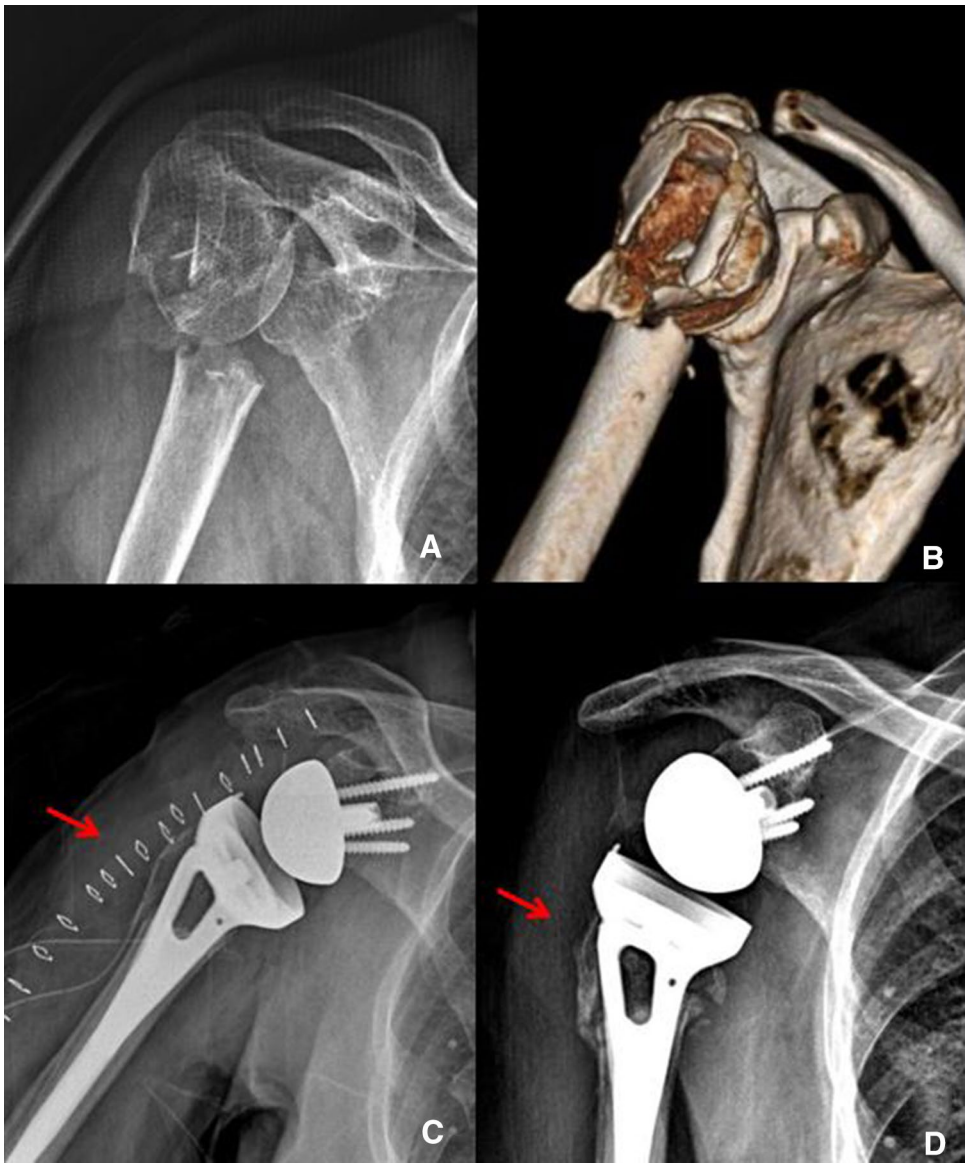

Fig. 2 **a**, **b** A 80-year old female had severely comminuted proximal humeral fracture with serious osteoporosis. **c**, **d** Reverse total shoulder arthroplasty using fracture stem was performed and the greater tuberosity was reattached. We found a well healed greater tuberosity (arrow) and satisfactory clinical outcomes at the final follow-up

Table 1 Demographic data of the two groups using reverse total shoulder arthroplasty with conventional stem vs fracture stem of in complex proximal humeral fracture in Asian elderly

	Non-fracture stem group	Fracture stem group	
No. of patients	25	20	
Male:female	6:19	2:18	0.738
Mean age (range) (years)	77.0 ± 5.5 (65–86)	81.3 ± 7.0 (70–92)	0.001
Operated side (right/left)	13/12	12/8	0.110
BMI	23.7 ± 3.7 (15.9–30.8)	25.4 ± 3.8 (17.4–32.3)	0.308
Fracture type			
2 part Fx or Fx/DL	2 cases	2 cases	0.235
3 part Fx or Fx/DL	5 cases	7 cases	
Head splitting Fx	2 cases	0 cases	
4 part Fx or Fx/DL	13 case	10 cases	
Others (nonunion, malunion, locked DL)	Locked DL (1) Mal-union (1) Non-union (1)	Locked DL(1)	

Fx/DL fracture/dislocation, *Fx* fracture, *DL* dislocation

Table 2 Clinical outcomes of reverse total shoulder arthroplasty using non-fracture stem vs. fracture stem for complex proximal humeral fractures in elderly patients

	Non-fracture stem group ($n=25$)		Fracture stem group ($n=20$)		p value
	Mean	Range	Mean	Range	
Clinical outcomes					
Pain VAS	2.4 ± 2.4	0–8	1.3 ± 1.5	0–4	0.168
ASES	67.7 ± 17.1	26–98.5	78.3 ± 9.9	65–95	0.070
UCLA	21.3 ± 8.0	7–34	28.4 ± 3.7	21–33	0.032
SST	4.7 ± 3.0	0–11	6.1 ± 2.2	3–9	0.186
Range of motion					
Forward flexion (°)	106 ± 34	40–150	115 ± 23	90–150	0.423
Abduction (°)	106 ± 35	45–150	102 ± 29	45–150	0.762
ER at side (°)	22 ± 17	0–70	25 ± 14	10–45	0.594
IR at back	L3	Buttock-T9 level	L4	Trochanter-T10 level	0.121

Table 3 Radiological outcomes of reverse total shoulder arthroplasty using non-fracture stem vs. fracture stem for complex proximal humeral fractures in elderly patients

	Non-fracture stem group ($n=25$)		Fracture stem group ($n=20$)		p value
	Mean	Range	Mean	Range	
Radiologic outcomes					
Tuberosity failure	17/25 (68%)		10/20 (50%)		0.226
Heterotopic ossification	7/25 (28%)		5/20 (25%)		0.823
Glenoid/Stem loosening	4/25 (16%)		0		0.064
Periprosthetic fracture	4/25 (16%)		0		0.064
Notching	13 (Gr 0: 11, Gr 1: 8, Gr II: 5, Gr III: 1)		6 (Gr 0: 14, Gr 1: 5, Gr II: 1)		0.051

between the tuberosity and acromion. At that time, HO might decrease glenohumeral joint motion around the proximal humerus and this proximal fixation might be responsible for more distal stem movement and secondary humeral stem loosening around the distal humerus. It is mechanism looked like loosening of hip joint arthroplasty (Vancouver type B2). These failed tuberosity-related HO might cause secondary humeral stem loosening and periprosthetic humerus fracture around the distal humerus. In the revision surgery, long humeral stem revision augmented with whole humerus strut allograft was performed (Fig. 5). Among two humeral stem revision cases, removal of whole implants due to infection was performed in 1 case. None of all patients had glenoid component loosening, instability or dislocation.

Discussion

Our study showed that RTSA yielded good functional outcomes and improved satisfaction rate for RTSA treatment of PHF in older adults. However, RTSA using non-fracture conventional stem showed higher humeral stem loosening and revision rate compare to fracture stem. Patients with RTSA using non-fracture stem could develop humeral stem loosening and subsequent periprosthetic fracture because of tuberosity failure related secondary HO.

Two arthroplasty options are available for the treatment of complex PHF in elderly osteoporotic patients: HA and RTSA. Plausinis et al. [14]., reported that tuberosity fixation and consolidation issues were the most widespread complications and represented the prime cause of failure and revision in the HA for PHF. Antuna et al. [15], reported generally stable results over time, with 84% of shoulders free or almost free of pain, but with limited recovery of mobility in the shoulder HA for acute PHF. Boileau et al. [12]., reported tuberosity malposition occurred in 50% of patient with HA and demonstrated it correlated with an unsatisfactory result, superior migration of the prosthesis, stiffness or weakness, and persistent pain. Results of HA for complex four-part PHF in the elderly have been unreliable for such a quite common tuberosity nonunion, malunion and resorption [16]. On the contrary to HA, RTSA, originally introduced for the indication of rotator cuff arthropathy, has been suggested as an alternative in the treatment of acute PHF [17], where displacement of the tuberosities leads to a relatively deficient rotator cuff. In a systematic review of shoulder arthroplasty for acute PHF, RTSA patients still have postoperative dysfunction despite well-controlled pain and tuberosity repair was associated with significantly higher external rotation

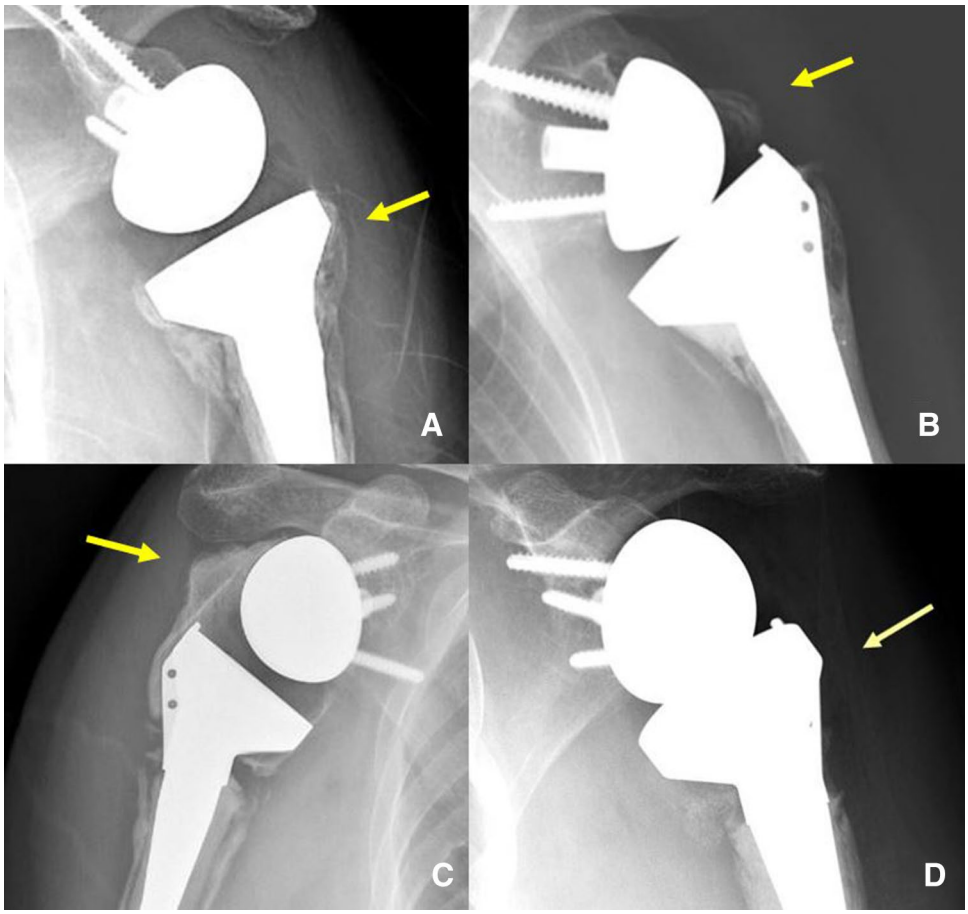

Fig. 3 Radiologic finding of the greater tuberosity healing in the Reverse total shoulder arthroplasty with conventional stem. **a** Complete healing of the reattached tuberosity, **b** partial healing of the tuberosity. A tuberosity bone fragment was migrated from the reattached tuberosity. **c** Heterotopic ossification around the humeral stem and tuberosity was found. **d** Complete absorption of the greater tuberosity

compared to no repair (24° vs 15°; $p=0.0003$) [13]. Gallinet et al. [8] reported that RTSA showed better results in terms of abduction, anterior elevation and Constant score except external rotation. Garrigues et al. [18] also indicated that RTSA provides improved functional outcomes compared with HA for fractures in elderly patients [19]. However, Young et al. [20] reported no statistically significant differences between 2 groups in outcome scores or ROM in the comparative study of functional outcomes of RTSA versus HA in the primary treatment of acute PHF.

Tuberosity healing is a critical factor for HA [6]. In HA, tuberosity healing is related with whole functional outcomes, on the other hand, in RTSA, it is totally related with improvement of external rotation [21]. Gallinet et al. [22] reported that there was a significant difference in external rotation after tuberosity fixation in RTSA. They compared a group with tuberosity repair with healing in anatomic position versus a group without repair or with malunion or nonunion of the tuberosities. The first group showed better external rotation (49° vs 10°), and Constant scores (65 vs 50). In addition, tuberosity failure was the main problem for low patient satisfaction, poor ROM and ratings of activities of daily living [23]. However, Chun et al. [24] reported that there were no significant differences in functional outcomes and ROM between the two groups, with the exception of external rotation, which was better in the healed tuberosity group (only 37% of patients). They suggested that tuberosity healing is not a prerequisite for satisfactory outcomes after RTSA for 4-part PHF in elderly patients. However, they used the conventional non-fracture stem of RTSA in their study.

Fracture stem of the RTSA was designed for better bone healing for the proximal bone defect of unstable PHF. The healing rate of the tuberosity can be affected by kinds of humerus stem used in the hemiarthroplasty of complex PHF. Krishnan et al. [25] reported that the use of fracture-specific stems during HA for PHF appears to improve functional use of the injured shoulder and tuberosity healing compared to conventional non-fracture stems. In the RTSA for PHF using a fracture stem, Garofalo et al. [26] reported that RSA with a fracture stem for the treatment of acute PHF resulted in a radiographic tuberosity healing rate of 75%. In our series of 45 patients, a radiographic tuberosity failure was found in 60% (27/45). Poor bone quality of older aged person might cause poor tuberosity healing in both group. These high failure rate of tuberosity could be related to age factor of this population in whom mean age was over 80 years with poor osteoporotic bone quality. Because these aged patients (mean 80 years old) had a poor quality of cuff tendon and

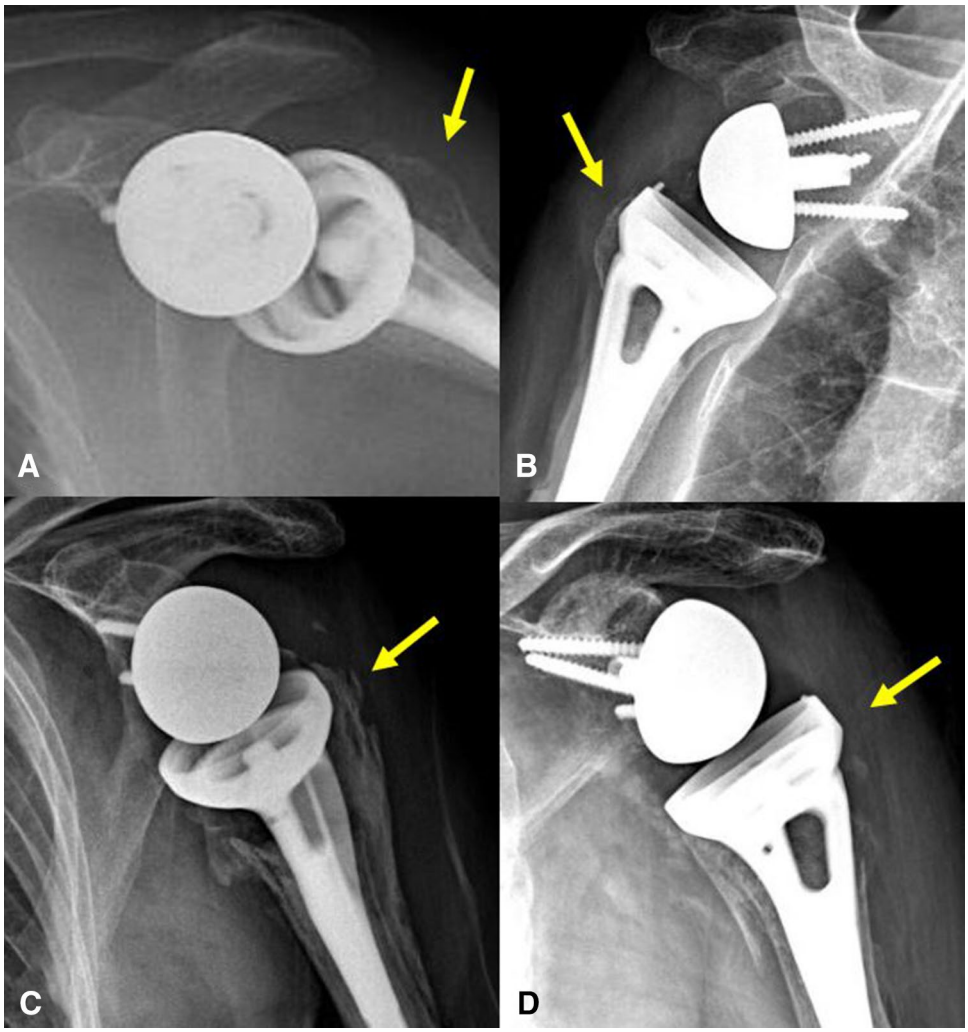

Fig. 4 In the reverse total shoulder arthroplasty using a fracture stem, X-ray showed **a** complete healing, **b** partial healing, **c** heterotopic ossification around the humeral stem and tuberosity and **d** complete absorption of the greater tuberosity

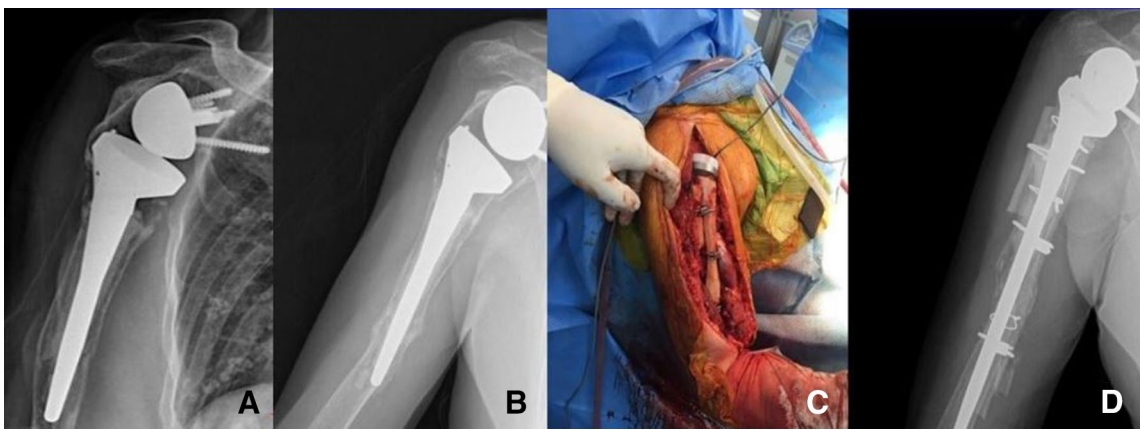

Fig. 5 **a**, **b** Secondary heterotophic ossification due to tuberosity migration or failure caused fixed glenohumeral motion and then periprosthetic humeral fracture (Vancouver type B2) due to distal cemented stem loosening was developed. **c**, **d** In the revision surgery, long stem revision augmented with humeral allograft was performed. At 1 year after revision surgery, humeral allograft was well incorporated to the humeral stem. She was pain free, and was very satisfied with the result

also decreased motivation, clinical outcomes were suspected to have similar clinical outcomes between two groups. Recently, several surgical technique were reported for better tuberosity healing for RTSA. Among them, recent a hybrid cementation-impaction grafting technique results in a high tuberosity healing rate with restoration of external rotation after RTSA for fracture [27]. The incidence of scapular notching has been reported in the range of 19–96% in patients with RTSA treated for cuff tear arthropathy [28]. In our study, as a most common complication, we encountered scapular notching in 20 patients (44%) with RTSA and there were no harmful effects on the clinical outcomes at the last follow-up. The effect of scapula notching remains controversial but there is concern about the long-term outcome of patients with these scapula defects [29, 30].

In our series, we found two humeral stem loosening among four periprosthetic fractures in patients using conventional non-fracture stem. There are limited studies to date that have focused on humeral loosening as a mode of failure in RTSA. The uncemented nature of the humeral component for the RTSA in proximal humeral fractures was known to result in early loosening or failure. For the suggested mechanism of these cemented stem loosening in our study, we suspected that tuberosity failure such as tuberosity fracture migration might cause secondary HO, and also fixed proximal portion of RTSA due to HO might cause distal humeral stem loosening and secondary periprosthetic fracture (Vancouver classification B2: cantilever bending mechanism due to heterotopic ossification). Tuberosity fracture migration above proximal humerus might be related to HO and then fi{Youn, 2016 #53}xed proximal humeral stem might develop secondary loosening of cemented stem around the entire humerus, especially distal humerus. It's loosening mechanism of the RTSA using conventional non-fracture stem was similar to the cantilever bending mechanism of the cemented hip arthroplasty [31]. If tuberosity fracture was too comminuted to fix and the possibility of tuberosity migration was too high, careful trial of tuberosity repair during the RTSA using fracture stem should be cautioned in these complex PHF.

Our study has several limitations. Retrospective patients' evaluation was done and also there was no control group in this study. In addition, we had a relatively small sample size and short-term follow-up periods with these aged patients (over 80 years old), which decreases the strength of the results. The introduction time interval in Korea between two non-fracture vs fracture stems meant that developed surgical tool and surgeon experience caused better tuberosity healing than early experience of conventional stem over fracture stem. However, we initially could not use the non-fracture stem in these fracture cases owing to government's regulations in the early period of our study. In the future, a prospective, randomized controlled trial would be helpful to prove the best results.

Conclusions

Both non-fracture stem and fracture stem in complex PHF of elderly patients has significant impact on clinical outcomes but no statistically significant differences on radiological outcomes except tuberosity failure, stem loosening and revision surgery. RTSA using non-fracture stem showed higher humeral stem loosening and revision rate compared to RTSA using fracture stem.

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Compliance with ethical standards

Conflict of interest The authors report no conflict of interest.

Informed consent Informed consent was obtained from all individual participants included in the study.

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