Original Article

Radiographic Changes and Clinical Outcomes Associated with Two Different Press-Fit Humeral Stems in Primary Reverse Shoulder Arthroplasty

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Abstract

Background: Reverse shoulder arthroplasty (RSA) is used commonly for a wide range of indications. The complications after the total shoulder replacements have been reported to be related with the prosthesis design. The type of the humeral stem is a consideration to reduce complication. Radiographic changes are seen at a high rate with new-generation press-fit stems. **Aim:** This study aims to reduce proximal humeral bone loss after RSA could have been achieved with adjustable humeral stem when compared with monoblock stem. **Methods:** A retrospective analysis was made of 52 patients treated with RSA using a press-fit humeral stem prosthesis. The patients were separated into two groups according to the type of humeral stem. The first group included 26 patients (18 females, 8 males) who underwent RSA using adjustable humeral stem. The second group included of 26 patients (17 females, 9 males) for whom monoblock humeral stem was used. Clinical and radiological evaluations were made based on the information obtained at 1, 3, 6, 12, and 18 months postoperatively. The follow-up duration was at least 18 months. **Results:** There was no statistical difference between the adjustable and monoblock groups in respect to gender, age, height, and weight. According to the functional measurements at the final follow-up, no statistically significant difference was determined between the groups with respect to the Constant, UCLA, Oxford, DASH, and VAS values. In terms of radiographic changes, both groups were seen to have been similarly affected. It was found that, irrespective of the stem type used, the humeral side radiographic adaptation was found to be high, which negatively affected the functional results ($P < 0.05$). **Conclusion:** The increased radiographic stress shielding adaptation leading to humeral osteolysis was found to have a negative effect on the functional results with the press-fit technique irrespective of stem design.

Keywords: *Osteolysis, press-fit, reverse shoulder arthroplasty*

Introduction

Reverse shoulder arthroplasty (RSA) can be performed for indications such as rotator cuff arthropathy, primary glenohumeral arthritis, revision shoulder arthroplasty, tumor resection, fracture sequelae, or displaced proximal humerus fractures.[1] The range of indications has increased interest in reverse shoulder prostheses, and this increasing interest has naturally led to an increase in complications. Complication rates of up to 68% have been reported in the original. Grammont-type prosthesis design; therefore, the search for a change in prosthesis designs continues with the aim of reducing complications.[2]

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The most frequently encountered complications of reverse shoulder prostheses are scapular notching, glenohumeral dislocation, acromion and scapula spine fractures, deltoid weakness, and loosening of the glenoid component.[3] The effects on humeral side complications of the humeral component neck-shaft angle, the use of a short/long stem, cemented and cementless stems, and the canal filling ratio of the humeral stem have been examined.

Radiographic findings, such as humeral stress shielding, subsidence, and loosening, have been compared with clinical results.[4]

Although a few studies in the literature have examined humerus-origin complications, there has been a noticeable increase in publications in recent years.[5] The aim of this study was to evaluate the clinical and humeral side radiographic results in a patient population who underwent RSA performed by a single surgeon using two different reverse shoulder prostheses in the form of press-fit adjustable and monoblock humeral stems.

Material and Methods

Approval for the study was granted by the Ethics Committee of the [decision no: AESH-EK1-2023-016, dated: 22.03.2023]. All study procedures complied with the principles of the Helsinki Declaration.

A retrospective analysis was made of 52 patients treated with reverse shoulder prosthesis by a single surgical team at the between January 2018 and January 2021. The study included 52 patients treated with a press-fit humeral stem prosthesis because of glenohumeral osteoarthritis, inflammatory shoulder arthropathies, rotator cuff tear arthropathies, or complex proximal humerus fractures. The patients were separated into two groups according to the type of humeral stem. Group I included 26 patients (18 females, 8 males) for whom adjustable humeral stem was used (Next shoulder solutions, Türkiye: RSA), and Group II included 26 patients (17 females, 9 males) for whom monoblock humeral stem was used (Fx Solution, France: RSA Humelock II Reversed).

The 75 reverse shoulder arthroplasties performed during the study period were reviewed, and eight patients with cemented reverse shoulder prosthesis, seven patients with uncemented prosthesis where the humeral stem could not be applied with the press-fit technique, three patients who required revision with RSA for various reasons following hemiarthroplasty/total shoulder arthroplasty, and five patients who did not continue follow-up were excluded from the study.

Data were collected from the patients' medical records, including demographic data, shoulder range of movement angles of the operated and healthy shoulders, the Constant-Murley Shoulder Outcome Score, the University of California-Los Angeles (UCLA) shoulder scale, Oxford Shoulder Score, the Disabilities of the Arm, Shoulder and Hand (DASH) score, visual analog scale (VAS) values, and complications and information about additional surgeries. Clinical and radiological evaluations were made based on the information obtained at 1, 3, 6, 12, and 18 months postoperatively and at the final follow-up examination.

Surgical procedure and rehabilitation

All operations were performed using the same technique as the deltopectoral approach.

The reverse shoulder prosthesis technique has been sufficiently described in the literature. In trauma cases, after press-fit placement of the humeral stem, the prosthesis was fixed using nonabsorbable sutures to provide anatomic recovery. To improve the healing of the tuberosity, cancellous bone grafts taken from the humeral head were used when necessary. In both groups, humeral stems, 120 mm in length and of varying thickness to sit press-fit, were used. No distal locking screw was used in any patient.

Postoperatively, all patients used an arm sling for 6 weeks. In the early postoperative period, passive elbow, wrist, shoulder movement, and pendulum exercises were performed three times a day. Active movements and strengthening exercises were permitted after the sixth postoperative week.

Radiographic evaluation

Plain radiographs of the shoulder were obtained using the humerus anteroposterior (AP) and axillary lateral X-ray techniques. Evaluations were made with respect to osteolysis, subsidence, and stress shielding on the early postoperative and final follow-up radiographs.

Areas of humeral radiolucence were evaluated using the seven zone classification, which was adapted for the shoulder from the system described by Gruen *et al*.[6] to evaluate stress shielding in hip prostheses. Zones 1 and 7 include the metaphyseal component. Zones 2 and 6 refer to the proximal half of the diaphyseal component. Zones 3 and 5 refer to the distal half of the diaphyseal component, and zone 4 refers to the distal tip of the stem. Each zone was evaluated with respect to the presence of condensation lines (CL), cortical bone resorption or osteopenia (CNO), and spot weld (SW).

The presence of subsidence or radiolucence lines of ≥2 mm in more than three areas between the early

postoperative and final follow-up radiographs was accepted as loosening.[7]

Clinical evaluations

The clinical evaluations were made according to the final follow-up examinations of the patients, which were performed in a standing position. Bilateral shoulder flexion, abduction, internal rotation, and external rotation range of movement (ROM) angles were measured using a universal goniometer. External rotation and internal rotation were evaluated with the arm at the side. Internal rotation scoring was evaluated as 0: lateral thigh, 2: buttock, 4: lumbosacral junction, 6: L3 (waist), 8: T12 and 10: T7 (interscapular).[8] At the final follow-up examination, the Constant-Murley Shoulder Outcome Score, the UCLA shoulder scale, Oxford Shoulder Score, DASH score, and VAS values were measured.

Statistical analysis

The data obtained in the study were analyzed statistically using SPSS ver. 28 software.

The findings were first given as frequencies, and then comparisons were made of the modular and nonmodular groups according to the patient characteristics. When the number of observations of the groups was <50, the conformity to normal distribution was examined with the Shapiro–Wilk test. In the paired group comparisons of numerical variables with normal distribution, the independent samples *t*-test was applied, and when the distribution was not normal, the Mann–Whitney U-test was used. When comparing the measurement values of the operated and healthy sides of the same patient, the Wilcoxon matched sample test was applied. If at least one of the values expected in the cells was <5, the Fisher test was used, and if >5, Pearson Chi-square analysis was applied. Correlations between numerical variables were examined with Spearman correlation analysis when the data were not normally distributed.

Descriptive statistics were stated as mean ± standard deviation (SD), median, minimum, and maximum values for numerical variables and as number (n) and percentage (%) for categorical variables. A value of $P < 0.05$ was accepted as the level of statistical significance.

Results

The male/female ratios were similar in Groups I and II (p: 0.768). No statistically significant difference was determined between the groups in respect to patient age, height, and weight ($P > 0.05$) [Table 1].

In Group I for which adjustable stem was used, 13 patients were operated on because of osteoarthritis and 13 patients because of fractures. In Group II for which monoblock stem was used, 15 patients were operated on because of osteoarthritis and 11 patients because of fractures.

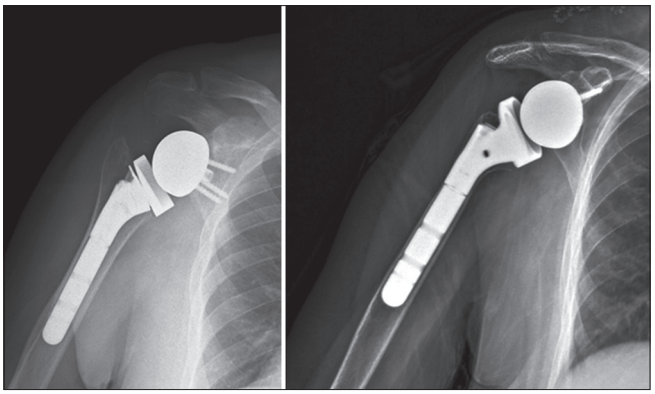

Figure 1: Radiographs of a patient in the adjustable group taken in the early postoperative period and at 29 months postoperatively, showing cortical thinning and osteopenia in zones 1, 2, and 7

There was no statistically significant difference between the groups with respect to indications (p: 0.578). The mean follow-up period was 25.42 months (range, 18–35 months) in Group I and statistically significantly longer at 42.69 months (range, 18–65 months) in Group II ($P < 0.001$).

Radiographic evaluations

In the evaluations with respect to CNO, the most intense concentrations were seen to be in zones 1, 2, and 7 [Figure 1]. The most intense changes in CNO, SW, and CL were determined to be in zones 1 and 7 [Figure 2]. Although there were differences between the zones, when the radiographic changes were evaluated between the groups, both groups were seen to have been similarly affected. When all the zones were examined together, no statistically significant difference was determined between the adjustable and monoblock groups ($P > 0.05$) [Table 2].

Functional evaluations

When the ROM values were compared between the healthy shoulder and the operated shoulder applied with the reverse prosthesis, there were statistically significantly worse functional results in all the movements of the operated shoulders compared to the healthy sides ($P < 0.001$). No statistically significant difference was determined between the adjustable group and the monoblock group with respect to the measured values of the operated and healthy sides for flexion, extension, abduction, internal rotation, and external rotation ($P > 0.05$) [Table 3].

When all 52 patients were evaluated together, a reverse shoulder prosthesis was applied to 24 patients because of fracture and to 28 patients because of arthritis. The

Table 1: Comparisons of the demographic characteristics of the patients in the adjustable group and the monoblock group

Variable	Adjustable (group I)				Monoblock (group II)				
	Mean	SD	Min	Max	Mean	SD	Min	Max	*P*
Age (years)	69.23	10.66	45	88	70.65	10.66	37	88	0.632[t]
Height (cm)	161.96	6.97	152	174	163.42	6.54	154	178	0.384[U]
Weight (kg)	66.15	6.37	52	75	66.96	9.78	50	98	0.956[U]

Table 2: Relationships between the stress shielding zone groups and the Adjustable and Monoblock groups

Variable	Adjustable		Monoblock		Test statistic	*P*
	n	%	*n*	%		
ZONE 1						
No change	7	26.92	6	23.08	0.109	0.991[F]
CL	3	11.54	3	11.54		
CNO	15	57.69	16	61.54		
SW	1	3.85	1	3.85		
ZONE 2						
No change	18	69.23	17	65.38	1.279	0.528[F]
CL	1	3.85	0	0.00		
CNO	7	26.92	9	34.62		
SW	0	0.00	0	0.00		
ZONE 3						
No change	25	96.15	25	96.15	2.000	0.368[F]
CL	1	3.85	0	0.00		
CNO	0	0.00	0	0.00		
SW	0	0.00	1	3.85		
ZONE 4						
No change	25	96.15	25	96.15	0.000	1.000[F]
CL	1	3.85	1	3.85		
CNO	0	0.00	0	0.00		
SW	0	0.00	0	0.00		
ZONE 5						
No change	26	100.00	26	100.00	0.000	1.000[F]
CL	0	0.00	0	0.00		
CNO	0	0.00	0	0.00		
SW	0	0.00	0	0.00		
ZONE 6						
No change	25	96.15	23	88.46	2.083	0.353[F]
CL	1	3.85	1	3.85		
CNO	0	0.00	0	0.00		
SW	0	0.00	2	7.69		
ZONE 7						
No change	14	53.85	11	42.31	0.860	0.651[F]
CL	1	3.85	2	7.69		
CNO	11	42.31	13	50.00		
SW	0	0.00	0	0.00		

n: number of observations; *P*: statistical significance; F: Fisher exact test; CL: condensation line; CNO: cortical narrowing and osteopenia; SW: spot weld

mean flexion and abduction values of the patients who underwent surgery because of arthritis were found to be higher but not to a level of statistical significance. No statistically significant difference was determined between the patients with respect to the measured values of the operated and healthy sides for flexion, extension, abduction, internal rotation, and external rotation ($P > 0.05$) [Table 4].

According to the measurements taken at the final follow-up examination, no statistically significant difference was determined between the adjustable and monoblock groups with respect to the Constant, UCLA, Oxford, DASH, and VAS values ($P > 0.05$) [Table 5].

Relationships between radiographic changes and functions

The whole sample of 52 patients treated with adjustable and monoblock stem prostheses was evaluated. The mean follow-up period was 34.06 ± 12.75 months. The adaptations seen in one zone were examined numerically with respect to CL, CNO, and SW. For example, if there was CNO only in zone 1 in a patient, a score of 1 was assigned, and if in another patient there was CNO in zone 1 and SW in zone 3, a score of 2 was assigned. A statistically significant moderate-level negative relationship was determined between the number of affected regions in the radiographically adapted zones and the flexion, extension, abduction, and internal rotation values of the operated side ($P < 0.05$). An increase in the number of regions showing adaptation did not show a statistically significant negative effect only on external rotation [Table 6].

Complications

In Group I, heterotopic ossification developed in the shoulder joint of one patient, which severely restricted ROM. Fracture of the acromion was seen in one patient, and this was treated conservatively. Periosteal reactions formed during the follow-up of the humeral stem end in two patients. Malrotation was determined in the humeral region in the early postoperative period in one patient, so the humeral component position was corrected by loosening the correction screw without changing the humeral stem. A periprosthetic fracture developed at 13 months postoperatively in one patient, and in the treatment of this, the 120 mm length humeral stem was exchanged for a 200 mm humeral stem, and stabilization was strengthened with a distal locking screw. An error was made in the technique in one patient using

Table 3: Comparisons of the functional values of the adjustable and monoblock groups

Variable	Adjustable					Monoblock					Test statistic	*P*
	Mean	SD	Med	Min	Max	Mean	SD	Med	Min	Max		
Flexion operated	121.73	36.98	110	40	175	130.19	35.65	145	45	170	0.819	0.413[U]
Healthy	174.23	12.70	180	120	180	166.35	31.10	180	45	180	-0.888	0.375[U]
Extension operated	29.42	5.35	30	20	40	30.96	6.93	30	15	40	1.101	0.271[U]
Healthy	40.00	2.45	40	30	45	37.88	7.24	40	15	45	0.596	0.551[U]
Abduction operated	113.27	42.57	105	20	175	125.00	38.70	137.5	40	170	0.918	0.359[U]
Healthy	173.08	19.75	180	80	180	164.81	33.60	180	45	180	-0.965	0.335[U]
Internal rotation operated	4.73	1.48	4	2	8	4.46	1.30	4	2	6	-0.689	0.491[U]
Healthy	8.15	1.38	8	4	10	7.46	1.84	8	2	10	-1.505	0.132[U]
External rotation operated	40.96	10.49	40	20	60	40.00	12.08	40	20	70	-0.604	0.546[U]
Healthy	61.92	9.06	60	35	75	59.23	10.74	60	45	75	-0.96	0.337[U]

Table 4: Comparisons of the functional values of the patients in the fracture and arthritis groups

Variable	Fracture					Arthritis					Test statistic	*P*
	Mean	SD	Med	Min	Max	Mean	SD	Med	Min	Max		
Flexion operated	119.79	40.74	110	40	170	131.25	31.64	140	60	175	0.932	0.351[U]
Healthy	168.13	29.88	180	45	180	172.14	17.50	180	90	180	-0.332	0.740[U]
Extensionoperated	30.63	7.27	30	15	40	29.82	5.18	30	15	40	-0.247	0.805[U]
Healthy	38.33	5.84	40	15	45	39.46	5.15	40	20	45	1.158	0.247[U]
Abduction operated	113.54	45.62	115	20	170	123.93	36.14	130	60	175	0.745	0.456[U]
Healthy	164.79	35.12	180	45	180	172.50	18.98	180	80	180	-1.107	0.914[U]
Internal rotation operated	4.63	1.61	4	2	8	4.57	1.20	4	2	6	-0.220	0.826[U]
Healthy	7.92	1.91	8	2	10	7.71	1.41	8	4	10	-0.947	0.344[U]
External rotation operated	41.04	13.02	40	20	70	40.00	9.62	40	30	65	-0.242	0.809[U]
Healthy	59.79	11.08	60	35	75	61.25	8.99	60	45	75	0.468	0.640[U]

Table 5: Comparisons of the Constant, UCLA, Oxford, DASH, and VAS values of the adjustable and monoblock groups

Variable	Adjustable					Monoblock					Test statistic	*P*
	Mean	SD	Med	Min	Max	Mean	SD	Med	Min	Max		
Constant	73.04	22.62	83.50	21	95	74.73	17.04	80.00	33	100	-0.230	0.818[U]
UCLA	28.69	6.93	31.50	13	35	27.73	4.94	28.50	18	35	-1.090	0.276[U]
Oxford	34.85	11.47	38.00	12	48	36.92	7.21	38.00	20	48	0.202	0.840[U]
DASH	22.85	25.53	5.50	0	75	20.27	19.95	9.00	2	75	0.599	0.549[U]
VAS	2.38	2.08	2.00	0	8	2.31	1.41	2.00	0	5	0.421	0.674[U]

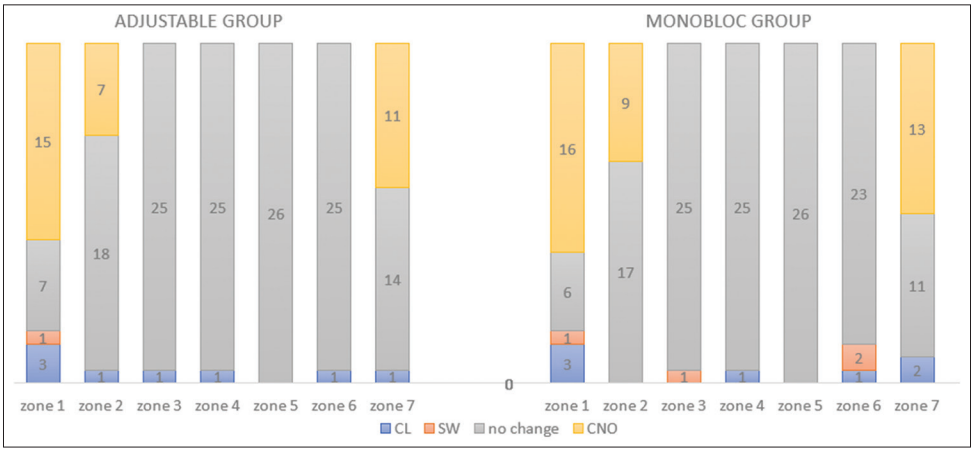

Figure 2: Graph showing the radiographic changes according to the zones. CL: condensation line; CNO: cortical narrowing and osteopenia; SW: spot weld

Table 6: Relationships between the number of affected regions in the radiographic zones and the functional values

Variable	Value	Zone number
Flexion	s	-0.503
	P	<0.001
Extension	s	-0.327
	P	0.018
Abduction	s	-0.498
	P	<0.001
Internal rotation	s	-0.322
	P	0.020
External rotation	s	-0.221
	P	0.116

P: statistical significance value; s: Spearman correlation coefficient

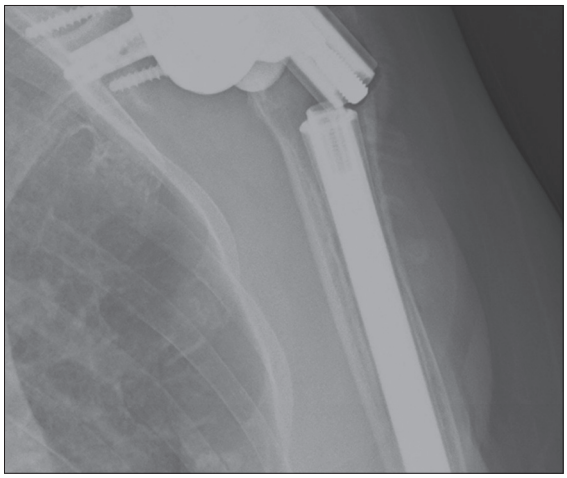

Figure 3: Humeral disassembly developed associated with the use of a short connection screw in a patient in the adjustable group

a short connection screw to connect the humeral stem and humeral component, and humeral disassembly occurred [Figure 3]. This problem was resolved with the use of a longer connection screw.

In Group II, a scapular spine fracture developed in one patient, type 3 acromioclavicular separation in one patient, and a humeral stem tip fracture in one patient. These three patients were treated conservatively. Periosteal reaction was seen to have formed during the follow-up of the humeral stem end in one patient. Prosthesis dislocation occurred in one patient, so revision was applied to the humeral stem by removing the whole stem, correcting the angle and then replacing it.

Discussion

In this study, reverse shoulder press-fit prostheses with two different humeral stem designs were applied to 52 patients who were similar in terms of age, gender, and indications.

Although there was a difference between the groups with respect to the follow-up periods, the shortest follow-up period was 18 months. Similar radiographic and functional results were obtained in both groups. However, there was a negative effect on the functional results of the number of involved regions associated with radiographic stress shielding adaptations.

The relationship between clinical results and humeral side radiographic changes in patients treated with reverse shoulder prosthesis has been examined in very few studies. Stress shielding refers to the adaptations formed against the changes in stress distribution formed after prosthesis placement and has been shown more in humeral osteolysis with the effect of stress shielding in press-fit stems. As the force is transferred more to the implant from the bones around the stem in press-fit stems, resorption occurs over time in the tuberosity and cortices. As the muscle attachment of zones 1, 2, and 7 is deprived of stress, there is thought to be more osteolysis.[9] In the current study, osteolysis was most frequently determined in these zones. The use of the non-press-fit technique (low-filling ratio), together with a distal locking screw, can be considered an alternative to the press-fit technique.

On the other hand, there are also some studies in the literature that have reported that adaptive humeral changes developing due to stress shielding in patients who have undergone anatomic total shoulder arthroplasty do not lead to poor functional results[10] There has been a recent increase in studies of radiographic and functional comparisons in patients who have undergone reverse shoulder prosthesis surgery. In a study by Mazaleyrat *et al*.,[11] the clinical and radiographic relationships were evaluated between press-fit and cemented stems in cases of RSA, and it was reported that although not statistically significant, the active movements were worse in the press-fit group, which was attributed to greater tuberosity resorption. Erickson *et al*.[12] examined short-stem and standard-stem press-fit reverse shoulder prostheses, and the radiographic and functional results were worse in standard stems. The stress-shielding rates in the literature vary greatly, from 9% to 97.4%. In a case series by Harmsen *et al*.,[3] it was stated that high stress shielding rates could be associated with the formation of internal stress shielding without external stress shielding, in contrast to other reports. There may not be a direct effect of adaptations, such as SW and CL, on function, but in the current study, the aim was to examine the adaptation formed on the humeral side as a whole.

As a result, a significant difference was determined between the amount of adaptation and the functional

results regardless of the design of the press-fit stem used.

The humeral components of the prostheses used in both groups of the current study were coated with plasma-sprayed commercially pure titanium (CP Ti) and hydroxyapatite (HA), and the humeral cup (L.+0,+9 mm 10° angled) and glenosphere (centric/eccentric 36 and 40 mm) properties were similar. In the monoblock group (Humelock) reverse shoulder prostheses, the stem thickness was 8, 10, 12, or 14 mm and the length was 120 mm. In the adjustable (next) reverse shoulder prostheses, the humeral stem thickness was 8, 9, 10, 11, 12, 13, 14, or 15 mm, and the length was 120, 160, 180, or 200 mm. In addition, the humeral component thicknesses can be combined to be compatible with each other at 10, 12, and 14 mm. In this way, a greater range is obtained during the press-fit application, and a longer press-fit stem can be easily used.

Reverse shoulder prostheses with an adjustable humeral stem provide a great advantage, especially in revision surgery.[3] When there is a need for revision, the humeral (metaphyseal) component can be changed without removing the humeral stem. Another advantage of adjustable systems is that when there is humeral bone resorption and loosening, it can be easily changed for a longer stem, and the revision can be made easier using distal locking screws. However, it must not be ignored that complications can develop in the long term arising from the connection screws in the design of the adjustable humeral component. During the application of the monoblock reverse shoulder prosthesis, it has been experienced in some cases that a humeral component of single thickness can lead to strain in the tuberculum minor.

Although high loosening rates and poor results have been obtained with first-generation press-fit humeral components, these complications have been overcome with new-generation designs (coating and changes in stem design). It has not been fully confirmed, but it is thought that metal and polythene debris formed because of scapular notching or poyethylene debris due to cement particles can lead to loosening in the humeral stem.[10] In the same way, the formation of metal debris originating from the connection point in the application of adjustable humeral stems can cause humeral stem loosening in the long term. Although radiographic changes, such as osteolysis and stress shielding, are seen at a high rate with new-generation press-fit stems, loosening has been reported at a rate of almost 0%.[3] No humeral loosening was observed in any of the press-fit reverse shoulder prostheses in our study with the shortest follow-up period of 18 months.

Complications that can develop during revision surgery and operating times have been reduced with press-fit humeral stems.[13] There has also been less stress shielding with press-fit stems.[5] Although no significant difference was found between the two groups in the current study applied with press-fit, the surgery may be easier with adjustable stems. Different results may emerge in similar follow-up periods. A study by Kim *et al*.[5] reported that reverse shoulder prostheses using a low filling ratio caused less humeral adaptation, but because of the rehabilitation process in that group, there was a difference in function. Shoulder rehabilitation can be started earlier by combining adjustable prostheses with a thin stem distal locking screw.

However, no example of humeral adaptations that can form can be found in the literature.

A limitation of this study could be that due to the retrospective design, data entries may have been missing during the follow-up period. The direct radiographs were examined as early postoperative and final follow-up radiographs because of interruptions in the follow-up of some patients, which naturally prevented the examination of the progression of bone adaptations.

There were significant differences between the two groups with respect to the follow-up period.

The follow-up period was mean 25.42 months in Group I and mean 42.69 months in Group II, but both periods were accepted as short term with respect to humeral side changes. Another limitation of the study was that bone changes were only evaluated with AP radiographs, whereas it would be possible to obtain more detail with 3-dimensional evaluations. It has been said that there may be a relationship between scapular notching and medial cortex bone resorption and that polyethylene wear may lead to stress shielding.[14] However, in the current study, only humeral side changes were examined. Finally, an age-related reduction in bone quality can affect the osteolysis process, but there was no evaluation in this respect in this study.

No statistically significant difference was established between adjustable and monoblock groups with respect to radiographic and functional outcomes. Yet, it was found that the humeral side radiographic adaptation was greatly high in reverse shoulder prostheses applied with the press-fit technique irrespective of stem design. The increased radiographic stress shielding adaptation leading to humeral osteolysis was found to have a negative effect on the functional results.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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