REVIEW

Optimizing baseplate position in reverse total shoulder arthroplasty in small-sized Japanese females : technical notes and literature review

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Abstract : The management of cuff tear arthropathy (CTA) has always been a challenge for shoulder surgeons. Introduction of reverse total shoulder arthroplasty (RTSA) helped in providing pain relief and improved shoulder function in patients with CTA. In this study, we aimed to evaluate the short-term clinical results and some clinical details regarding the types of available prosthesis, positioning, and size of the components for RTSA in a population of short-stature female Japanese. In our seven cases, the average glenoid size was 23.9 mm in width and 34.2 mm in height. The average width was smaller than the size of all available baseplates. We implanted reverse shoulder prostheses with baseplate that measured 28 mm in diameter and two locking screws. The center of the baseplate was shifted to allow slight anterior overhang relative to the anatomical center to avoid breakage of the posterior cortex and to achieve firm fixation. One case of humeral shaft fracture occurred while inserting the humeral stem and required encircling wiring. In our experience, the short term clinical results of RTSA were excellent, but a new prosthesis that is designed to fit the short stature of Asians with smaller glenoid and humerus should be considered. J. Med. Invest. 63 : 8-14, February, 2016

Keywords **:** *Reverse total shoulder arthroplasty, Glenoid morphology, Short stature, Japanese female*

INTRODUCTION

Reverse total shoulder arthroplasty (RTSA) was developed by Paul Grammont in 1985 to restore shoulder function in patients with cuff tear arthropathy (CTA) (1). In 1991, the original Grammont prosthesis was modified as the Delta III reverse prosthesis (Depuy International Ltd., Leeds, UK) in an attempt to prevent early failure of the glenoid component (2).

The basic concept of RTSA is reversal of glenohumeral joint anatomy by replacing the glenoid cavity with large-diameter convex metallic glenosphere and humeral head with concave polyethylene socket to cause distalization and medialization of the center of rotation of the shoulder (Figure 1) (3, 4). This prosthetic design increases the lever arm and force of the deltoid muscle, which acts as a stabilizer and main muscle of the shoulder (4). Therefore, a good-functioning deltoid that can compensate for the lack of a rotator cuff is a prerequisite for a satisfactory outcome of RTSA.

With increasing popularity of RTSA for CTA in the last decade, its applications has expanded to a variety of other conditions, including massive cuff tears without glenohumeral arthritis, three- or four-part fracture of proximal humerus, posttraumatic malunion, revision shoulder arthroplasty, tumor resection arthroplasty, osteoarthritis with large glenoid bony defects, chronic dislocation of the shoulder, rheumatoid arthritis, and post-infectious arthritis (3, 5-9). RTSA has been adopted in Europe since the 1980s, whereas it was approved by the US Food and Drug Administration in November 2003. Following its approval in the US, RTSA has been introduced in many countries, including Canada, South Korea, China, and India. Among developed countries, Japan has been the last to introduce this prosthesis in clinical practice in 2014. In fact, this was the first medical device approved without clinical trials by the Pharmaceuticals and Medical Devices Agency of Japan.

When RSA was approved in Japan, we were concerned that the size of the baseplate was too large for the Japanese population, especially for small female patients. Since scapular size and stature are closely correlated, a female patient with a smaller stature is expected to have a small glenoid (10). Ji *et al.* stated that it was

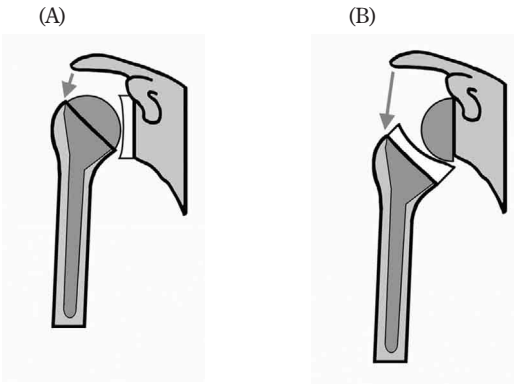

Figure 1. Diagrams of anatomical total shoulder arthroplasty (A) and reverse total shoulder arthroplasty (B). The strength of the deltoid muscle is increased due to the lengthening of the muscle fibers as well as the increase of the lever arm (arrows).

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difficult to insert a 29-mm baseplate and 36-mm glenosphere in the glenoid of a small Korean female (11). In this report, we presented our early clinical experience and some extra technical details that need to be considered for RTSA in women with relatively smaller glenoid and humerus sizes.

INDICATIONS AND CONTRAINDICATIONS

The Japanese Orthopaedic Association made guidelines for RTSA indications (Table 1) even before it was introduced in the country (12). The best indication was for pseudoparalytic shoulder patients who cannot elevate their arm actively. Radiographic findings of arthritic changes were also required. Considering the survival rate in previous reports, RTSA should be performed in the elderly over the age of 70 years (6, 14). RTSA is not a preventive surgery, but a final salvage procedure (15). Contraindications for RTSA include dysfunction of the deltoid, patients with active flexion of more than 100°, reparable rotator cuff tear, and acute or traumatic pseudoparalysis that is expected to recover.

Table 1 Summary of guideline for reverse total shoulder arthroplasy in Japan

1. Surgical Indications
   A) Absolute indications
   1) Cuff tear arthropathy with pseudoparalysis (Grade 4,5 by Hamada's classification)
   2) Massive rotator cuff tear (Grade 2,3 by Hamada's classification) with pseudoparalysis and stage 3 or 4 fatty infiltration in supraspinatus and infraspinatus
   B) Relative indications
   1) 3 or 4 part fracture of the proximal humerus in the elderly over 70 years old
   2) Malunion after the fracture of the greater tuberosity
   3) Rheumatoid arthritis with severe dysfunction of the rotator cuff
   4) Revision surgery from conventional total shoulder arthroplasty
   5) Postoifection arthritis
   6) Primary osteoarthritis with large bone defect on the glenoid
   7) Others including bone tumor and chronic shoulder dislocation
2. Contraindications
   1) Dysfunction of the deltoid
   2) Patients with active flexion to more 100°
   3) reparable rotator cufftear
   4) Acute or traumatic pseudoparalysis

PREOPERATIVE PLANNING

Preoperative computed tomography (CT) was the most useful modality for optimal placement of the glenoid component. CT data were imported into a three-dimensional analysis software. Two-dimensional images in the coronal, axial, and sagittal planes were created with the axial plane positioned perpendicularly to the plane of the scapula. Height and depth of the glenoid were measured (Figure 2) ; the location and extent of glenoid erosion were also evaluated. The axial CT image 13-14 mm superior to the inferior glenoid rim was used to determine the optimal placement of the baseplate. Two-dimensional images were more useful than three-dimensional images when creating the template because the position of the center post, which determined the center of the baseplate, was critical to avoid anterior or posterior perforation of the scapular body. The baseplate was placed at 0° of retroversion relative to the plane of the scapula. On a small glenoid in a small patient, there was a risk for posterior breakout if the baseplate was placed at the anatomical center of the glenoid. Slight anterior placement of the baseplate could avoid that risk, but with overhang of the baseplate anteriorly (Figure 3). The optimal position of the baseplate varied among the patients according to scapular morphology.

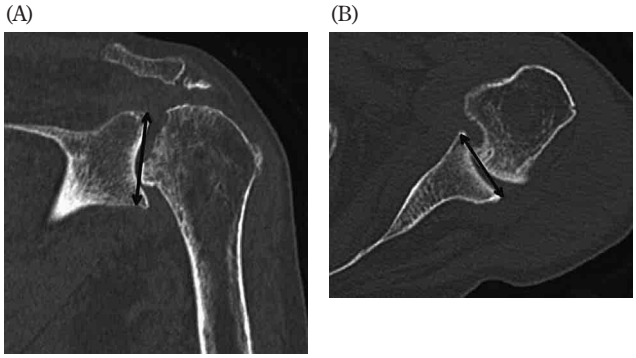

Figure 2. Preoperative CT scan planning for reverse total shoulder arthroplasty (RTSA). (A) The superior-inferior height (arrow) of the glenoid is measured on coronal section. (B) The anterior-posterior width (arrow) of the glenoid is measured on axial section.

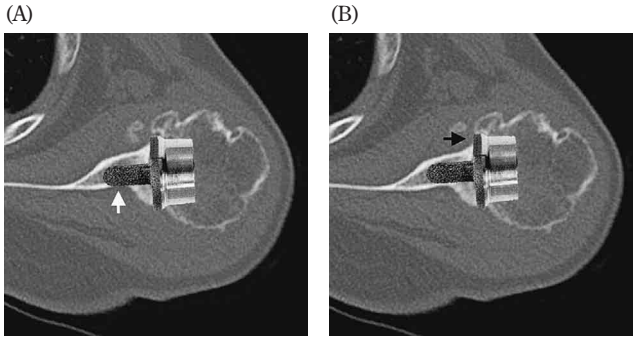

Figure 3. Preoperative planning of baseplate placement during RTSA. (A) If the baseplate is placed at the anatomical center of the glenoid, there is a risk for breakage of the posterior cortex (white arrow). (B) Slight anterior placement can avoid this risk, but with extra overhang of the baseplate anteriorly (black arrow).

CHOICE OF IMPLANTS

Currently, three types of implants are available in Japan : Aequalis Reverse II shoulder (Tornier, Montbonnot, France), Trabecular Metal Reverse Shoulder System (Zimmer, Warsaw, IN, USA), and SMR Modular Shoulder Replacement (Lima, Udine, Italy). Tornier Aequalis prosthesis offers baseplates with two different sizes, regular 29 mm and mini 25 mm ; the baseplate can be fixed to the glenoid surface with four screws located superiorly, inferiorly, anteriorly, and posteriorly. The Zimmer prosthesis contains a 28-mm baseplate with trabecular metal center post and superior and inferior locking screws for initial fixation. Lima provides three types of oval-curved back baseplate, the smallest of which is 28 mm in height and 22 mm in width. The Lima prosthesis has two types of glenospheres, which have concentric and eccentric designs. Of these three, we prefer the use of the Zimmer prosthesis. First, the mini 25-mm Tornier baseplate is still too large for the small glenoid of Japanese females and using this may result in insufficient screw fixation, especially anteriorly and posteriorly.

Furthermore, recent biomechanical studies reported that four screws were not necessary to provide adequate initial glenoid-baseplate fixation (16, 17). The antero-posterior overhang of the baseplate may be allowed and has not been associated with any adverse outcomes. A large baseplate with longer distance between the superior and inferior screws may provide better initial fixation strength and increased contact area compared with that of the mini 25-mm baseplate. The center peg of the Lima prosthesis was also too large for our study population and its curved-back design was not applicable for a glenoid with massive bone defects requiring bone grafting.

SURGICAL PROCEDURES

The operation was performed with the patient placed on a semi-beach chair position under general anesthesia, with or without regional anesthesia. The head of the table was raised approximately 25-30° to reduce venous pressure. The shoulder should be off the edge of the table to allow complete extension of the arm, which is important for humeral preparation.

The deltopectoral approach was always used for two reasons. One was to allow easier access to the inferior portion of the glenoid to avoid superior tilting of the baseplate. Another reason was to preserve the deltoid muscle, which would be the main muscle for active forward flexion after RTSA. The long head of the biceps tendon was tenodesed, if present. The subscapularis was released from the lesser tuberosity and tagged for later repair. The intraarticular portion of the biceps was excised. The upper portion of the pectoralis major was partially released to aid in exposure of the inferior portion of the glenoid, which was particularly useful in a small-sized female patient.

The humeral head was dislocated by adduction of the arm, with progressive external rotation and extension, and osteotomized with 10° of retroversion for female patients in reference to the axis of the forearm with the elbow flexed at 90°. Osteotomy was performed at the same level as that used during anatomical total shoulder arthroplasty because the angle of inclination of the humeral prosthesis was 53° for the Zimmer humeral prosthesis. Resection of the humeral head was performed slightly higher than that for the Tornier prosthesis, with a 65° angle of inclination. After osteotomy of the humeral head, glenoid preparation was started before preparing the metaphyseal region to avoid fracture of the metaphyseal bone.

To fully expose the glenoid, the glenoid labrum was completely excised and an extensive circumferential periglenoid capsulotomy was then performed. Complete circumferential exposure of the glenoid was necessary for proper reaming and component insertion (Figure 4). The long head of the triceps was released to provide space for the glenosphere. The base of the coracoid process and the inferior glenoid edge were identified carefully. The axis of the coracoid process to the inferior glenoid edge was marked and the insertion point for the guide pin was chosen according to the preoperative CT plan. The guide pin was inserted with 10-15° of inferior tilting under fluoroscopic control to avoid superior tilting of the glenoid component. The drill guide was not used because it obstructed good visualization of the glenoid surface ; instead, it was placed on the glenoid surface through the guide pin to determine if the outer rim of the drill guide aligned with the inferior rim of the glenoid. This was also confirmed fluoroscopically (Figure 5). Guide pin placement was critical for the placement of the baseplate in the proper position. A 6-mm pilot hole was then drilled over the guide pin and the glenoid surface was reamed flat. The remaining peripheral bone was removed with a burr for full seating of the glenosphere. The center post hole was enlarged with a 7.5-mm drill. The baseplate was implanted until the component was completely flushed with the glenoid surface. Orientation of the baseplate was achieved by aligning the superior screw hole with the base of the coracoid. The baseplate was fixed with two locking screws. Throughout the procedure, each step was confirmed fluoroscopically to ensure the proper placement of the implant.

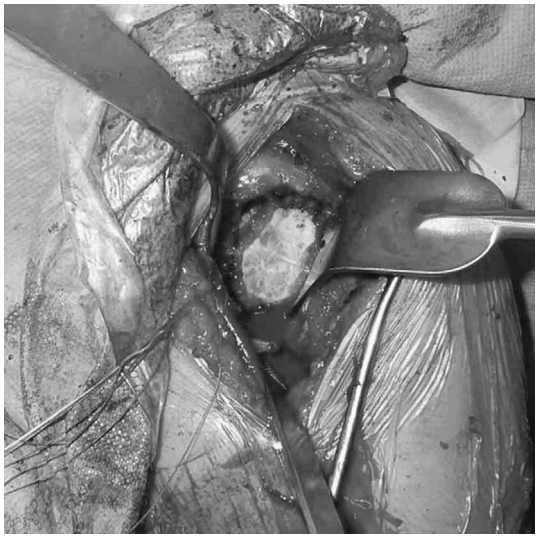

Figure 4. Complete glenoid exposure during RTSA. The glenoid is exposed after periglenoid capsulotomy through a deltopectoral approach.

The proximal humerus was then prepared with a conical reamer with 10° of retroversion. A 36-mm trial glenosphere and a trial humeral component with a standard trial liner were then positioned and prosthesis was reduced. To establish appropriate stability of the prosthesis, the thickness of the polyethylene liner was chosen based on the tension of the deltoid muscle and the conjoined tendon. Implant stability was confirmed by checking all directions. Excessive tension or difficult reduction may lead to insufficiency fracture of scapula, acromion, or humerus, along with axillary nerve palsy due to traction injury ; hence, care was taken (4, 9). The commercially available Zimmer system provided a retentive liner with 65° angle of inclination, which can improve stability without increasing humeral length.

The glenosphere was inserted prior to the humeral component ; the humeral stem was implanted with or without bone cement, according to bone quality. The prosthesis was reduced after insertion of polyethylene liner. The subscapularis tendon was repaired with transosseous sutures to the medial aspect of the lessor tuberosity.

POSTOPERATIVE REHABILITATION

Each patient was placed in a sling for 6 weeks. Only elbow, wrist, and finger motions were permitted for the first 3 weeks, followed by mild active-assisted forward elevation. Active and passive external rotations were prohibited for 6 weeks to protect the repaired subscapularis tendon. Resistive exercise was delayed until 12 weeks. Previous literatures have not focused on the postoperative rehabilitation protocol but home exercise or gentle rehabilitation is recommended in the Japanese guidelines (12). Aggressive rehabilitation without enough knowledge on RTSA may induce dislocation of the prosthesis. The surgeon and physical therapist

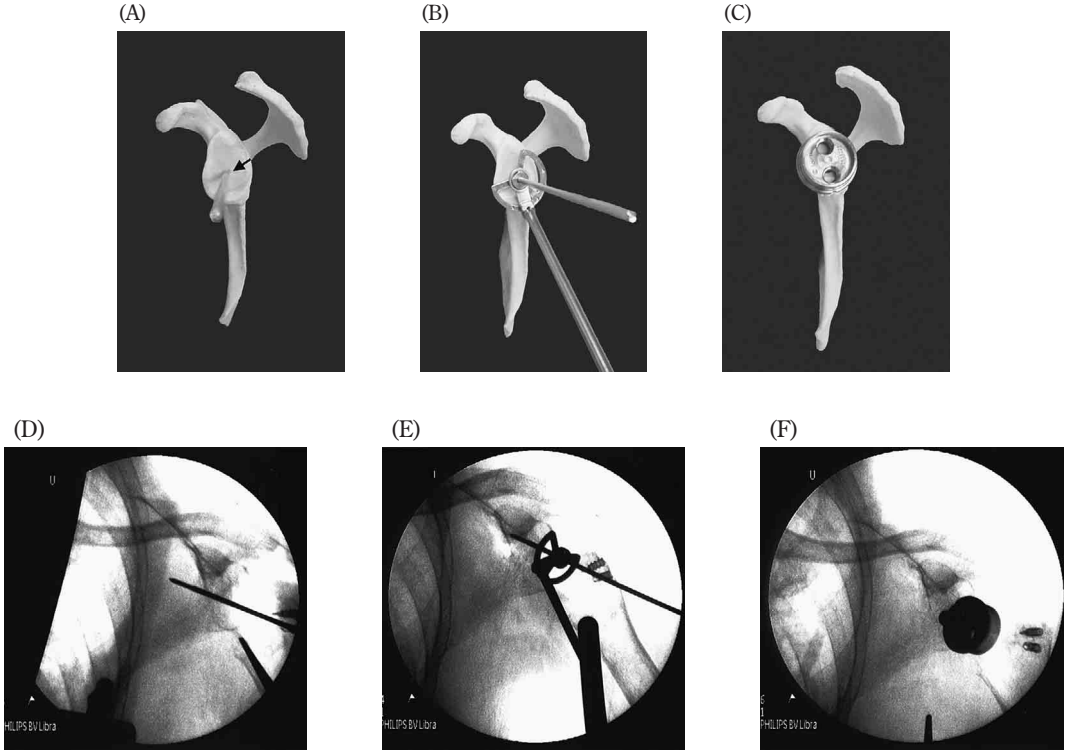

Figure 5. Diagram and actual fluoroscopic glenoid preparation during RTSA. The guide pin (black arrow) is inserted freely with 10-15° of inferior tilt (A, D) The drill guide is then placed on the glenoid surface through the guide pin to determine that the outer rim of the drill guide aligns with the inferior rim of the glenoid (B, E). The baseplate is implanted after reaming (C, F).

should be aware that RSTA may dislocate with the arm in internal rotation and adduction in conjunction with extension.

CASE PRESENTATION

Seven female patients with mean age of 77.0 years (range, 71-89 years) ; mean height of 148.4 cm (SD 7.9 cm) ; and mean body weight of 52.6 kg (SD 9.5 kg), underwent RTSA using Zimmer prosthesis. Preoperative diagnoses are shown in Table 2. All patients could not elevate their shoulder above 90° before operation.

On pre-operative assessment of the glenoid size on CT scan, we found a mean anterior posterior width of 23.9 mm and superior inferior height of 34.3 mm (Table 2). The Tornier mini glenoid baseplate of 25 mm in diameter is still too large for the female glenoid, which may result in insufficient bone stock for anterior and posterior screw placement. Since the height of the glenoid was sufficient for placement of a 28-mm baseplate, an implant design with only superior and inferior screws was more compatible for small females ; therefore, Zimmer trabecular metal reverse shoulder system was used in all our cases. One intraoperative complication consisted of a humeral shaft fracture that occurred during insertion of the humeral stem ; this required encircling wiring to stabilize (Figure 6).

Case 1 : A 74-year-old woman complained of pain and inability to elevate her left shoulder for 3 months after she pulled a box. Her passive range of motion (ROM) was 160° for flexion, 160° for abduction and fifth lumbar level internal rotation, and 60° for external rotation with the arm on the side ; her active ROM on flexion and adduction was 0°. On plain radiograph the acromiohumeral distance was less than 5 mm. Magnetic resonance imaging (MRI) demonstrated massive tear and fatty infiltration of the supraspinatus (grade 3) and infraspinatus and teres minor (grade 4), according to Goutallier classification (Figures 7A, 7B) (18). The

Table 2 Height, weight and size of the glenoid

	Age (y.o.)	Sex	Height (cm)	BW (kg)	Diagnosis	Glenoid Height (mm)	Glenoid Width (mm)
Case 1	74	female	149.8	54.3	CTA	29.8	23.6
Case 2	77	female	147.9	46.6	Recurrent tear	33.1	23.2
Case 3	89	female	136	35.0	CTA	32.8	29.4
Case 4	81	female	148.1	51.0	Primary OA	34.9	23.7
Case 5	75	female	156.0	61.0	Primary OA	34.9	23.7
Case 6	72	female	159.0	61.4	Secondary OA	32.8	29.4
Case 7	71	female	141.7	59	Post-infective	39.1	20.8
Average	77.0		148.4	52.6		34.2	23.9

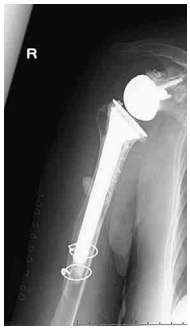

Figure 6. Intraoperative *in situ* humeral shaft fracture during humeral stem insertion, which required encircled wiring to stabilize the periprosthetic fracture.

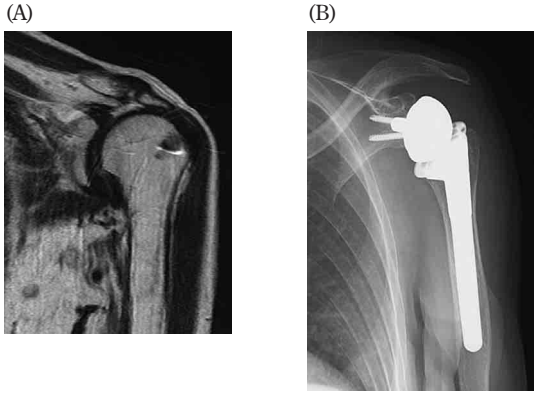

Figure 8. (A) T2-weighted oblique coronal MRI 2 years after surgery demonstrated recurrent tear. (B) Postoperative antero-posterior radiograph.

patient was diagnosed as having CTA, for which RTSA was performed successfully without any intraoperative complications (Figure 7C).

Case 2 : A 78-year-old woman complained of left shoulder pain that recurred 2 years after arthroscopic rotator cuff repair, without any precipitating cause. Her active flexion was severely restricted to 60° with passive flexion of 160°. Preoperative UCLA shoulder score (19) was 12 points ; MRI demonstrated recurrent tear of the repaired tendon, which was retracted to the glenoid level (Figures 8A). Hence, RTSA was performed (Figure 8B). At the 8-month postoperative follow-up, active ROM for both flexion and abduction were 150°, improving the UCLA shoulder score to 29 points.

Case 3 : An 89-year-old woman complained of left shoulder pain and restricted ROM for 8 months. Her active flexion and abduction was 20°. Plain radiograph showed collapse, sclerosis, and proximal migration of the humeral head (Figure 9A). A bony defect of humeral head was confirmed on CT scan, without any bony defect of the glenoid (Figure 9B). The proximal part of the humeral stem could not be implanted in the proximal humeral canal because the proximal humeral size of this patient was much smaller compared with the size of the conical reamer. Satisfactory press fit fixation could not be obtained ; therefore, the humeral stem was fixed with cement (Figures 9C, 9D).

DISCUSSION

The natural history of rotator cuff tear leading to CTA is not well known. Most of the studies demonstrated its occurrence mostly in the dominant shoulder and with female predominance (3). Since the concept of RTSA was developed in Europe and then established worldwide, the implant sizes and designs were most compatible with the European population. Therefore, the components were usually oversized when implanted in the Asian population, especially in women whose glenoid size was considerably smaller.

An anatomical and clinical study done by Ji *et al.* on a Korean population showed a significant difference between the sizes of the male and female glenoids [17.1 (SD, 2.1 mm) vs. 15.4 (SD, 1.6 mm), respectively] and difficulty in surgically inserting the standard 29-mm baseplate in a small glenoid, especially in female patients (11). In their experience, firm fixation of the anterior and posterior compression screws was possible in only 60% cases, but this did not affect the overall stability of the glenoid baseplate because the superior and inferior locking screws were firmly fixed in all cases. Churchill *et al.* reported that the male glenoid width and height were 27.8 (SD, 1.6 mm) and 37.5 (SD, 2.2 mm), respectively ; whereas the female glenoid width and height were 23.6 (SD, 1.5 mm) and 32.6 (SD, 1.8 mm), respectively (20).

Recently, a mini 25-mm glenoid baseplate has become commercially available. An experimental study by Chae *et al.* comparing

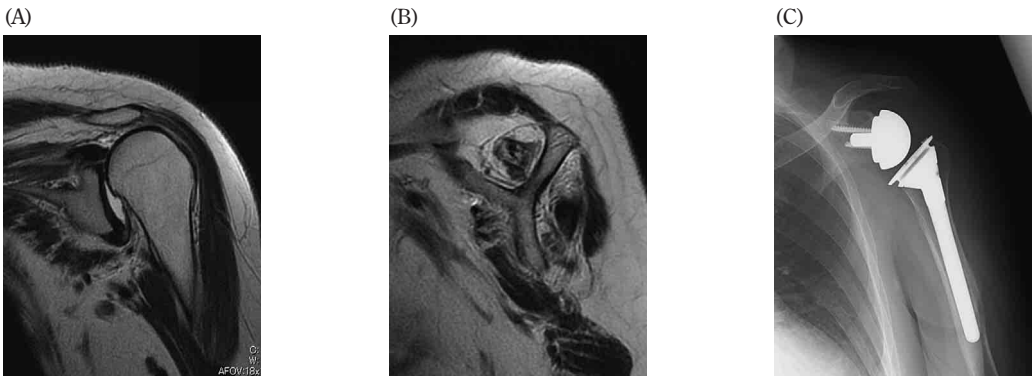

Figure 7. A 74-year-old woman complaining of left shoulder pain and restricted ROM for 3 months. (A) T2-weighted oblique coronal MRI shows torn supraspinatus and infraspinatus tendons that were retracted to the level of the glenoid. (B) T1-weighted MRI on oblique sagittal Y-shaped view demonstrates atrophy and fatty infiltration of the supraspinatus and infraspinatus muscles. After RTSA, (C) plain radiograph shows the prosthesis *in situ*.

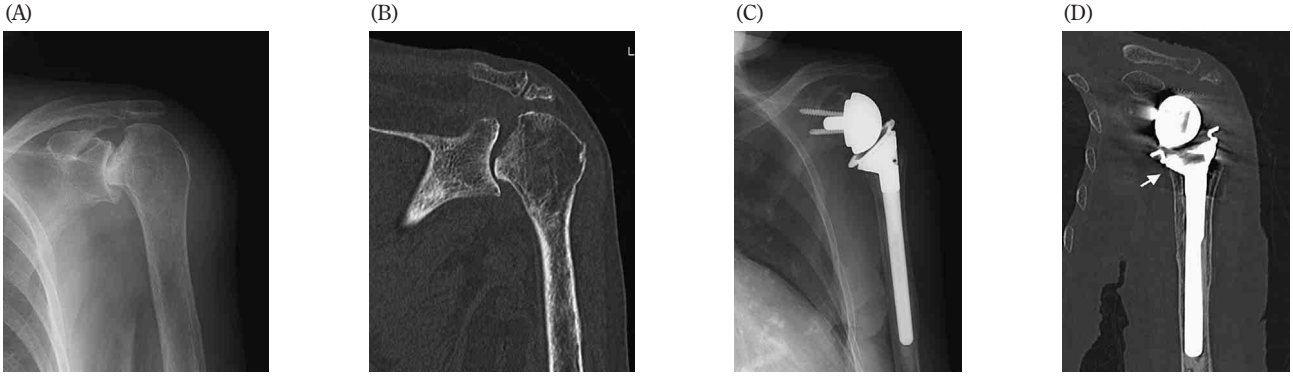

Figure 9. Preoperative (A) plain radiograph and (B) CT scan show bony destruction of the humeral head, decreased joint space with sclerosis, and proximal migration of the humerus. (C) Prosthesis was implanted with cement. (D) The proximal part of the humeral stem could not be implanted in the proximal humeral canal because the proximal humeral size was much smaller than the conical reamer.

25-mm and 29-mm baseplates in fresh frozen cadavers demonstrated that the 25-mm baseplate had less micromotion and greater impingement-free ROM, although a statistically significant difference was not evident (21). They assumed that the bone stock of a small glenoid may be insufficient for fixation of a large 29-mm baseplate, especially by the anterior and posterior screws, and this may influence biomechanical stability. In this study, the size of the glenoid that was measured on preoperative CT scan revealed that even a 25-mm mini baseplate was still too large for a Japanese female. We used the Zimmer 28-mm reverse baseplate, with only superior and inferior locking screws that were good enough for securing the fixation of the glenoid component. Even in a smaller female, the height of the glenoid was large enough to fix these two screws. We also shifted the center of the baseplate slightly anterior to the anatomical center to allow for overhang of the baseplate and avoid breakage of the posterior cortex ; this technique may have enabled us to achieve good bone stock for firm fixation of both the baseplate center post and the screws.

In conclusion, the currently available size of the humeral stem for RTSA may be mismatched for small women. The exterior diameter of the proximal humeral stem must be the same size as that of the glenosphere. Out of a total of 42 cases, three cases of periprosthetic fracture of the proximal metaphysis requiring encircling wiring around fracture were reported by Ji *et al.* (11). In cases wherein the humeral stem could not be implanted in a small proximal humeral canal, the use of stem alone, instead of inlay stem, may be more feasible. The length of the humeral stem may also be longer for small women. New prosthesis designed for the anatomical morphologies of the Asian population should be required.

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