

Clinical and Radiological Outcomes of Bony Increased Offset-Reverse Total Shoulder Arthroplasty in the Asian Population

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Abstract

Background: Bony increased offset-reverse total shoulder arthroplasty (BIO-RSA) was proposed which uses autograft harvested from the patient's humeral head to lateralize the glenoid baseplate. This technique provided the lateralization of the center of rotation and the reduction of the scapular notching. Few studies have reported outcomes of BIO-RSA in the Asian population. We reported the first report of clinical and radiological outcomes of BIO-RSA in the Asian population at mid-term follow-up.

Methods: From June 2012 to August 2017, a total 38 patients with average age of 73 ± 6 years operated by the BIO-RSA technique with minimum two-year follow-up (average 36.7 ± 16 months) were enrolled in our study. Indications of the BIO-RSA were rotator cuff tear arthropathy, massive irreparable cuff tear without osteoarthritis, primary osteoarthritis with glenoid defect, recurrent shoulder dislocation with massive cuff tear, and glenoid fracture sequela. We excluded patients with acute proximal humerus fracture, avascular necrosis and revision RSA performed using allo- or autograft. We evaluated clinical and radiological outcomes of BIO-RSA at the last follow-up.

Results: VAS, ASES, UCLA, and SST scores improved significantly from preoperative (average-5, 39.4, 16.2, 3.9) to postoperative (average- 1.7, 78.9, 28.3, 7.8, p-value < 0.05). All range of motion except internal rotation improved significantly at the last follow-up (p-value <0.05) and the bone graft was incorporated with the native glenoid in all the cases (100%). However, scapular notching was observed in 23/38 (60.5%) of patients. Intraoperative complications were three metaphyseal fractures and one inferior screw malpositioning. Postoperative complications included one heterotopic ossification, one scapula neck stress fracture, one humeral stem loosening, and one late infection.

Conclusions: BIO-RSA results in improved clinical outcomes at mid-term follow-up in the Asian population. Although better cosmesis and advantage of glenoid lateralization were observed in our study along with similar complications rates as compared to conventional RTSA, we observed higher rates of scapular notching to previously reported rates in BIO-RSA studies.

Background

Reverse total shoulder arthroplasty (RTSA) is a relatively new development in the field of shoulder surgery and is undergoing constant refinement. However, there is no consensus on the single best implant design or technical aspect of the procedure. History of RTSA dates to the 1970s when this concept of reversing was proposed for the first time [1]. There were many modifications of the initial design but none with clinical success. Modern RTSA designs used primarily are based on the pioneering work of Grammont who first proposed the concept of medialization and distalization of the center of prosthesis rotation [2]. Nevertheless, this prosthesis also showed design-related complications such as scapular notching, instability, aseptic loosening on long-term follow-up, and thus, needed further refinement. While instability is a complication which can be addressed by using thicker polyliner or metallic humeral spacer, thereby achieving more deltoid tension and better balancing of the prosthesis; aseptic loosening is shown to

reduce with uncemented stem implantation and remains more of a complication of cemented stems [3]. However, notching remains the most common complication which needs surgical technique modification or implant design modification or both and is still to have final solution. Inferior overhang of the glenosphere, inferior tilting of the glenosphere, lateralization of the center of the prosthesis rotation by increasing the glenosphere arc, and adding metal augmentation of the glenosphere are all described methods to prevent scapular notching [4, 5].

However, these techniques have also shown drawbacks. Inferior tilting of the glenosphere can increase the tension on the deltoid and has also been shown to reduce the longevity of the implant [6, 7]. Increasing the glenosphere arc or adding metal augment shifts the center of prosthesis rotation within the glenoid component and increases the unbalanced load on the glenoid component with each movement which can lead to early glenoid component loosening [8]. As an alternative to these techniques, Bony Increased Offset-RSA (BIO-RSA) was proposed which uses autograft harvested from the patient's humeral head to lateralize the glenoid baseplate. This technique is proposed to maintain the center of rotation at the bone implant interface, thus providing dual benefit of lateralizing the center of rotation thereby causing reduction in scapular notching, improvement in rotations; and also preventing unbalanced loading of the glenoid component [9]. However, there is still controversy about development of notching after BIO-RSA (Fig. 1). Furthermore, glenoid lateralization of BIO-RSA in the small sized scapula of the Asian elderly could cause higher tension of the deltoid muscle and difficult reduction of the reverse prosthesis and few studies have reported outcomes of BIO-RSA in the Asian population.

The purpose of this study was to evaluate the clinical and radiological outcomes of BIO-RSA in the Asian population at the mid-term follow-up. We hypothesized that BIO-RSA would lead to improved clinical outcomes in indicated patients along with less scapular notching and postoperative complications.

Materials And Methods

This is a retrospective study of 38 patients who underwent RSA using Bony Increased Offset technique (BIO-RSA) from June 2012 to August 2017 at single centre. All the patients presented during the study period with cuff tear arthropathy, massive retracted irreparable cuff tear (Patte stage 3 or Goutallier stage 3/4), primary/secondary glenohumeral osteoarthritis with massive cuff tear, recurrent shoulder dislocation with massive cuff tear and glenoid fracture sequela were included in the study. We excluded acute proximal humerus fracture, AVN, and revision RSA cases. In the acute proximal humerus fracture, BIO-RSA was not attempted as primary treatment because of concern of non-availability of adequate humeral head bone stock for autograft harvest. Also, patients younger than 65 with massive cuff tear received an alternate form of treatment (partial repair or superior capsule reconstruction) and were not included in the study. We also operated three revision RSA cases during the study period (two humeral head allografts and one iliac autograft) with BIO-RSA. However, those patients who received revision surgery were not included in the study. All the patients were operated by single surgeon-senior author of this study. The 36 mm glenosphere and 25 mm diameter glenoid baseplate with 25 mm peg length was

used without inferior tilt. For the humeral stem, we used the cemented stem in 30 patients and uncemented stem in eight patients.

Glenohumeral arthritis along with cuff retraction and fatty infiltration (Goutallier stage) was evaluated in all the patients preoperatively. Glenoid morphology was classified according to the types described by Walch [10] to aid in planning and positioning the glenoid component intraoperatively. Post-operatively, all the patients were followed for a minimum 2 years. Average follow-up period was 36.7 ± 16 (Range: 24-78) months. Post-operative outcomes were evaluated with radiographs, clinical scores and range of motion evaluation. Radiographic follow-up included three monthly shoulder x-rays during first year after operation and yearly x-rays thereafter. Scapular notching, signs of osteolysis and implant (glenoid and humeral component) loosening were specifically evaluated. The clinical outcome evaluation included ASES, UCLA, SST, VAS scores along with range of motion (ROM) evaluation.

Surgical technique

All the patients were operated in the beach chair position under general anaesthesia supplemented with interscalene block. The deltopectoral approach was used in all the cases. After identifying the cephalic vein and retracting it laterally, the plane was developed between deltoid and pectoralis major muscles. Upper pectoralis major tendon were released from its attachment site leaving approximately 5 mm of stump laterally to repair at the end of the procedure. Next, the clavipectoral fascia was incised and the conjoint tendon was identified and retracted medially. Then subscapularis was identified vessels running across its inferior margin ligated. Next, the biceps long head tendon was tagged, tenotomized, and then the subscapularis was tagged and removed from its humeral attachment, lesser tuberosity. The humeral head was dislocated and using the standard preparation guide with 20° retroversion, the humeral cut was performed. The autograft of 7 mm thickness was harvested from the excised humeral head. We avoided 10 mm thickness autograft owing to higher tension during the prosthesis reduction. The glenoid was prepared in standard fashion with minimum reaming up to the subchondral bone. The harvested graft was fitted in the 25 mm diameter glenoid baseplate with 25 mm peg length and was inserted in the predrilled peg hole without inferior tilt (neutral) (Fig.2) Usually, the baseplate was fixed with four screws and then the 36 mm glenosphere was implanted. Next, the humeral stem was prepared in the standard fashion with the stem guide and 20° retroversion. Trials were inserted and the adequacy of tension and stability was checked before final humeral stem implantation. Trans-osseous holes were drilled followed by the passage of No. #2 ethibond from the holes before the final stem insertion for subscapularis reattachment. Humeral stem was then inserted and adequacy of tension was checked again with the trial liner and the subscapularis tendon was reattached. This was followed by liner insertion as per the trial size and reduction of the prosthesis. Two drains were inserted to reduce the fluid or hematoma collection in the dead space followed by wound closure in layers.

Postoperatively, we immobilized all the patients in an abduction brace for six weeks. Only elbow, hand and wrist mobilization were allowed along with pendulum exercises. At six weeks, the brace was weaned

off and gradual mobilization was initiated which was continued for three months postoperatively. And after three months, gradual strengthening exercise program was performed.

Statistical analysis

A p-value of <0.05 was defined as statistically significant. All statistical analyses were performed using the SPSS statistical package version 20.0 (SPSS Inc, Chicago, Illinois). Measurements were expressed as mean \pm standard deviation with a confidence interval of 95% for continuous variables. In order to measure the impact of intervention, we used the paired t-test to compare postoperative measures with preoperative measures. The internal rotation was measured substituting scores in place of verbal description, with the buttocks/sacrum considered as 0 and then each lumbar vertebra adding a score of 2 incrementally. T12 was defined as a score of 12 and each thoracic vertebra added 1 score of internal rotation incrementally. The maximum level of IR i.e. T3 was considered as 21 score of internal rotation.

Results

There were nine males and 29 females in our study with the average age of the patients being 73 ± 6 years (range 64–87 years). Average BMI of the patients was 24.79 (range 18.81–33.18) (Table-1).

According to the Hamada classification [11], there were six patients with grade 4B, 5 patients with grade 4A, nine patients with grade 3, 10 patients with grade 2 and eight patients with grade 1 arthropathy. Grade 1 patients were either having history of recurrent dislocation or had isolated massive irreparable cuff tear. As per the study by Walch [10], there were 24 patients with A1, three patients with A2, 7 patients with B1, three patients with B2 type of glenoid and one patient with type C glenoid. Improvement in the clinical parameters with p-value shown in the table below (Table 2). All the scores, namely ASES, UCLA, SST and VAS improved significantly postoperatively as compared to the preoperative status. Also active forward flexion, abduction and external rotation, improved significantly as compared to the preoperative status (p -value < 0.05). Internal rotation also showed improvement when compared with preoperative scoring. However, this improvement was not significant (p -value = 0.138). Radiolucent lines around the humeral stem were observed in 16/38 (42.11%) patients. However, only one patient developed stem loosening at three years follow-up. The glenoid graft was incorporated in all the patients (100%). Scapular notching was observed in 23 patients (60.52%) and the grading distribution is shown below (Table 3).

Table 1
Patients' demographics of Bony Increased Offset-Reverse Total
Shoulder Arthroplasty.

Parameter	
Age	72.94 ± 5.57 years
Sex (M:F)	9:29
BMI (kg/m ²)	24.79 ± 3.20
Etiology	
Cuff tear arthropathy : 23 patients Recurrent shoulder dislocation due to massive cuff tear : 5 patients Osteoarthritis with poor quality cuff : 3 patients Isolated massive irreparable cuff tear: 6 patients Glenoid fracture sequelae : 1 patient	

Table 2
Clinical scores and range of motion at the final follow-up after
Bony Increased Offset-Reverse Total Shoulder Arthroplasty.

Parameter	Preop	Postop	p-value
VAS	5 ± 1.64	1.71 ± 1.2	0.000
ASES	39.43 ± 22.41	78.91 ± 11.83	0.000
UCLA	16.22 ± 7.48	28.34 ± 3.34	0.000
SST	3.94 ± 3.5	7.8 ± 1.91	0.000
Range of motion			
Forward elevation	102 ± 33.49	134.86 ± 18.28	0.000
Abduction	93.65 ± 37.17	132.84 ± 19.74	0.000
External rotation	22.30 ± 12.78	31.35 ± 11.47	0.000
Internal rotation	5.81 ± 5.51	7.32 ± 3.92	0.138

Table 3
Scapular notching at minimum two-year follow-up after Bony Increased Offset-Reverse Total Shoulder Arthroplasty.

Notching grade	Two-year follow-up
0 (No notching)	15
1	7
2	13
3	3
4	0

Intraoperative complications included one inferior screw malposition and three humeral metaphyseal fractures which were treated with simple wiring. Postoperative complications observed were one heterotopic ossification (1.5 months), one scapula neck fracture (27 months) (Fig. 3), one humeral stem loosening and one late infection. The humeral stem loosening patient presented with occasional pain (VAS 2) and restriction of motion (forward flexion 110, abduction 110, external rotation 20, internal rotation L4). However, she refused to undergo revision surgery (Fig. 4). The infection case presented after 33 months of the primary procedure (RTSA) and was treated with implant removal and PROSTALAC insertion (Fig. 5).

Discussion

Our study showed that BIO-RSA showed improved clinical outcomes in Asian populations at mean three years follow-up as the clinical outcomes and ROM except internal rotation improved significantly. The overall rate of notching was 60.52% (23/38). However, there was no case of grade 4 glenoid notching. 100% graft incorporation and no case of glenoid loosening were observed at the last follow-up. We observed 4 intraoperative and 4 postoperative complications which are discussed further in this section.

This is the first study reporting BIO-RSA outcomes in the Asian population. Previously, few studies have reported outcomes of BIO-RSA in the Asian population. Among BIO-RSA instrumentation, large or extra-large BIO-RSA cutting guide could make thicker glenoid autograft, and these glenoid lateralization of BIO-RSA developed too much tension and difficult reduction of the prosthesis in the small sized glenoid. This was very important consideration of Asian population in BIO-RSA. We usually harvested 7 mm thickness humeral autograft and avoided 10 mm thickness autograft owing to higher tension during the prosthesis reduction.

Conventional RTSA is known to produce scapular notching, less improvement in rotational movements, impingement free movements; and poor cosmesis due to medialization of the center of rotation [12]. Boileau et al [9]. originally described the method of BIO-RSA in 2011 to solve these problems. But since

then, not many have adopted this technique. According to their results, the humeral autograft incorporated completely in 98% of cases (41 of 42) and partially in one. At a mean of 28 months postoperatively, no graft resorption, glenoid loosening, or postoperative instability was observed. We also had 100% graft incorporation with no glenoid loosening or instability. In their study, significantly increased active anterior elevation and external rotation at the final follow-up was noted, similar to our findings. They reported inferior scapular notching in 19% (eight of 42) and 86% (36/42) patients in their series were able to internally rotate sufficiently to reach their back over the sacrum. Although internal rotation improvement was observed in our study similar to their study with 37/38 patients being able to internally rotate to reach above the sacrum, the rate of notching was 60.5% (23/38) which is much higher than their reported rate. However, no grade 4 notching was observed and notching did not have impact on functional outcomes in our study and this rate of notching is less than the reported rates of notching with conventional RTSA (> 63%) [2, 13].

There have been few studies reporting BIO-RSA outcomes but their results reported are not similar. A comparative study between conventional and BIO- RSA was reported [14]. There was bone graft incorporation in all BIO-RSA with no evidence of graft resorption. However, the BIO-RSA technique was associated with an increase in scapular stress fracture rate when compared to the standard RSA (9.1% in the standard RSA and 16.7% in the BIO-RSA). But, this was not found to be significant ($p = 0.64$). We also had one case of scapular neck stress fracture which was managed conservatively. In the same study, statistically significant difference was identified when comparing the rates of scapular notching (standard RSA 68% vs BIO-RSA 33%; $p = 0.028$). Another study did not show any advantage of BIO-RSA over conventional RTSA including scapular notching [15]. However, their notching rate was low (5%) as compared to our study. Contradictory to this, Athwal et al.[16] reported significantly higher frequency of scapular notching ($P = .022$) in the RSA cohort than in the BIO-RSA cohort: 75% versus 40%, but no other outcome measures were statistically different, including range of motion, strength, and validated outcome scores in their study. All of their patients had either grade I/II notching. In our study, 87% (20/23) patients developed grade I/II notching and remaining 13%(3/23) had grade III notching with no patients showing grade IV notching. This high grade notching is much lower than reported with the conventional RTSA (> 25%).

We believe there are multiple factors to consider for notching as shown by various studies including humeral neck shaft angle, inferior overhang of the glenosphere, inferior tilting of the glenosphere, increasing glenosphere arc [4, 5]. Reason of scapular notching is usually contact between liner and bone at terminal range of motion, especially adduction and internal rotation. By using bone-graft on glenoid, there can be added advantage of relatively more impingement free motion i.e. instead of curved inferior border of glenoid, there is almost horizontal inferior border of glenoid after grafting similar to long neck scapula. This can increase impingement free range of motion to certain extent but cannot prevent liner from contacting the glenoid at terminal range of motion in adduction and internal rotation. However, further biomechanical studies are required to quantify this hypothesis. Also, higher rates of notching observed in our study as compared to other BIO-RSA studies may be because of our study population and prosthesis sizing limitation. As already quantified, the East Asian population has smaller glenoid sizes,

especially females [17]. This reverse prosthesis design was not originally designed according to their morphology. All our patients received 25 mm base plate with 36 mm glenosphere which was not the case with the previous study. Athwal et al. [18] have reported 62% notching rate with 25 mm glenoid base plate (without bony increased offset) in their series which is near to our rate of notching (60.5%). Many studies have shown reduction in notching and higher impingement free adduction with larger glenosphere of diameter 42 or 44 mm rather than 36 or 38 mm diameter glenosphere which may also explain the notching rate in our study [19–23].

Boileau et al.[24] have expanded the application of BIO-RSA and reported their outcomes in glenoid deficiency using angled BIO-RSA with trapezoidal graft. However, in our study, we had three cases of severe glenoid defects, but they were managed with standard humeral head autograft (similar to trapezoidal graft) only without any complications.

As an alternative to BIO-RSA, two other lateralization options are available, metallic glenoid lateralization, and humerus lateralization. Metallic glenoid lateralization is a similar concept to the lateralized center of rotation and the results as reported by Cuff et al.[25] have been really encouraging with reduced rate (9%) for scapular notching and no glenoid loosening. However, they reported 3% asymptomatic humeral stem loosening which is a concern. Also, Harman et al.[8] reported substantially increased moment (69%) at baseplate-bone interface which may possibly lead to loosening of the baseplate and has been a particular concern with this technique of lateralization. In our study with BIO-RSA, we encountered one humeral stem loosening case. Overall rate of radiolucent lines around the humeral stem in our study was 44.74% (46.66% for cemented stems vs 25% for un-cemented stems). Though our aseptic loosening rate is similar to other studies, finding of radiolucent lines is higher than reported with conventional RTSA (15.9% for cemented stems and 9.5% for uncemented stems) [26].

The introduction of humerus lateralization has been a recent development and has shown equally good results. Franceschetti et al.[27] in their comparative study between BIO-RSA and 145° onlay curved stem showed similar clinical outcomes with equally reduced rates of scapular notching. Only improvement in the BIO-RSA group over the curved stem group significantly increased external rotation in the BIO-RSA group. However, it did not result in improved functional outcomes. The curved humeral stem provides an easier lateralization alternative technically as compared to BIO-RSA. In an analysis of 485 consecutive cases, scapular spine fractures showed increased prevalence after the humeral onlay short stem design RSA [28]. However, there are a little comparative studies and long-term comparative studies are needed to prove superiority of either method.

There were six complications in our series. The first is one case of heterotopic ossification observed on X-ray at 1.5 months postoperatively. Verhofste et al[29] et al has reported very high incidence i.e. 29.5% of heterotopic ossification following RTSA. Although this incidence is much higher than our study, the point of similarity between their study and our study is timing of the heterotopic ossification. They have reported that 81.6% of heterotopic ossification developed within first three months postoperatively, similar

to our findings. Also in our study, patients with heterotopic ossification did not have an altered functional outcome as compared to other patients, similar to their finding.

The second complication was inferior screw malposition, also observed in one case. The screw was proud from the inferior aspect meaning that it was directed inferior to the inferior border of glenoid and lateral border of the scapula. However, no glenoid loosening was observed at mid-term follow-up. This was technical complication and we now prefer almost horizontal direction of the screw especially in the long neck scapula patients. The third complication was intra-operative humerus metaphyseal fracture which occurred in three patients and was treated with circumferential circlage wiring and none of the patients developed subsidence of stem. However, gradual resorption of bone noted at the medial calcar area and GT area without any sign of subsidence/ loosening on subsequent X rays.

As already mentioned previously we also noted one humeral stem loosening which developed in one of the patients with cemented stem without any sign of infection. The patient complained of occasional pain (VAS 2). On examination, there was restriction of motion (forward flexion 110, abduction 110, external rotation 20, internal rotation L4) and in radiographs, lysis around the humeral stem with rotation of the stem was noted. Infection was ruled out and patient advised revision of the stem to improve clinical outcome further. However, because of minimal complaint from the patient and advanced age (80 years), she did not want to undergo revision operation. This is similar to the aseptic loosening rate (1.18%) observed with the cemented humeral stem as reported by Gilot et al[3].

The fifth complication was one case of late infection developing 33 months after surgery. The patient was treated with PROSTALAC (antibiotic impregnated cement) insertion. And is yet to receive revision prosthesis surgery. The patient is one year postoperative after PROSTALAC insertion with healing of the wound but unable to receive the revision surgery due to aggravated comorbidities (pacemaker and age 91 years at present, the oldest patient of our study). As reported in the literature, functional outcomes of infection patients are usually poorer than primary RTSA [30], the same was the finding in our study. And the sixth complication as described previously was non-traumatic scapula fracture which developed after 27 months of primary procedure. The fracture occurred at the site medial to the tip of the glenoid screws and was minimally displaced. Kirzner et al.[14] have reported significantly higher scapula stress fracture with BIO-RSA as compared to conventional RTSA. However, our rate was much less than their series (2.6 vs 16.7%), this complication also must be considered while using BIO-RSA. The patient was managed conservatively with arm sling for six weeks. Three-month x-ray showed callus formation and there was no impact on the functional outcome.

There are few shortcomings of our study. First, we did not include a cohort to compare our data which can give more relevant analysis of a particular method with a definite conclusion. Second, we relied on X-ray to check autograft incorporation rather than performing postoperative CT scan in every patient. However, many times artefacts on postoperative CT scan also obscure perfect visualization. Third, the study design was retrospective and the number of patients (38) was small with only mid-term follow-up.

Conclusion

BIO-RSA is a promising modification in the conventional RTSA design showing improved clinical outcomes with similar rate of complications at short-term as compared to conventional RTSA. However, we observed more rate of scapular notching than reported in the previous series without impact on the functional outcome. More long-term comparative studies with the newer concepts like humeral lateralization needs to be conducted to adequately prove superiority of either method.

Abbreviations

Bony increased offset-reverse total shoulder arthroplasty: BIO-RSA, MRI: Magnetic resonance imaging, FF; forward flexion, Abd: abduction, ER: external rotation, IR: internal rotation. UCLA: University of California at Los Angeles scale, ASES: American Shoulder and Elbow Surgeons score, SST: Simple Shoulder Test score

Declarations

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Author's contributions

J-JH designed the study, managed the acquisition of data, analyzed and interpreted the data (with support from a statistician, who had access to the full dataset) and drafted and edited the manuscript. Kirtan Tankshali, Sang-Eun Park and me made substantial contributions to the design of the study, the analysis and interpretation of the data, revised the manuscript for important intellectual content, and contributed to writing and editing. Dong-Whan Suh, Min-Kyu Park, Wan-Jae Cho and Young-Hun Han made substantial contributions to the interpretation of the data, and revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The study was approved by Institutional Review Board: approved by Daejeon St. Mary's Hospital (# DC17RESI0067)

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Figures

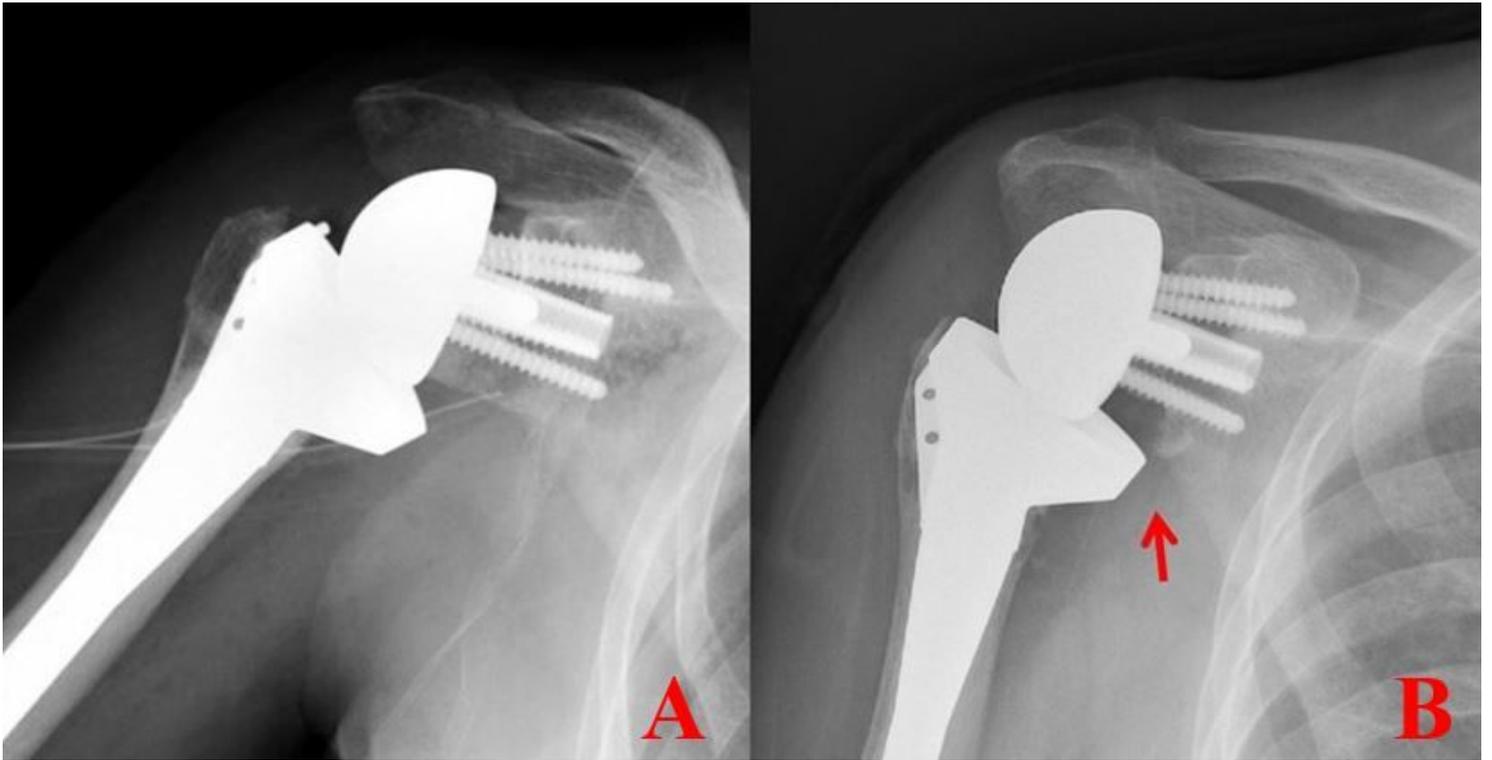


Figure 1

Immediate X ray showing graft placement on glenoid (A) 2 years follow-up X ray shows grade 3 scapular notching (B)

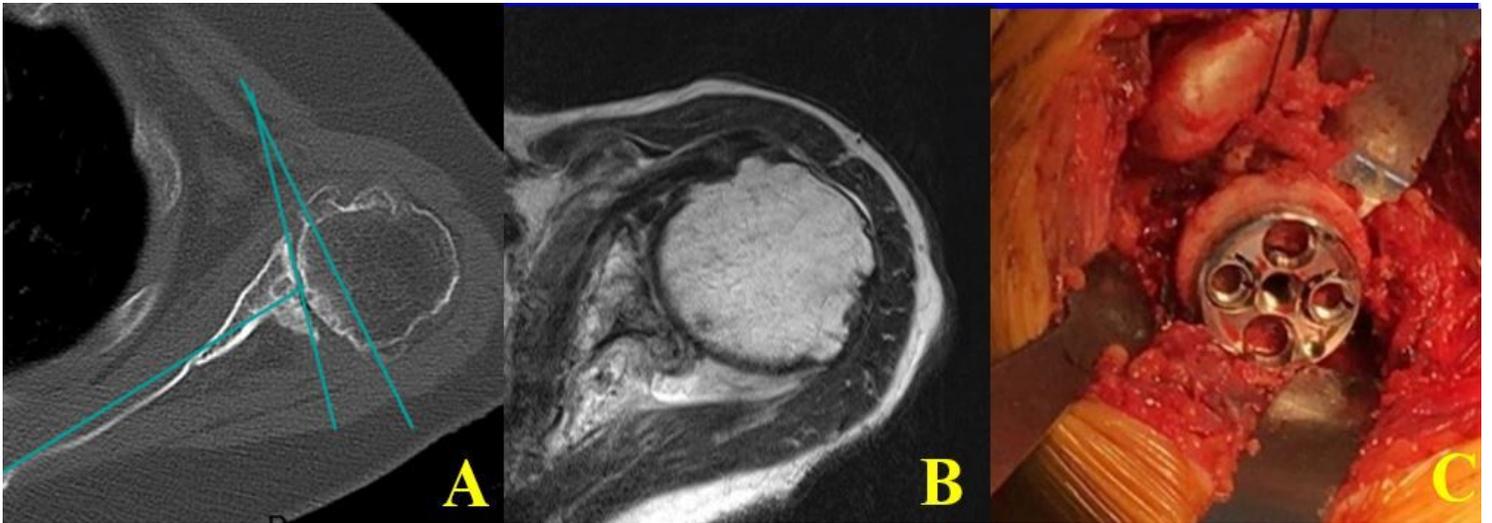


Figure 2

Preoperative axial CT scan (A) and MRI (B) showing type C glenoid (C) showing intraoperative placement of autograft on the glenoid baseplate.

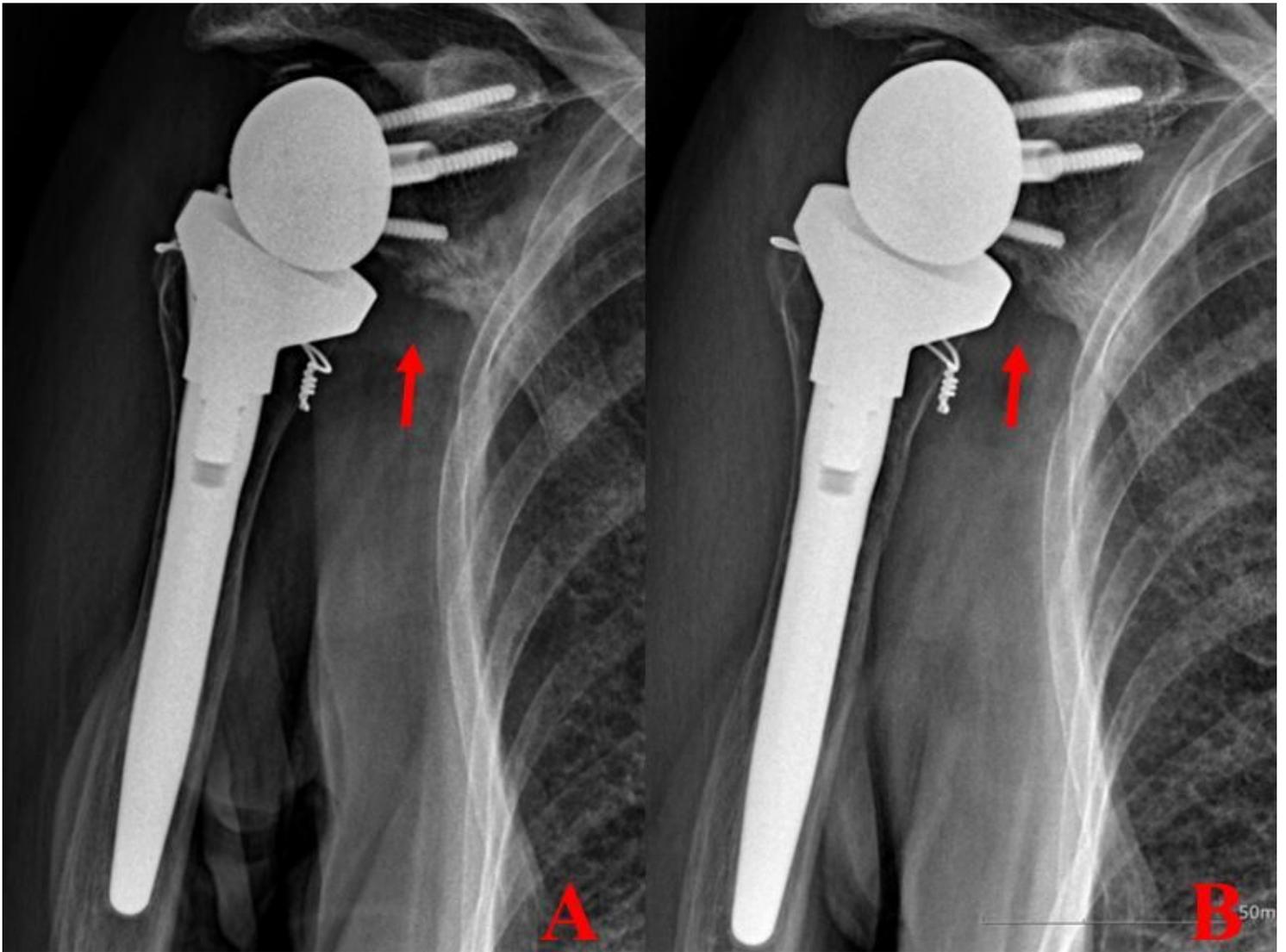


Figure 3

(A) Scapular neck stress fracture developed after trivial trauma(B) Callus formation seen at 3 months with conservative treatment

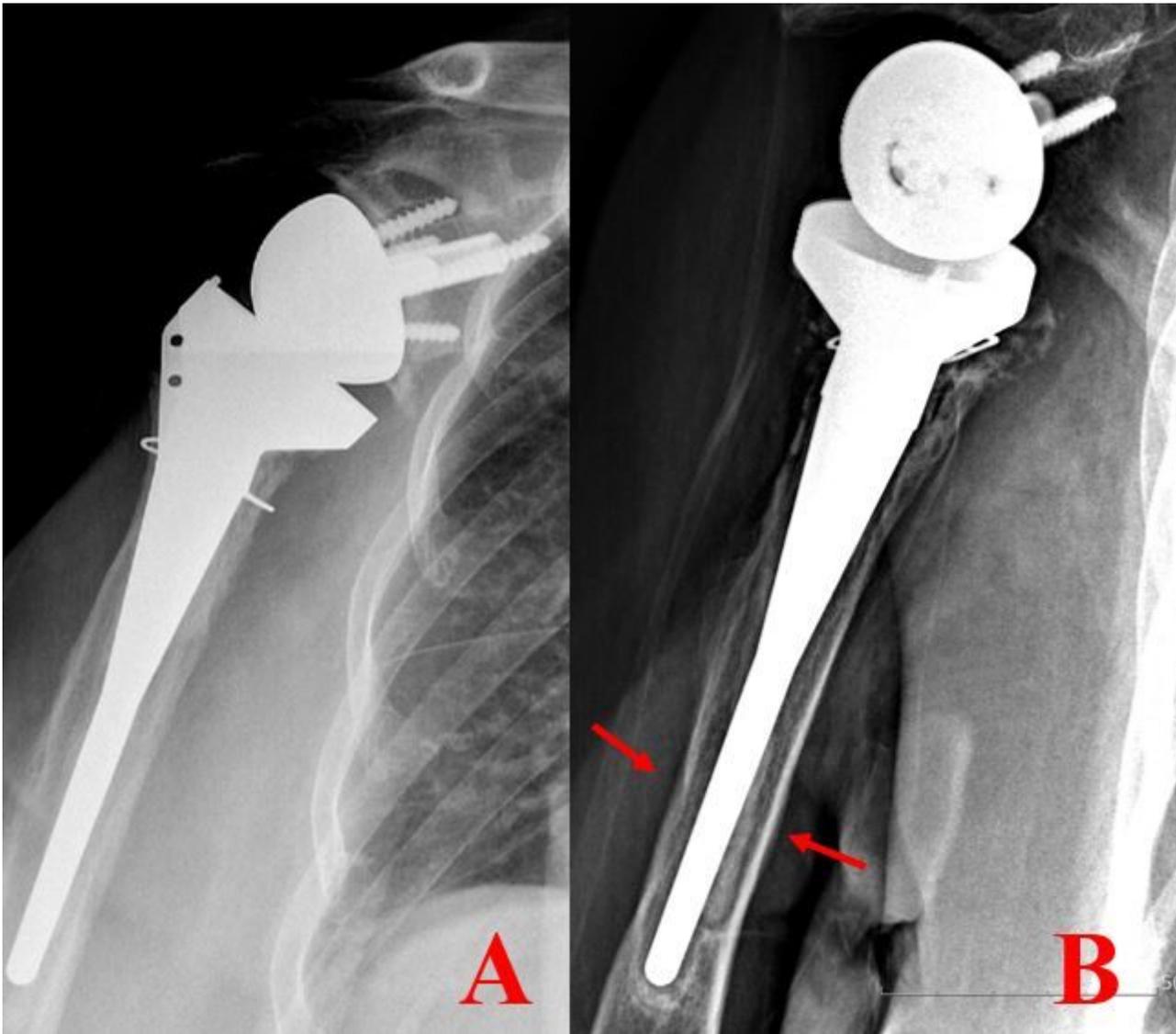


Figure 4

(A) Immediate post-operative X ray (B) Aseptic loosening of cemented humeral stem at 2 year follow-up

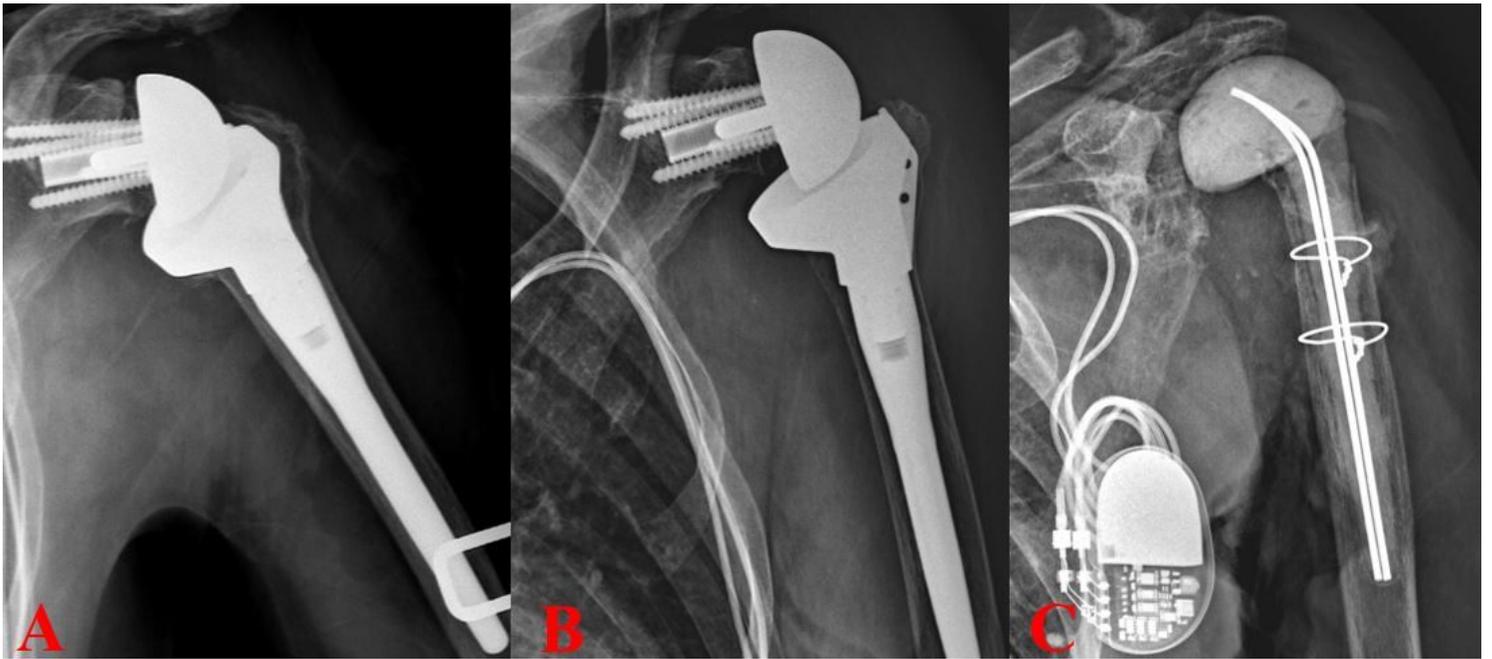


Figure 5

(A) Immediate post-operative X ray (B) 33 months follow-up with acute onset infection- X ray showed scapular notching with no definite radiologic finding of infection (C) 3 months after PROSTALAC insertion