ORIGINAL

Influence of the glenoid baseplate position on the direction and length of the superior and inferior locking screws

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Abstract : Introduction : Superior screw insertion in reverse shoulder arthroplasty (RSA) carries the potential risk of suprascapular injury. The purpose of this study was to evaluate how the baseplate position affects the superior screw position and length in RSA. Methods : Three-dimensional (3D) computer simulation models of RSA were established using computed tomography data of baseplates with superior and inferior screws and 3D scapular models from 10 fresh cadavers. Superior screw position, the distance from the superior screw hole to the suprascapular notch, and the screw lengths were measured and compared among various baseplate positions with two inferior tilts (0 and 10 degrees) and three rotational patterns (11–5, 12–6, and 1–7 o'clock in the right shoulder). Results : For the 1–7 o'clock/inferior tilt 0 degrees baseplate, the superior screw located anterior to the SS notch in all shoulders, the distance to the SS notch was the longest (12.8 mm), and the inferior screw length was the shortest (23.1 mm). Conclusion : Although there is a concern of a short inferior screw length, initial fixation using a baseplate with 1–7 o'clock rotation and an inferior tilt of 0 degrees appears preferable for SS nerve injury prevention during superior screw insertion. J. Med. Invest. 69 : 185-190, August, 2022

Keywords **:** *reverse total shoulder arthroplasty, baseplate rotation, baseplate tilt, peripheral screw*

INTRODUCTION

Reverse shoulder arthroplasty (RSA) has become a widespread treatment for patients with not only massive irreparable rotator cuff tears or cuff tear arthropathy (1-4), but also for patients with primary glenohumeral osteoarthritis and posterior glenoid deficiency (5). RSA has a unique configuration that consists of a humeral component (as the socket), a glenosphere (as the ball), and a baseplate to fix to the glenoid via screws instead of cement. Despite improvements in RSA implants (6), accessory devices (7), and surgical techniques, many complications, including catastrophic failure, scapular notching, infection, joint dislocation, and iatrogenic neurological compromise, have yet to be resolved (1, 8, 9). These neurological compromises have been described as caused by compression from the superior and posterior peripheral screws in RSA in a cadaver study (10, 11) and case report (12).

Although superior screws are dispensable for the initial rigid baseplate fixation (13), they may impinge into the suprascapular (SS) notch, fossa of the supraspinatus, and spinoglenoid notch, leading to a risk of SS nerve injury. On the other hand, in peripheral fixation, the screw position depends on the baseplate position, which involves a superoinferior tilt and anteroposterior rotation. An inferior tilt is reportedly necessary to prevent mechanical failure due to early loosening (14) and scapular notching (15). However, the greater the inferior tilt, the greater the risk of superior scapular nerve injury, as the screw trajectory also increases upward. Regarding rotation, Stephan *et al.* reported on the baseplate rotation for achieving optimal rocking superior and inferior screw placement (15). It is easy to assume that an anterior rotation decreases the risk of neurological compromise. However, screws with insufficient length cannot obtain good purchase. Moreover, the influence of the baseplate position in terms of combination of tilt and rotation on the superior screw position and screw length remains unclear. Therefore, the present study aimed to investigate how variation in the baseplate position in RSA affects not only the superior screw position, but also the distance from the SS notch to the superior screw hole and the screw length, via computer simulation. Our hypothesis was that baseplates with a posterior rotation would result in an increased risk of SS nerve complications because the screw tip would be more likely to penetrate posterior to the SS notch.

METHODS

Ten fresh-frozen human cadavers (6 males, 4 females) with a mean age of 57.6 years (range, 50–68 years) were used. This study was approved by the research board of Tokushima University Hospital (reference no. 1828) and conducted according to the Guidelines for Cadaver Dissection in Education and Research of Clinical Medicine (Japan Society and Japanese Association of Anatomists).

The cadaveric whole bodies were subjected to computed tomography (CT) imaging. Glenoid and humeral heads without osteoarthritis, abnormal version, and bone loss were confirmed before the study. Scapulae were extracted to establish three-dimensional (3D) bone models using Mechanical finder™ (RCCM). Additionally, a 25-mm baseplate and 3.5-mm locking screws in a Comprehensive Reverse Shoulder System (Zimmer Biomet, Warsaw, IN, USA) were purchased for use in this study. CT

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imaging of the baseplate fixed with locking screws was performed to create a 3D model in the same fashion as that for the scapulae. In the computer simulation, the 3D model of the baseplate with locking screws was placed on the 3D models of the glenoid using the Mechanical finder by a senior shoulder surgeon (K.M.). To make the simulations more realistic, the baseplate was placed along the inferior border of the glenoid to prevent scapular notching. In addition, the baseplate was set parallel to the glenoid version according to the top view of the 3D model.

First, glenoid height and width were investigated in CT axial image. Scapular height and width were also done using 3D image to confirm scapular morphology. To investigate the effect of baseplate rotation, three baseplate rotations were established based on the line connecting the superior and inferior locking screw holes on the enface view of the glenoid in right shoulder cases (Figure 1) : parallel to the 12–6 o'clock line (12-6 o'clock), 20 rotated degrees anteriorly (corresponding to the 1–7 o'clock line ; 1-7 o'clock), and rotated 20 degrees posteriorly (corresponding to the 11–5 o'clock line ; 11-5 o'clock). Moreover, to investigate the effect of baseplate tilt, two baseplate tilts were established using the anterior view of the 3D model (Figure 2) : parallel to the line connecting the superior and inferior glenoid tubercles (inferior tilt 0 degrees), and with a 10-degree inferior tilt on the scapular line (inferior tilt 10 degrees). Hence, six patterns of baseplate positions were defined as follows : 11–5 o'clock/inferior tilt 0 degrees (Simulation 1) ; 11–5 o'clock/inferior tilt 10 degrees (Simulation 2) ; 12–6 o'clock/inferior tilt 0 degrees (Simulation 3) ; 12–6 o'clock/inferior tilt 10 degrees (Simulation 4) ; 1–7 o'clock/inferior tilt 0 degrees (Simulation 5) ; and 1–7 o'clock/inferior tilt 10 degrees (Simulation 6).

The position at which a screw penetrated the bone cortex was defined as a screw hole in the 3D models. If the superior screw penetrated the anterior scapular body cortex on the anterior view of the 3D model and was not found on the superior view, the superior screw hole was considered as located anterior to the SS notch. If the superior screw was not found on the anterior view and it penetrated the posterior glenoid neck, supraspinatus fossa, and spinoglenoid notch on superior and posterior views, the superior screw hole was considered as located posterior to the SS notch (Figure 3). The distance from the SS notch to the screw hole (Figure 3) was measured using a 25-mm baseplate for calibration on the anterior view of the 3D image using Image J® software. Superior and inferior screw length, defined as the distance from the lateral side of the baseplate to the screw hole (Figure 3), were measured in the same fashion.

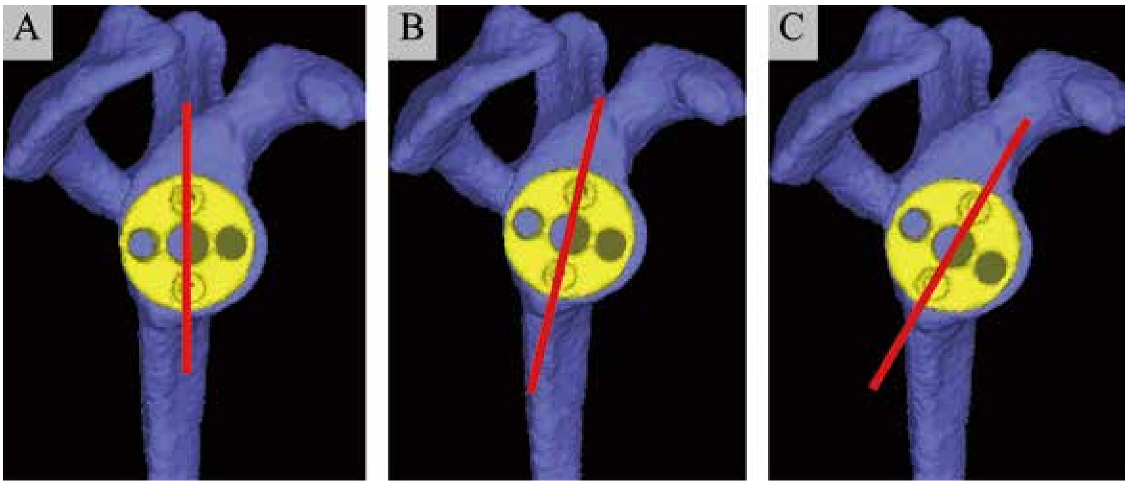

Figure 1. Baseplates are shown in three anti-rotation positions, (A) 11–5 o'clock, (B) 12–6 o'clock, and (C) 1–7 o'clock, in terms of the superior–inferior screw position on the enface glenoid view.

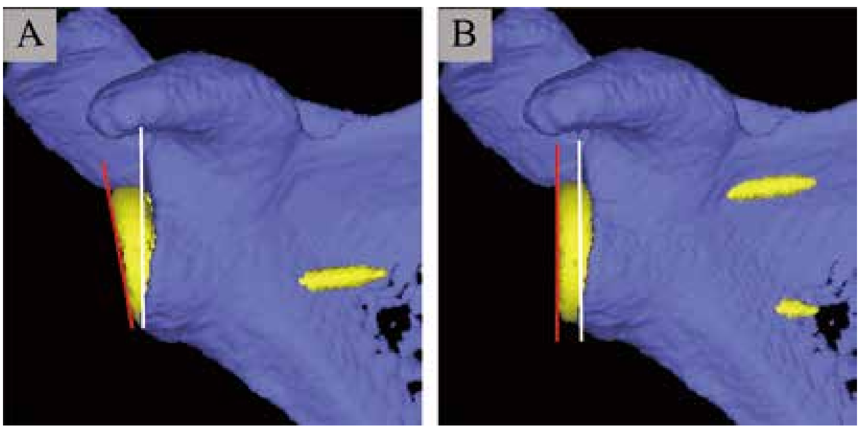

Figure 2. Baseplates are shown with (A) 10 degrees of inferior tilt on the anterior view and (B) 0 degrees.

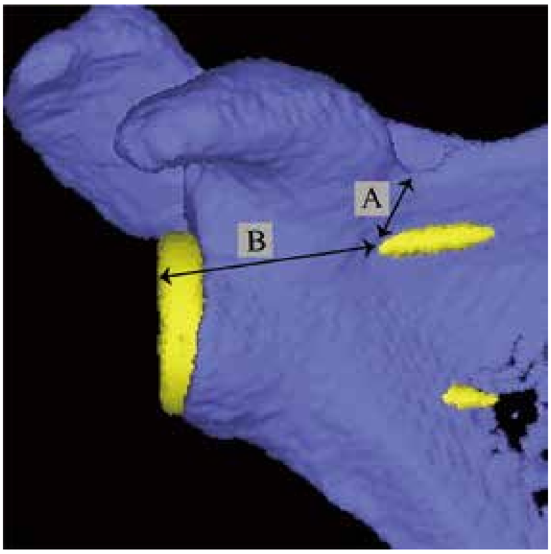

Figure 3. (A) Distance from the suprascapular notch to the superior screw hole and (B) the screw length were measured as shown.

STATISTICAL ANALYSIS

Superior screw hole position was compared among the 6 simulations using the χ^2 test, with a residual analysis as the post hoc test. The distance to the SS notch and the superior and inferior screw lengths were compared by analyses of variance, with the Bonferroni correction for the post hoc comparisons. Date analysis was performed using SPSS version 28 (IBM Corp., Armonk, NY, USA). P <.05 was considered statistically significant.

RESULTS

In term of scapular morphology, the mean glenoid height and width were 33.3 mm (range, 26-40), 25.6 mm (range, 19-30), respectively. The mean scapular height and width were 135 mm (range, 102-149), 122mm (range, 99-138), respectively. Among the 6 simulations, Simulation 2 (11–5 o'clock/inferior tilt 10 degrees) had the fewest shoulders (n = 3) with the superior screw tip located anterior to the SS notch (Table 1). In all simulations, with the exception of Simulation 2 (11–5 o'clock/inferior tilt 10 degrees), there were more shoulders with the superior screw tip located anterior to the SS notch than shoulders with the superior screw tip located posterior to the SS notch. Especially, for Simulation 5 (1–7 o'clock/inferior tilt 0 degrees), the superior screw was located anterior to the SS notch for all shoulders ; however, the difference in frequency failed to reach statistical significance (p = 0.056).

The overall mean distance of the SS notch to the superior screw hole was 9.4 mm, and the overall mean superior and inferior screw lengths were 25.2 mm and 28.7 mm, respectively (Table 2). Among the 6 simulations, the mean distance from the SS notch to the superior screw hole in Simulation 5 (1–7 o'clock/inferior tilt 0 degrees) was significantly longer than that in Simulation 4 (1–7 o'clock/inferior tilt 0 degrees). The mean superior screw length did not significantly differ among the 6 simulations. However, Simulation 5 had the mean shortest inferior screw length (23.1 mm), and significant differences were observed in all comparisons to Simulation 5, with the exception of Simulation 6 (Simulation 5 vs Simulations 1, 2, 3, 4). In Simulation 6, the inferior screw length was significantly shorter than those in Simulations 1 and 2.

DISCUSSION

According to only one case report of SS neuropathy after RSA (11), persistent pain and discomfort over the trapezius resulted from 2 cm of the superior screw protruding into the SS notch. Consequently, SS nerve decompression was required. Molony *et al*. also described the risk of SS nerve injury by superior screw placement in a cadaveric study (9). The SS nerve arises from the superior trunk of the brachial plexus and runs distally to the superior scapular notch and inferior to the transverse scapular ligament. It then runs through the spinoglenoid notch to the infraspinous fossa to provide motor innervation to the infraspinatus (16). In addition, the articular branch separates from the nerve trunk superior to the SS notch. After passing through the notch, it runs superolaterally around the base of the coracoid process to the posterior shoulder capsule (17). The distances tips closer to SS notch may lead to SS nerve complication, regardless of whether the screw penetrates anteriorly or posteriorly. But we have to consider the occurrence of SS nerve injury whenever the superior screw is located posterior to the SS notch during

Table 1. Comparisons in the location of superior screw tips among 6 simulations

Simulation	Anterior		Posterior	
	Count	ASR (p-value)	Count	ASR (p-value)
1. R ; 11–5/IT ; 0	7	-0.55 (0.59)	3	0.55 (0.59)
2. R ; 11–5/IT ; 10	3	-3.82 (<0.01)	7	3.82 (<0.01)
3. R ; 12–6/IT ; 0	9	1.09 (0.28)	1	-1.09 (0.28)
4. R ; 12–6/IT ; 10	8	0.27 (0.79)	2	-0.27 (0.79)
5. R ; 1–7/IT ; 0	10	1.91 (0.06)	0	-1.91 (0.06)
6. R ; 1-7/IT ; 10	9	1.09 (0.28)	1	-1.09 (0.28)

Simulations are indicated according to baseplate position as follows : Number ; simulation type, R : baseplate rotation, IT : inferior tilt. For example, a baseplate rotated to 11–5 o'clock with an inferior tilt of 0 degrees (Simulation 1) is indicated as R ; 11–5/IT ; 0.
Anterior and Posterior are indicate as scapulas with superior screw tip penatelated to anterior or posterior cortex, respectively.
ASR : Adjusted standardized residual

Table 2. Comparisons in the distance from screw hole to the SS notch and screw lengths among 6 simulations

1. Distance from screw hole to SS notch (mm)

	Mean	St.d	P	Difference among 6 baseplate patterns
1. R ; 11–5/IT ; 0	10.2	1.6		
2. R ; 11–5/IT ; 10	8.7	1.5		
3. R ; 12–6/IT ; 0	7.7	1.8		
4. R ; 12–6/IT ; 10	5.8	1.9	0.01[a]	simulation 4 vs 5
5. R ; 1–7/IT ; 0	12.8	1.6	0.01[a]	simulation 5 vs 4
6. R ; 1-7/IT ; 10	11.3	2.3		
total	9.4	1.8	0.01[b]	

2. Superior screw length (mm)

	Mean	St.d	P	Difference among 6 patterns
1. R ; 11–5/IT ; 0	28.8	1.6		
2. R ; 11–5/IT ; 10	24.5	1.5		
3. R ; 12–6/IT ; 0	25.8	1.8		
4. R ; 12–6/IT ; 10	27.7	1.9		
5. R ; 1–7/IT ; 0	22.0	1.6		
6. R ; 1-7/IT ; 10	22.5	2.3		
total	25.2	1.8	0.07[b]	

3. Inferior screw length (mm)

	Mean	St.d	P	Difference among 6 baseplate patterns
1. R ; 11–5/IT ; 0	32.8	1.6	0.00[a]	Simulation 1 vs 5, 6
2. R ; 11–5/IT ; 10	30.6	1.5	0.00[a]	Simulation 2 vs 5, 6
3. R ; 12–6/IT ; 0	29.8	1.8	0.00[a]	Simulation 3 vs 5
4. R ; 12–6/IT ; 10	30.6	1.9	0.00[a]	Simulation 4 vs 5
5. R ; 1–7/IT ; 0	23.1	1.6	0.00[c]	Simulation 5 vs 1, 2, 3, 4
6. R ; 1-7/IT ; 10	25.1	2.3	0.00[d]	Simulation 6 vs 1, 2
total	28.7	1.8	0.00[b]	

Simulations are indicated according to baseplate position as follows : Number ; simulation type, R : baseplate rotation, IT : inferior tilt. For example, a baseplate rotated to 11–5 o'clock with an inferior tilt of 0 degrees (Simulation 1) is indicated as R ; 11–5/IT ; 0.
a : P-value obtained by Bonferroni-corrected post hoc test
b : P-value obtained by one-way repeated measures analysis of variance
c : All p-values obtained by Bonferroni-corrected post hoc tests between Simulation 5 and Simulations 1, 2, 3, and 4 were below 0.01.
d : All p-values obtained by Bonferroni-corrected post hoc tests between Simulation 6 and Simulations 1 and 2 were below 0.01.
St.d : standard deviation

drilling or insertion of it.

To our knowledge, only one report has investigated the impact of different rotational baseplate positions on the screw position or length in the cadaveric glenoid. According to Parsons *et al*., when the baseplate was positioned such that the superior hole was rotated 20 degrees posteriorly, the superior screw exited near the spinoglenoid notch in 5 of 6 specimens, which potentially placed the SS nerve at risk (18). We are also concerned about this risk when placing the baseplate with a posterior rotation, as our data showed that superior screws angled at 10 degrees superiorly were located posterior to the SS notch in 7 of 10 shoulders. For baseplates in the 12–6 o'clock or 1–7 o'clock position, the superior screw was located anterior to the SS notch in a large number of shoulders, regardless of superior or inferior screw angulation. To prevent SS nerve injury, Hart *et al*. proposed drawing the vertical axis crossing the supraglenoid and infraglenoid tubercles to distinguish between safe and danger zones in RSA, as performed previously for acetabulum in total hip arthroplasty (10). The present findings indicate that the baseplate should be rotated at least anterior to the 12–6 o'clock position.

Among the 6 simulations, only Simulation 5 had all superior screws located anterior to the SS notch. In addition, Simulation 5 had the longest distance from the superior screw hole to the SS notch. Accordingly, Simulation 5 might carry a low risk of SS nerve injury in baseplate fixation. Furthermore, Hart *et al*. showed that the tips of all superior screws were located in the bone or subscapularis muscle belly when the baseplate was set at 1–7 o'clock in the right shoulder with 15 degrees of inferior tilt

(10), which is similar to Simulation 6 in the present study. Thus, the baseplate placement in Simulation 6 could also be relatively safe in terms of preventing nerve injury. However, there are concerns that changing the superior and inferior screw positions might change the respective screw lengths. Our results suggest that the baseplate position does not affect the superior screw length. However, the inferior screw length was likely to be shorter when the baseplate was rotated anteriorly to the 1–7 o'clock position, such as in Simulations 5 and 6. The reason for this is that the direction of the inferior screw changed posteriorly and the insertion point of the inferior screw was close to the posterior far cortex. In order to obtain screw purchase, therefore, a multidirectional screw oriented anteriorly might be preferable over a fixed locking screw in term of the inferior screw.

Our study has several limitations. First, the study comprised a computer simulation ; thus, it is unclear whether the same results would be obtained in a cadaver study or clinical examination. Second, the distance from the SS notch to the screw hole and the screw length were measured on two-dimensional simulation images. Although we believe that this was not a problem because a measurement comparison was performed in this study, some measurement errors were included when compared with 3D measurements. Third, only fixed-angle screws were used for the superior and inferior screws. Although the optimal trajectory and screw length have been investigated in terms of variable-angle screws in previous studies, it was difficult to do so in a computer simulation. Humphrey *et al*. proposed the use of variable-angle screws for inferior screws in particular because inferior fixed screws may not achieve good screw purchase if the scapular pillar is missed (12). Moreover, our study also showed that the inferior screw length (mean 16 mm) was shorter than the superior screw length. Therefore, we speculate that the optimal inferior screw trajectory should be directed anteriorly to achieve long screw length or good purchase. Fourth, the length and direction of anterior and posterior screws for baseplate fixation was not investigated in this study. In particular, the potential risk of superior scapular nerve complication due to insertion of posterior screw was already revealed by several cadaveric studies (9, 19). However, it is not likely to be always used for all cases in clinical situation. According to Jah *et al*., small glenoid was too large to fix anterior and posterior screws in Japanese patients (20). Some biomechanical studies demonstrated that there was no significant difference between baseplate fixation 2 screws and 4 screws in term of baseplate fixation (21, 22). Although we therefore prioritized superior screw over posterior screw in this study, further consideration about posterior screw will be necessary in the future.

CONCLUSION

Among the 6 simulations of various baseplate positions, the risk of SS nerve injury during superior screw insertion was the lowest for the baseplate positioned with rotation to 1–7 o'clock and 0 degrees of inferior tilt, and was the highest for the baseplate positioned with rotation to 11–5 o'clock and 10 degrees of inferior tilt.

CONFLICTS OF INTEREST

We don't have any financial supports to disclose.
None of the authors have any conflicts of interest associated with this study.

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