

The Study of Screw Placement Parameters for Ogawa Type I Acromial Fractures by 3D Technology

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Abstract

Background: Acromial fractures are rare and there is no consensus on fixation, but more and more studies have reported using two screws to fix Ogawa type I acromial fractures. The objective of this study was to obtain the ideal length, diameter, insertion point and angle of the screw using a novel 3D technology.

Methods: Scapula CT data of 100 human subjects were obtained to reconstruct 3D models. The transparency of 3D models was then downgraded along the axial perspective (the view perpendicular to the cross section of the acromial axial) to find the maximum translucent area. Two virtual screws were placed from the anterior edge of the acromial until they penetrated the posterior cortical bone. The largest diameters and lengths of the screw were measured, and the direction and insertion point of the screw were observed.

Results: The mean maximum lengths of medial and lateral screws were 43.33 ± 6.17 mm and 39.23 ± 6.01 mm, respectively. The mean maximum diameters of medial and lateral screws were 4.71 ± 1.23 mm and 4.97 ± 1.07 mm, respectively. The study found differences in screw length, diameter and insertion point between males and females. The differences sexes in screw angle were not statistical significance.

Conclusions: Using the 3D model, we demonstrated that the distal acromial can be safely placed with two screws and provide valuable guidance for screw fixation of Ogawa type I acromial fractures.

Introduction

Acromion fractures are rare injuries, accounting for about 8%-16% of scapula fractures[1, 2].The injury mechanism of fracture is mainly caused by direct shoulder violence, indirect humeral head impingement or complications following reverse total shoulder arthroplasty. Due to the weight of the upper limb and the pull of the deltoid muscle, the acromial bone block will shift, which leading to the narrowing of the subacromial space and rotator cuff tearst, resulting in shoulder pain and limited movement.

In 1997, Ogawa proposed a practical classification based on the location of acromial fracture line and anatomical structure[13]. He classified acromion fractures as follows: Type I fractures consist of those of anatomic acromion and extremely lateral scapular spine. Type II fractures comprise those located in more medial spine and descending to spinoglenoidal notch. This classification is recognized and used to guide treatment.

Unfortunately, there is no consensus on the treatment and fixation method of acromial fractures. The usual fixation methods include Kirschner wires, tension band and anatomical locking plates[3, 9, 13].However, in the type I fracture ,conventional plate fixation is not recommended because of the very thin and small nature of the osseous anatomy. Fixation with Kirschner wire cannot pressurize the fracture end and is prone to early fixation failure [4, 12]

At present, in the treatment of distal acromial fractures, two cannulated screws instead of Kirschner wire fixation is considered to be an effective method which had high postoperative fracture healing rate and no complications[5–8].Peckett et al. reported that 17 patients with symptomatic acromial fractures were fixed with two 3.5mm screws and the postoperative healing rate was 94%[6]. Garnon et al. demonstrated the good technical feasibility of percutaneous image-guided screw fixation for the treatment of pathological distal acromial fractures[8]. In previous studies, only the diameter of the screw was reported, and the difference was large. The length, the insertion point and the ideal angle for the two screws were not given any guidance.

3D simulation technology has been widely used in the field of orthopedic surgery to help surgeons understand anatomical structures (nerves, vessels) and anatomical parameters (length, angles, anatomical axis)[22, 23]. At present, there have been many reports on the use of this technique to guide screw fixation of different parts of fracture. However, there is no report of using 3D simulation technique to guide screw fixation of acromial fracture. The objective of this study was to obtain the implantation point, the optimal axial angle, diameters and lengths of the two screws by using a 3D simulation.

Materials And Methods

One hundred chinese subjects without fractures and lesions of right scapula were collected between January 2019 and November 2020 in this study. There were 50 male and 50 female. The mean age of the patients was 54.21 ± 15.42 (range 20–85). All patients received 64-slice spiral CT continuous slice scan in our hospital and obtained the original data in DICOM format. All the original data were imported into the Mimics software one by one. The 3D models of the scapula was obtained through image segmentation and region growth operations of the software.

To determine the effective screw passage, we reduced the transparency of the 3D models and rotated the 3D models to an axial view, which was parallel to the cross section of the distal acromion. Then, The outline of a translucent area resembling an oval shape is clearly shown(Fig. 1A). We observed and adjusted the position of the model to maximize the translucency area and divided it evenly into two parts. Two computer-aided design screws were placed perpendicular to the translucent zone and gradually increased in diameter, defined as the maximum diameter when the screws did not penetrate the boundary of the zone(Fig. 1B).The screw length was then adjusted until it had just penetrated the posterior bone cortex and the value was recorded(Fig. 2A-C). The anatomical markers of the acromioclavicular articular surface and the distal anterior edge of the acromium are easily accessible and recognized. To determine screw location, the distance from the insertion point to the acromioclavicular articular surface and the distal anterior edge of the acromium was marked. The L1 and L2 distances for the medial screw(MS)and the L3 and L4 distances for the lateral screw(LS)were recorded(Fig. 3A and B) The upper plane of the distal acromion is selected as the reference plane, which is called plane A. The down dip angle between the screw and plane A was measured and recorded as angle α (Fig. 4A). A plane perpendicular to plane A is defined as plane B. The inclination angle between the screw and plane B was measured and recorded as angle β (Fig. 4B).

The experimental data were analysed by SPSS 25.0 statistical software. All continuous variables were presented as the mean and standard deviation. The t test was used to compare the data between between males and females. Statistical significance was accepted at $P < 0.05$.

Results

The reconstructed scapula model shows the safety zone of the acromial screw as shown in Fig. 1

The mean maximum lengths of medial and lateral screws were 43.33 ± 6.17 mm and 39.23 ± 6.01 mm, respectively. The mean maximum diameters of medial and lateral screws were 4.71 ± 1.23 mm and 4.97 ± 1.07 mm, respectively. The mean distance L1 was 7.25 ± 1.71 mm, L2 was 6.38 ± 1.82 mm, L3 was 17.04 ± 2.27 mm and L4 was 5.89 ± 1.63 mm. In the above data, the differences between males and females were of statistical significance ($P < 0.05$).

The mean α and β angles for males and females are recorded in Table 3. The mean α angles and β angles are $13.98 \pm 5.03^\circ$ and $6.53 \pm 5.10^\circ$, respectively. The differences sexes were not statistical significance ($P > 0.05$).

Discussion

The acromion is an important part of the superior shoulder suspensory complex. Acromion fracture is considered as a special type of intra-articular fracture. If it is not properly treated, it will inevitably affect the functional of the shoulder joint. The complication associated with nonoperative treatment of displaced acromial fractures have been reported, including painful stiff shoulder, activity limitation, symptomatic nonunion, acromioclavicular joint separation and subacromial impingement[14–22]. Therefore, early surgical intervention is considered reasonable.

In retrospect, acromial fractures are rarely reported and there were no consistent treatment plan. Owage[13] recommends that patients with type I acromial fractures be treated with Kirschner wire or tension band fixation. However, there are reports of Kirschner wires loosening, fracture redisplacement, and needle tract infection after using this fixation method[4,11,12]. We also do not recommend for the use of Kirschner wires because they does not provide adequate compression at the fracture site.

The screw fixation has been gradually recognized for its ability to provide adequate fracture compression and offer satisfactory fracture stability[5–8, 12, 20]. Peckett et al [6]recommended the use of double tension screws instead of Kirschner wires in 26 patients with acromial fractures. Kim et al[5]reported that 27 patients were fixed with two cannulated screws without postoperative complications such as screw displacement or local infection. Unfortunately, recommendations on the maximum diameters and lengths and the optimal entry points and appropriate angles of two screws for distal acromial fractures have not been reported.

The application of 3D computer models in the field of orthopedics is mature and reliable[24]. We use this method to conduct big data research and collect relevant data to provide help for surgeons. In order to avoid the aggravation of fracture and screw loosening caused by repeated adjustment of screw direction and replacement of screws in the operation.

In the past, screws of different diameters have been used to treat acromial fractures, including 3.0mm, 3.5mm, 4.0mm, and even 5.0mm[5–8]. According to the information in our study, the maximum diameters were 5.69 ± 0.81 mm(MS) and 5.81 ± 0.76 mm(LS) in males and 3.73 ± 0.67 mm(MS) and 4.13 ± 0.56 mm (LS) in females. This is consistent with previously reported screw sizes. we recommend the use of at least 3.5mm screws in females and at least 5.0mm screws in males. We also recorded the length of the two screws. The length of screws were 50.79 ± 4.33 mm(MS)and 43.26 ± 4.64 mm(LS) in males and 41.87 ± 4.19 mm(MS) and 35.20 ± 4.28 mm (LS) in females. Due to individual and gender differences, we recommend preoperative evaluation and measurement on imaging data.

Acromion shape varies from person to person. Bigliani et al. divided into three types according to the acromion morphology, in which the proportion of curved and hooked acromion was 81.6% [10]. This not only increases the difficulty of screw implantation, but also increases the chance of screw penetration into the subacromial space. Therefore, the insertion point and direction are two important indexes that affect the safe placement of the screw. In our study, we found that the distance from the entry point to the acromioclavicular articular surface and the distal anterior edge of the acromial acromium was greater in males. This can be caused by a large shoulder blade in males. We recommend maximizing the inclination angle of the screw, because the screw pointing to the base of the scapular spine provides stronger fixation.

We studied acromion models of 100 human subjects, a large enough sample size. As the axial perspective is quite similar to the X-ray projection, the two screw parameters we obtained can provide valuable guidance to the surgeons. As the standard deviation of our results are relatively large, indicating that there are great differences between individuals, it is necessary to make preoperative planning for each patient.

There are some limitations about our research. First, we only studied the acromion of Chinese people, and these data may not be applicable to people from other countries. Second, software tools are not a substitute for experimental testing, and further cadaver or clinical studies are needed to verify the accuracy of the technique.

Conclusion

Using the 3D model, we demonstrated that the distal acromial can be safely placed with two screws and provide valuable guidance for screw fixation of Ogawa type I acromial fractures. By careful preoperative planning, screw placement can be done safely within the safe zone defined by our method. At the same time, it provides a kind of safety guarantee for the operation patients.

Abbreviations

3D: Three-dimensional; CT: Computed tomography; DICOM: Digital Imaging and Communication in Medicine; Mimics: Materialise's Interactive Medical Image Control System; SPSS: Statistical Package for the Social Sciences; MS: The medial screw; LS: The lateral screw

Declarations

Acknowledgements

Not applicable.

Authors' contributions

WZ and ZYS performed the study, analysed the data and drafted the manuscript. WYL, JY, LRH and SZH contributed to discussion of data, writing and editing of the article. XFY and BZ contributed to conception and study design and editing of the article. All authors read and approved the final manuscript. All authors have read the journal policies and have no issues relating to journal policies. All authors have seen the manuscript and approved to submit to your journal. The work described has not been submitted elsewhere for publication, in whole or in part.

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Availability of data and materials

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

Ethics approval and consent to participate

This study has obtained ethics approval and consent of the ethics committee in our hospital.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no conflict of interest.

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Tables

Table 1
Differences in medial screw between males and females

Group	Length (mm)	Diameter (mm)	L1 (mm)	L2 (mm)
All	43.33 ± 6.17	4.71 ± 1.23	7.25 ± 1.71	6.38 ± 1.82
Male	50.79 ± 4.33	5.69 ± 0.81	7.33 ± 1.69	6.88 ± 1.89
Female	41.87 ± 4.19	3.73 ± 0.67	6.17 ± 1.73	5.87 ± 1.59
t	10.478	13.165	0.494	2.875
P	0.000	0.000	0.000	0.005
the differences between males and females were of statistical significance (P < 0.05).				

Table 2

Differences in lateral screw between males and females

Group	Length (mm)	Diameter (mm)	L3 (mm)	L4 (mm)
All	39.23±6.01	4.97±1.07	17.04±2.27	5.89±1.63
Male	43.26±4.64	5.81±0.76	17.79±2.26	6.48±1.72
Female	35.20±4.28	4.13±0.56	16.29±2.03	5.29±1.28
t	9.033	12.478	3.497	3.930
P	0.000	0.000	0.001	0.000
the differences between males and females were of statistical significance (P < 0.05).				

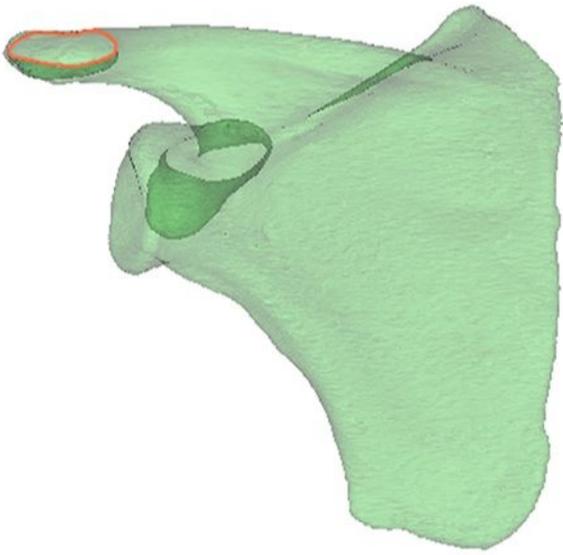
Table 3

Differences between males and females: angle α and β

Group	α (°)	β (°)
All	13.98 ± 5.03	6.53 ± 5.10
Male	13.53 ± 4.93	7.07 ± 4.88
Female	14.03 ± 5.14	6.99 ± 5.31
t	-0.941	1.061
P	0.375	0.291
The differences sexes were not statistical significance (P > 0.05).		

Figures

A



B

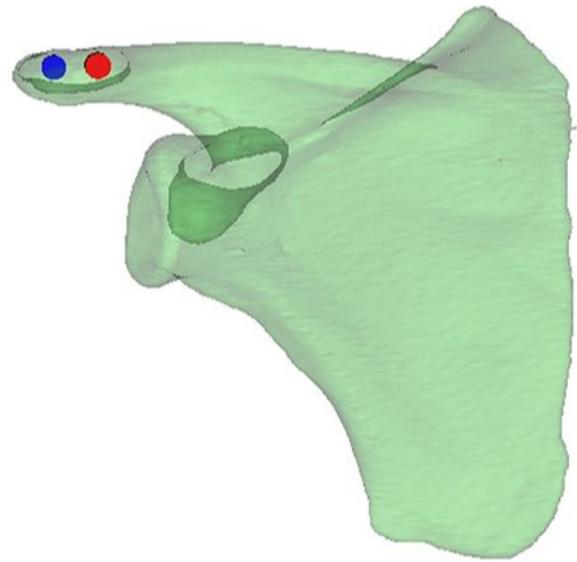


Figure 1

Find the largest screw path. A: The largest translucent area resembles an oval shape. B: Two computer-aided design screws were placed evenly in the translucent area. Then, the diameters were increased progressively until they reached the borderline of the area.

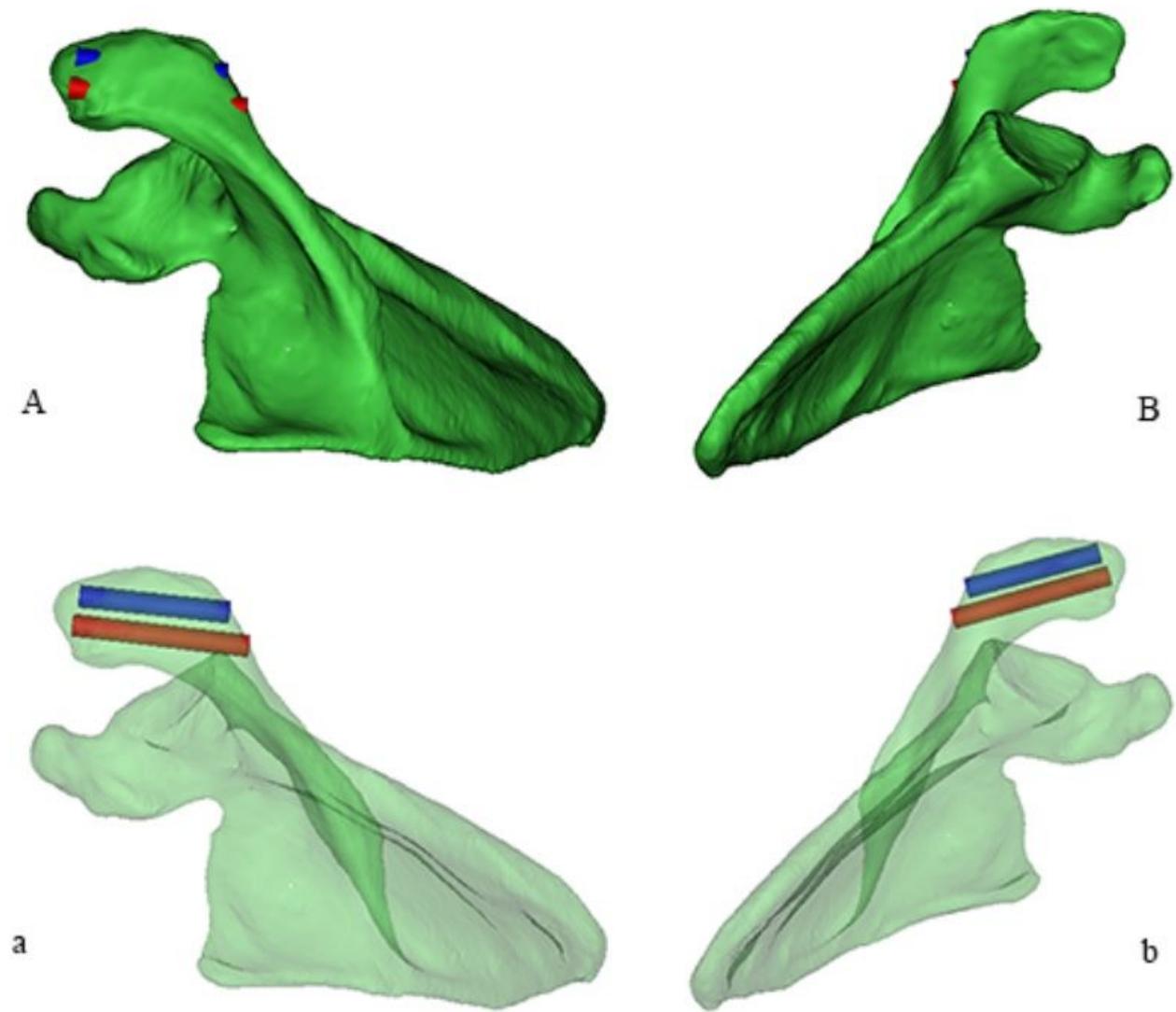


Figure 2

Observe the largest length and position of the screws A, B: Observed from the above and below of the opaque 3D model, respectively. The screws had the largest lengths and diameters just penetrating the cortical bone. a, b: The screws position were observed from the above and below of the translucent 3D model.

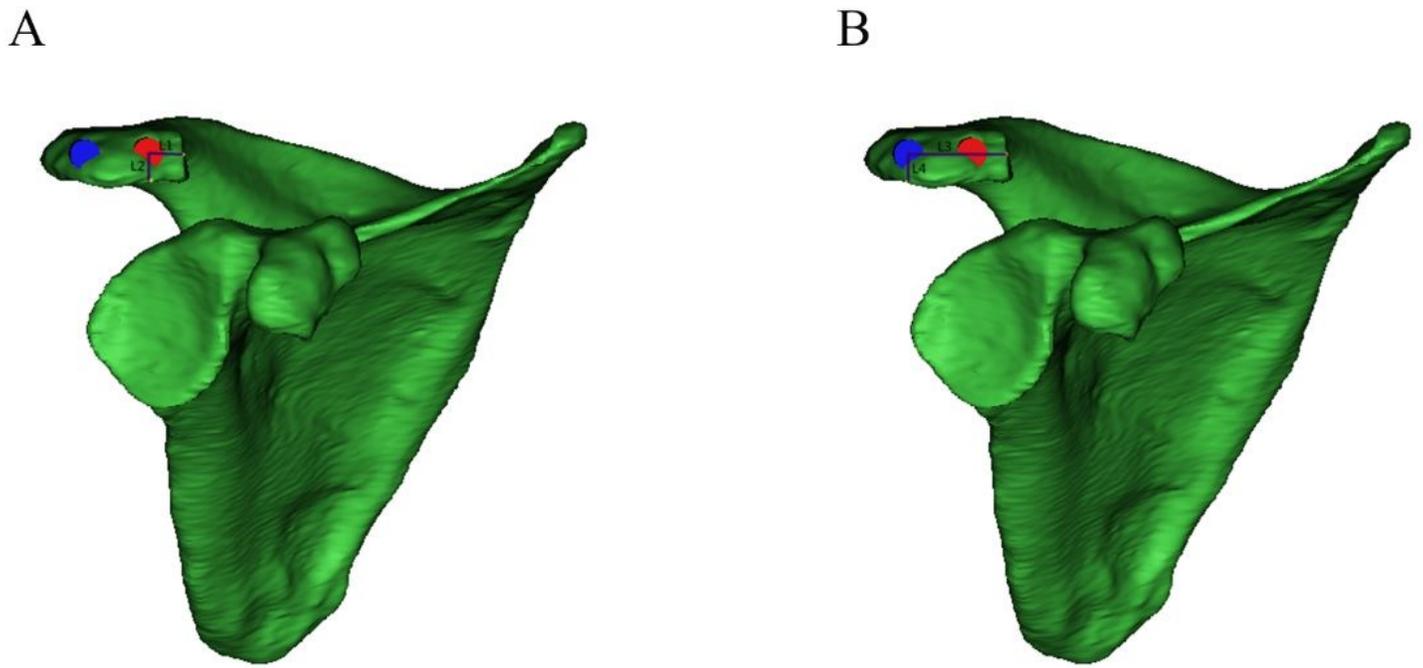


Figure 3

The measurement of Distance L1, L2, L3 and L4. A: The distances from the medial screw entry point to the acromioclavicular articular surface and the leading edge of the acromial were marked as L1 and L2, respectively. B: The distances from the lateral screw entry point to the acromioclavicular articular surface and the leading edge of the acromial were marked as L3 and L4, respectively

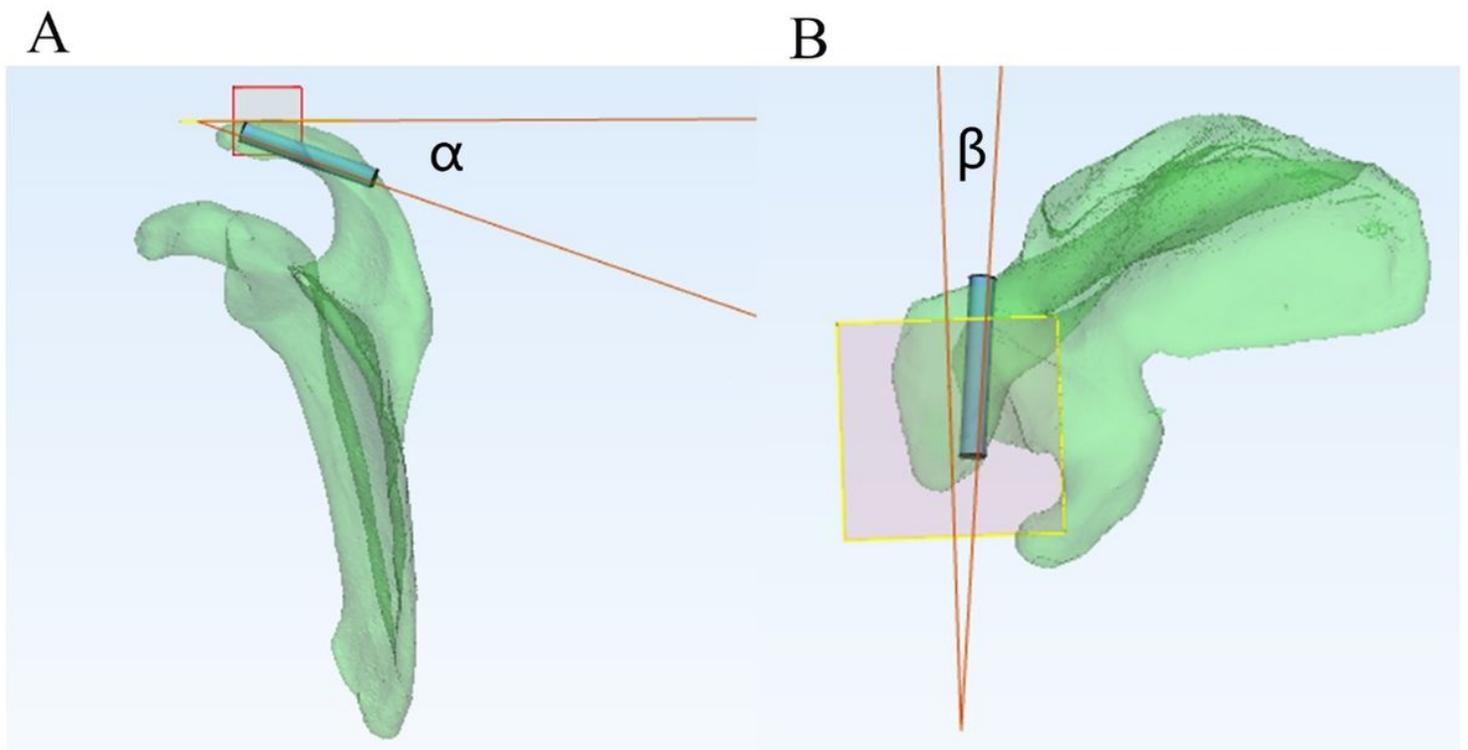


Figure 4

The measurement of angle α and β . A: The downdip angle between the screw and plane A was measured and recorded as angle α . B: The inclination angle between the screw and plane B was measured and recorded as angle β .