The largest secure corridor of the infra-acetabular screw — a 3-D axial perspective analysis

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Abstract

Background The infra-acetabular screw is placed from the pubis to the ischium and can be used as a special lag screw of the posterior column of the acetabulum. This study was performed to simulate the surgical procedure and try to obtain the ideal insertion point, diameter, length and angle of the screw through the method of axial perspective in Chinese patients.

Methods We randomly collected the pelvic computed tomography (CT) scans of 100 adults. DICOM-formatted CT-scan images were imported into Mimics software. The 3D digital model of the right semi-pelvic was established. A virtual cylinder representing the screw was placed from the pubis to the ischium to fix the posterior column. The largest secure diameter and length of the virtual screw were measured. The position of the insertion point and the directions of the screw were also researched.

Results The screw insertion safe zone can exhibit an irregular “tear drop” from the reconstructed pelvic model. The mean maximum diameter of screws was 4.03 ± 0.93 mm, and the mean maximum length of screws was 96.05 ± 7.19 mm. The screw insertion corridor with a diameter of at least 3.5 mm was found in 48 of 50 males (96%). We found gender-dependent differences for the mean maximum diameter and the maximum length of the screw. The position between insertion point and eminelntia iliopectinea was statistically significant in different genders.

Conclusions The study provides a valuable guideline for the largest secure corridor of infra-acetabular screw. We suggest an individual preoperative 3D reconstruction simulation for the ideal screw placement. Further biomechanical studies are needed to verify the function of the screw.

Background

The treatment of complex acetabular fractures complicated with quadrilateral displacement has been widely studied in recent years [1–6]. The goal of acetabular surgery is achieving perfect reduction and rigid fixation, allowing early joint movement and avoiding postoperative complications [1, 5, 7].

Early, Letournel and Judet have shown the screw path parallel to the quadrilateral wall [8]. The screw was used to fix the quadrilateral fracture and prevent the medial subluxation. The placement of this additional screw can also increase the fixation strength of plate for acetabular fractures [4, 5]. On this basis, Culemann et al described the infra-acetabular screw [1]. They showed the operative technique and indication of the screw. However, the placement of the infra-acetabular screw is technically demanding due to the unique and complex anatomy of the osseous area. A knowledge of the correct location of the insertion point and screw direction is essential to avoid penetrating into joint and injury to neurovascular structures [9].

At present, there are many studies on the application of CT data into various software for the fixation of periacetabular screws [7, 9, 10–13]. In previous studies, the method of axial perspective can help to find a larger anterior and posterior column screw path[10, 11]. The purpose of the study is to specify the ideal insertion point, the largest secure diameter and length, and the accurate angle of the infra-acetabular screw through the method of axial perspective.

Materials And Methods

We retrospectively collected the pelvic CT scans of 100 adults who had undergone continuous slice CT scanning at the imaging research center of our hospital between August 2016 and June 2019. Patients were excluded if they had pelvic or acetabular fractures, tumors, severe deformities, or severe hip inflammation. This study was approved by the Institutional Review Board of our hospital, and patients' informed consent was obtained. The mean age of the patients on whom the models were based was 43.16 ± 14.69 years (range 18–86 years).

DICOM-formatted CT-scan images of each patient were imported into Mimics software (20.0; Materialise, Leuven, Belgium). We removed the soft tissue, femoral head and sacroiliac joint by the function of image segmentation, region growth and multiple slice editing, respectively. A total of 100 right virtual semi-pelvic models were created.

We reduced the transparency of the semi-pelvic models and turned it to the axial perspective view, which was parallel to the posterior of obturator formamen from top to bottom (Fig. 1A). We observed and adjusted the position of the model to find the largest translucent area through the perspective view. Then, a translucent area like a tear drop was seen clearly (Fig. 1B). The area represented the infra-acetabular screw path and the outline represented the medial cortical bone. A virtual cylinder representing the screw was placed into the translucent area. The diameter was increased progressively and the maximum diameter was defined when the cylinder did not penetrate the border of the area (Fig. 1C). We observed and adjusted the length of the screw to make sure that the screw did not penetrate the cortical bone (Fig. 2A-D). The diameter and length of the virtual screw were measured. In order to confirm the position of screw, the distance from the insertion point to the eminelntia iliopectinea was measured. It was recorded as Distance S. The angle between the distance S and the line (the vertical line from the eminelntia iliopectinea to the arcuate line) was also measured and recorded as angle α (Fig. 3). According to the position of the two ends of the screw, the angle β (between the screw and sagittal plane) and the angle γ (between the screw and coronal plane) were calculated by the geometric formula.

The collected data were analyzed by SPSS 19.0 statistical software. The experimental data are represented as the mean ± SD. T tests were used to compare the data. Statistical significance was accepted at $p < 0.05$.

Results

The study subjects included 50 males and 50 females aged between 18 and 86 years old, with a mean age of 43.16 ± 14.69 years. As shown in Fig. 1-B, the screw insertion safe zone can exhibit an irregular "tear drop" from the reconstructed pelvic model.

As shown in Tables 1 and 2, the mean maximum diameter of screws was 4.03 ± 0.93 mm and the mean maximum length of screws was 96.05 ± 7.19 mm. The mean angle α was 21.73°±4.85° in males and 37.05°±7.51° in females. For the data captured above, the intersex difference was significant ($P < 0.05$). The distance between insertion point and eminelntia iliopectinea, and the angles β and γ of different genders were also recorded in Tables 1 and 2. However, the results were not statistically significant between males and females ($P > 0.05$).

Table 1
Comparison between different genders: Diameters of screws, Lengths of screws and Distance S.

Group	Diameter# (mm)	Length# (mm)	Distance S(mm)
All(n = 100)	4.03 ± 0.93	96.05 ± 7.19	12.84 ± 1.99
Male(n = 50)	4.59 ± 0.94	101.58 ± 3.55	13.16 ± 1.64
Female(n = 50)	3.94 ± 0.73	90.52 ± 5.43	12.52 ± 2.25
t value*	3.892	12.054	1.647
P value*	0.00	0.00	0.103

Note:* t and P are the results of gender comparisons. #For the Diameter and Length, intersex difference was significant ($P < 0.05$).

Table 2
Comparison between different genders: Degrees α, β and γ.

Group	α# (°)	β(°)	γ(°)
All(n = 100)	29.39°±9.94°	5.48°±1.11°	52.35°±5.71°
male(n = 50)	21.73°±4.85°	5.65°±1.12°	53.20°±5.33°
female(n = 50)	37.05°±7.51°	5.32°±1.08°	51.49°±5.99°
t value*	-12.122	1.487	1.511
P value*	0.00	0.14	0.134

Note:* t and P are the results of gender comparisons. #For the Degrees α, intersex difference was significant ($P < 0.05$).

The screw insertion corridor with a diameter of at least 3.5 mm was found in 48 of 50 males (96%) and 38 of 50 females (76%). However, the corridor with a diameter of at least 4.5 mm was found in 21 of 50 males (42%) and 12 of 50 females (24%) from the Fig. 4.

Discussion

In recent years, the treatment trend of acetabular fractures is toward less invasive single ilioinguinal approach, especially in elderly patients [14–18]. Due to the complex characteristic of pelvic anatomy, the safe region of screw placement is far away from the acetabulum, which will reduce the peri-acetabular stability [7]. The common fixation methods for acetabular fractures are lag screw fixation and plate osteosynthesis [10]. During the past research, lag screw fixation has achieved good outcomes [19.20]. The infra-acetabular screw can be applied via a single ilioinguinal approach to treat acetabular fractures involving a fracture line descending along the acetabular fossa and reaching the obturator formamen [1]. At present, there is no literature regards this screw as a lag screw for the posterior column, and there are few digital anatomical studies on its properties.

Mimics software has been widely used in 3D reconstruction for the development of digital orthopedics technology. In our study, we applied the 3D method of axial perspective as described in previous studies [10, 11, 21]. We found the largest secure screw path along the longitudinal axis of the anterior part of posterior column after reducing the transparency of the 3D model. Compared with previous studies of computer-assisted determination or virtual three-dimensional model [12, 22], the method of axial perspective shows another osseous channel for lag screw of posterior column. We increased the diameter of virtual cylinder progressively and monitored the virtual screw in the views of coronal plane, sagittal plane and horizontal plane, without violating the cortices and articular surface. Compared with previous human cadaveric studies [23, 24], the method used in our study not only saves manpower, materials and financial resources, but also can be repeated and verified by test results with high reliability.

In our research, the diameter and length of the infra-acetabular screw were significantly larger in males compared with females. This is due to the obvious anatomic differences in pelvic bones between female and male. In addition, the angle between screw and sagittal plane, the angle between screw and coronal plane, and the angle between the insertion point and the reference line (the vertical line from the emineIntia iliopectinea to the arcuate line) in females and males were observed in this study. This study showed that the angle of the screw and different planes between male and female had no statistical inference. Nevertheless, the angle α was significantly different in genders. This means that the position between the insertion point and the emineIntia iliopectinea is different between male and female. The reason for this may be that the obturator foramen was larger in males and the distance from the emineIntia iliopectinea to the posterior border of the obturator foramen is shorter.

Gras et al found that 93% pelves contained an infra-acetabular corridor with a diameter of at least 5 mm [13]. They also provided reference values for placement of a 3.5-mm cortical screw in the corridor. However, in our study, we found that the containable diameter of the screw was smaller in Chinese patients, especially in female. According to the information in our study, the maximum diameter to avoid cortical breaches is 4.59 ± 0.94 mm in male and 3.94 ± 0.73 mm in female. The screw insertion corridor with a diameter of at least 3.5 mm was found in 48 of 50 males (96%) and 38 of 50 females (76%). Only 21 males (42%) and 12 females (24%) possessed a corridor with diameter of at least 4.5 mm as shown in Fig. 4. If a lag screw is to be used, a 3.5-mm cortical screw is the first choice and a 4.5 mm-hollow screw may be considered in males. Nevertheless, due to individual and sex differences, the use of preoperative measurements and calculations by digital tools is recommended.

On the basis of mastering the diameter and length of screw, the insertion point and direction are two important factors affecting the safe placement of infra-acetabular screw. Unlike the common posterior column screw, the infra-acetabular screw needs to be placed through the middle window of ilioinguinal approach. Culemann et al reported that the entry point for the infra-acetabular screw is 1 cm caudal of the emineIntia iliopectinea and in the middle of the pubic ramus [1]. Baumann et al found that the ideal entry point for the infra-acetabular screw is 10.2 mm caudal and 10.4 mm medial of the emineIntia iliopectinea [7]. Gras et al found that the optimized entry points of infra-acetabular screws are located in the mediocaudal region of the emineIntia iliopectinea [13]. Different from previous studies, we found that the optimized insertion point is 13.16 ± 1.64 mm away from the emineIntia iliopectinea in males and 12.52 ± 2.25 mm in females. Meanwhile, the direction of the insertion point relative to the emineIntia iliopectinea and the implanted angles of the screw were also studied. The anatomic landmark of emineIntia iliopectinea is a large bony bump which can be well palpable and identified, so it can be used as an effective reference intraoperatively. The parameters of the infra-acetabular screw may provide the surgeon appropriate information of safe lag screw placement for the treatment of acetabular fracture with separation of both columns. The large standard deviation of our results indicates great differences among individuals. As a result, preoperative planning should be implemented detailedly for each patient. 3D reconstruction and simulated screw placement technique with digital software before operation are valuable.

There are some limitations to this study. We only analyzed the data according to the gender, not according to different age groups. In addition, we did not collect data according to height, weight or body bone density. These factors may affect the implantation of screws. We only studied the pelvises of Chinese people, who have different skeletal shapes than American and European populations. What is more, more biomechanical studies and related clinical research should be performed to compare the effect of the infra-acetabular screw with other acetabular screws.

Conclusion

We indicate a valuable guideline for the largest secure corridor of infra-acetabular screw, which can be used as a special posterior column lag screw. The ideal screw position and the size of the screws can be determined in 3D-models by digital software. Further biomechanical studies are needed to verify the strength and effect of the screw.

Abbreviations

3-D: 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; SD: Standard deviation

Declarations

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Not applicable.

Authors' contributions

BZ, WZ performed the study, analyzed the data, and drafted the manuscript. HL, LRH and SZH contributed to discussion of data, writing, and editing of the article. XFY, JY and WDM 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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Figures

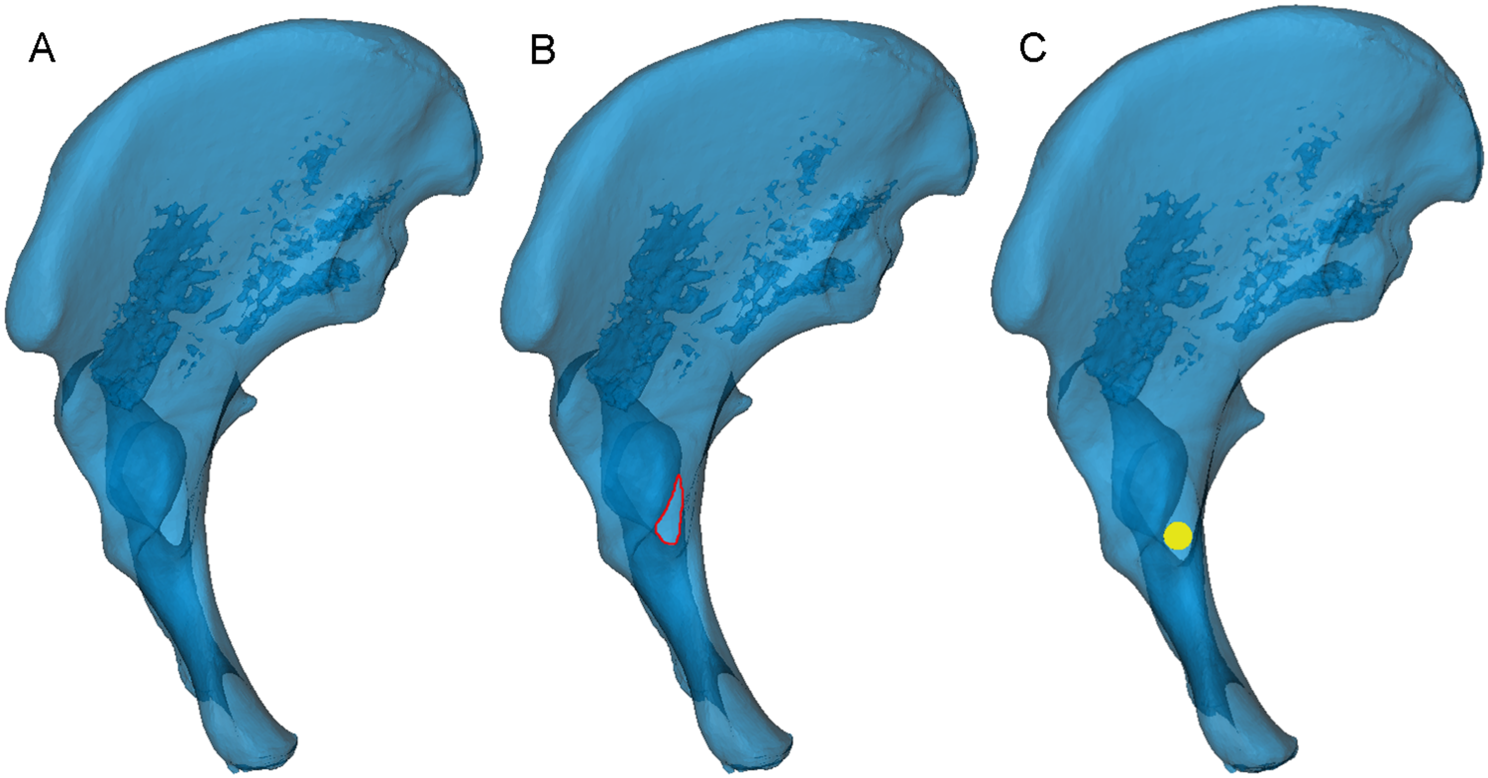

Figure 1

Find the largest screw path. A: The 3D model was turned to the axial perspective to find the largest translucent area. B: The outline of this translucent area (marked in red) represented the overlaying cortical bone, like a drop of water. C: A virtual screw was placed in the centre of the tear-drop area. Then, the diameter was increased progressively until it reached the borderline of the area (the yellow circle of the cylinder represents the largest screw).

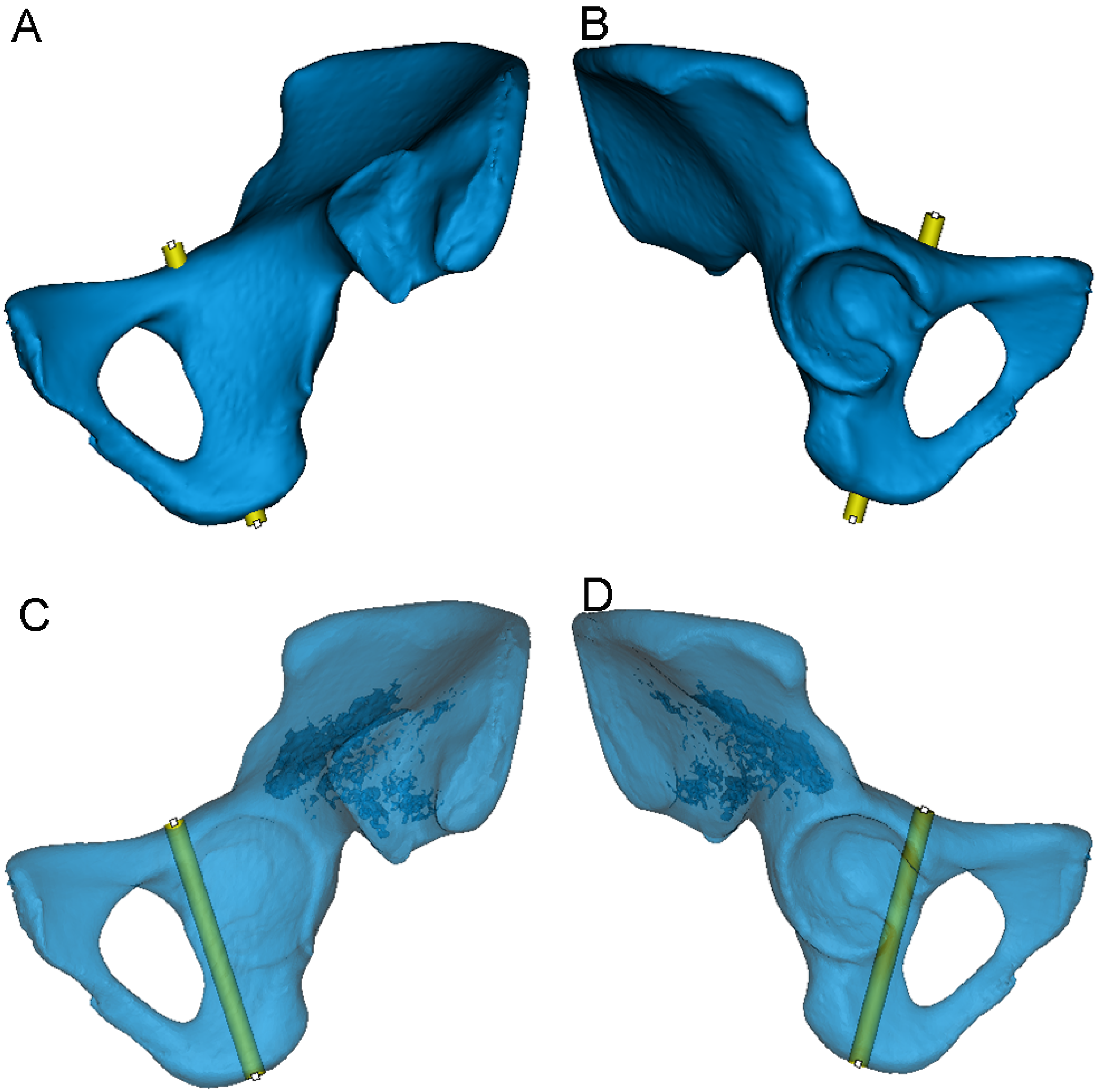

Figure 2

The position of the virtual screw was verified in the 3D model. A, B: Observed from the interior and exterior of the opaque 3D model, respectively. The screw has the largest diameter without penetrating the cortical bone. C, D: Adjusted to the optimal length of the screw from the translucent 3D model.

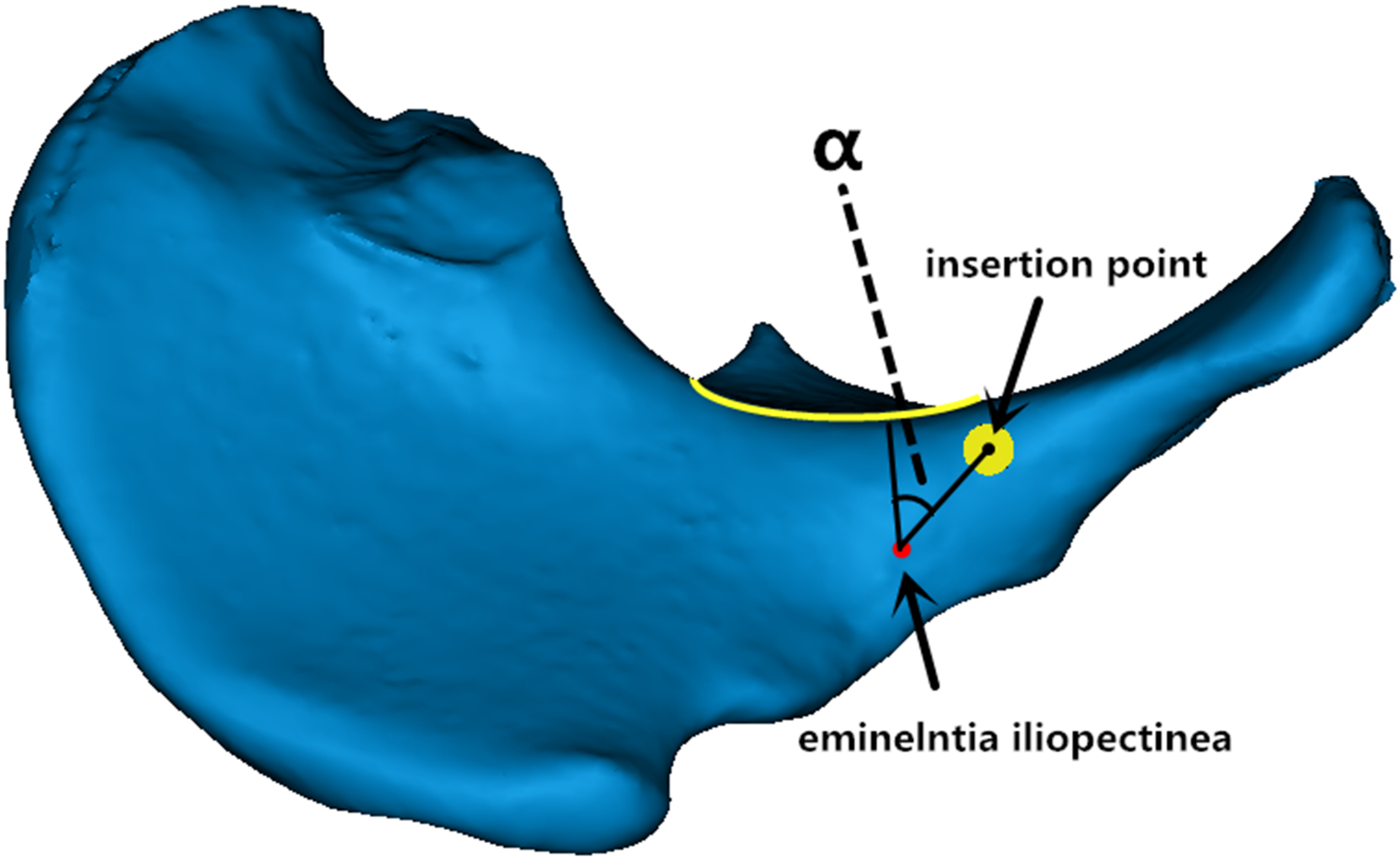

Figure 3

The measurement of angle α. The vertical line from the eminentia iliopectinea to the arcuate line (marked in yellow) was considered as the reference line. The angle between the distance S (from the insertion point to the eminentia iliopectinea) and the reference line was recorded as angle α.

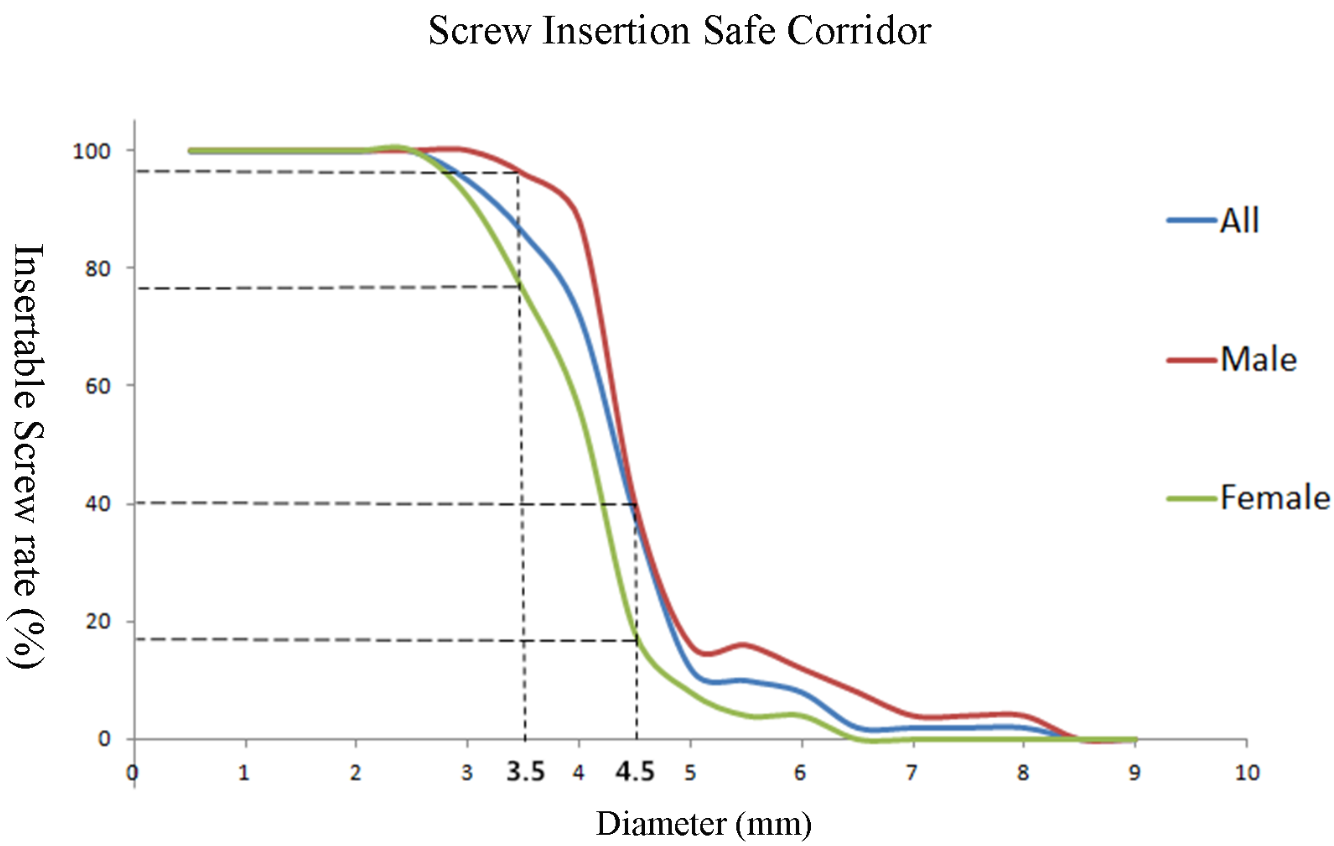

Figure 4

Distribution of the screw insertion safe corridor diameters. The screw insertion corridor with a diameter of at least 3.5mm was found in 48 of 50 males (96%) and 38 of 50 females (76%). The corridor with a diameter of at least 4.5mm was found in 21 of 50 males (42%) and 12 of 50 females (24%).