CT Imaging Anatomical Study of Percutaneous Magic Screw Fixation for Acetabular Posterior Column Fracture

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Research Article

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Abstract

**Background:** Research into minimally-invasive fixation of acetabular posterior column fracture has mostly focused on anatomic measurement through the ischial tuberosity in a retrograde manner, and few anatomic studies have been carried out on anterograde percutaneous Magic screws. The purpose of this paper was to discuss the entry point, entry direction and fixation range of Magic screws for fixation of acetabular posterior column fracture.

**Method:** Materialise’s Interactive Medical Image Control System (Mimics) 19.0 software was used to carry out three-dimensional (3-D) reconstruction based on the Computed tomography (CT) data of the pelvises of 100 cases. A virtual Magic screw was placed in the acetabular posterior column, and the screw entry point, entry direction, length, diameter, safety range and fixation range were determined. Osteotomy modeling was performed on the acetabular posterior column with virtual Magic screw fixation, and the changing law of the width of the screw channel was observed. The narrowest distance and position between the screw edge and the acetabulum were measured.

**Results:** The bone entry point of the Magic screw on the posterior side to the anterior inferior iliac spine and cephalad side to the acetabular top for the males were 33.32 ± 5.52 mm and 13.42 ± 3.68 mm, respectively; and those for females were 33.94 ± 5.43 mm and 9.11 ± 3.82 mm, respectively. The screw for males had a back rake angle of 57.37 ± 6.53° and a leaning inside angle of 52.12 ± 5.61°, with an angle of 15.16 ± 3.45° to the iliac wing. For females, those angles were 55.61 ± 7.94°, 51.53 ± 5.59° and 9.76 ± 3.69°, respectively. The maximum screw diameter was 6.97 ± 0.98 mm for males and 6.39 ± 0.85 mm for females. The screw length was 76.73 ± 9.20 mm for males and 63.64 ± 8.37 mm for females. The safety ranges of back rake angle and leaning inside angle of the 5.5 mm diameter screws for the males were 7.18 ± 3.32° and 9.42 ± 3.96°, respectively, and those of 5.2 mm diameter screws for females were 8.39 ± 2.83° and 10.37 ± 3.92°, respectively. For 60% of the male specimens, the screw fixation range was above the acetabular top, with a length of 60.45 ± 5.92 cm; and for 40% of the male specimens, the screw fixation range was below the acetabular top, with a length of 50.68 ± 6.49 cm. For females, 24% of the specimens were above the acetabular top, with a length of 52.19 ± 7.76 cm; and 76% of the specimens were below the acetabular top, with a length of 38.40 ± 4.35.

**Conclusion:** Percutaneous Magic screws provide a minimally-invasive fixation method for acetabular posterior column fracture with high surgical difficulty, and can be used to fix fractures located in the middle and upper segment of the posterior column.

Introduction

Acetabular fractures involving the posterior column account for more than 50% of all types of acetabular fractures [1], and the incidence of complications such as fracture malunion and traumatic arthritis caused by conservative treatment is as high as 50–60% [2]; thus, surgical treatment is often recommended. For acetabular posterior column fractures, reconstruction plates and percutaneous lag
screws can be used for fixation [3]. With the development of computer-aided technology, intraoperative fluoroscopy and navigation technology, percutaneous screw fixation of the acetabular posterior column has gradually become an important method of minimally-invasive treatment of posterior column fractures due to its advantages of less bleeding, low infection rate and less trauma, including retrograde fixation through the ischial tuberosity [4] and antegrade fixation of acetabular posterior column lag screws through the upper edge of the arcuate line [5]. In 2001, Starr et al. [6] first proposed the technique of using screws to fix posterior column fractures involving the acetabular quadrilateral plate. They called the screw a ‘Magic screw’, and the screw entry point was located at the upper margin of the acetabular top and posterior side to the anterior inferior iliac spine. The screw was directed to the sciatic spine towards the posteromedial side. Ruan et al. [7] reported the use of Magic screws with a diameter of 4.5 mm to fix five patients with quadrilateral plate fractures under 3-D navigation and introduced the surgical methods. Li et al. [8] revealed the perspective angle of Magic screws in the lateral position of the pelvis through measuring the pelvises of six corpses, but without specific research on the anatomical parameters of the screws.

To date, research into the use of minimally-invasive fixation of acetabular posterior column fracture has mostly focused on anatomic measurement through the ischial tuberosity in a retrograde manner, and few anatomic studies have been carried out on anterograde percutaneous Magic screws. Therefore, in this study, Mimics 19.0 software was used to reconstruct a 3-D model of the hemipelvis, allowing us to simulate the percutaneous anterograde placement of Magic screws, discuss the anatomical characteristics of the Magic screw channel, and determine the optimal screw entry point, direction, length, diameter, safety range and fixation range, thus providing reference data for clinical placement of Magic screws.

Materials And Methods

Inclusion and Exclusion Criteria

Inclusion Criteria:

1. The patient’s CT examination range included the pelvis and acetabulum.
2. There was no obvious lesion on the patient’s pelvis, acetabulum or sacroiliac joint.
3. The patient had no compulsive position when they were examined.

Exclusion Criteria:

1. Patients with tumors or fracture infection
2. Patients with pelvic malformations

Data Acquisition
All procedures were conducted in accordance with the Declaration of Helsinki and relevant policies in China. Pelvic CT imaging data in Digital Imaging and Communication in Medicine (DICOM) format from a total of 100 adult patients scanned between October 2019 and October 2020 were collected in the Second People's Hospital of Bengbu. The patients comprised 50 males and 50 females, ranging in age from 18 to 82, with an average age of 47. The CT scanner used was a Philips Ingenuity Core 128-row CT machine (Philips, Suzhou, China), and the scanning parameters were: tube voltage 120 kV, tube current 373 mA, slice thickness 0.8 mm, 512 × 512 matrix.

Hemipelvic Modeling and Virtual Magic Screw Placement

Data in DICOM format were imported into Mimics 19.0 software (Materialise, Leuven, Belgium) to model a 3-D reconstruction of the pelvis. For the reconstructed 3-D model of the right hemipelvis, multi-layer dissection was performed on the acetabulum with an interval of 1.0 mm, and the geometric boundary of the Magic screw channel safety zone was determined on each dissection layer. After extracting two-dimensional image coordinates of the geometric boundary point, a maximum inscribed circle of the boundary was fitted to obtain a circle center coordinate of the inscribed circle. Then a spatial line which is closest to each circle center point was fitted by using the least square method. The spatial line was then considered as the central axis of the geometrically-optimal screw channel, which was generated along the central axis and the maximum diameter of the Magic screw was determined (Figure 1).

Measurement of the Position of the Bone Central Entry Point and Measurement of the Length of the Magic Screw

In Mimics 19.0 software, the hemipelvic model was rotated to the lateral position of the hip joint, and the screw diameter was reduced to 1 mm. At this time, the intersection of the screw and the bone surface at the junction of the posterior side of the anterior inferior iliac spine and the upper part of the acetabular top was the central screw entry point, which was marked as point O. By measuring the horizontal distance OG from point O to the vertex of the anterior inferior iliac spine and the vertical distance OH from point O to the vertex of the upper margin of the acetabulum, the distance from the posterior side to the anterior inferior iliac spine and the distance from the cephalic side to the acetabular top were obtained. The intersection point of the screw edge and the surface of the sciatic spine was recorded as point P, and the distance between measurement points O and P was defined as the length of the screw (Figure 2).

Measurement of Entry Point Position of the Guide Pin on the Body Surface and Measurement of Soft Tissue Length

The body surface around the pelvis was reconstructed, and the body surface tissue was changed to translucent. The pelvis was rotated to the positive position, and the body surface projection point A of the anterior superior iliac spine was marked. The screw was extended to make it intersect with the body surface at point B, which is the entry point of the body surface guide pin. A rectangle was constructed with the diagonal AB, with one side AC of the rectangle being the length of the posterior side to the anterior superior iliac spine, and the other side BC being the length of the cephalic or caudal side to the
anterior superior iliac spine. Thus, we calculated the positional relationship between the body surface projection point of the anterior superior iliac spine and the entry point of the guide pin on the body surface. The length of the line OB was then measured to obtain the length of the guide pin passing through the soft tissue (Figure 3).

**Calculation of Magic Screw Placement Angle and Safety Range**

The maximum screw diameter measurements are presented in descending order with reference to the screw diameter at 95% for males and females. On the standard anatomic site of the human pelvis, the angle between the virtual screw and the sagittal plane was measured, i.e., the leaning inside angle, and the angle between the screw and the coronal plane was measured, i.e., the back rake angle. The exit point was fixed, and the entry point was moved on the coronal plane and the sagittal plane.

The screw was limited so as not to pierce the cortical bone of the channel, and the safety ranges of the back rake angle and the leaning inside angle of the screw with this diameter were calculated (Figure 4).

The midpoint M of the line connecting the vertex of the anterior inferior iliac spine and the vertex of the greater sciatic notch was indicated; the lateral point N of the vertex of the anterior superior iliac spine was marked; the lowest point of the outer surface of the iliac nodule was marked as point Y; a plane S was constructed by crossing the points M, N and Y; the plane S was extended to make it intersect with the screw at point X; then the angle between the screw and plane S was measured, that is, the angle between the screw and the lateral wall of the iliac wing (Figure 5).

**Determination of the Fixation Range of the Magic Screw**

The closer the fracture line is to the entry point, the more easily iatrogenic fracture would occur during screw placement, and thus, the distance between the screw entry point and the fracture line was set as two times the diameter of the screw. The distance was taken as the upper boundary of the fixation range in this study. When a lag screw is used to fix a fracture, the screw thread should cross the fracture line, so that in this case, the lower boundary of the screw fixation range is 16 mm from the most distal end of the screw (the set screw thread length is 16 mm).

After the pelvis was rotated to the lateral position of the hip joint, the pelvic model was transparentized. Line L₁ was drawn from the vertex of the lower margin of the acetabulum to the sciatic spine, and a line parallel to L₁, L₂, was drawn from the vertex of the upper margin of the acetabulum. After the maximum diameters of the screw were arranged in descending order, the diameters of the screws at 95% of the men and the women respectively were taken as a reference. The point Q that was two times the screw diameter from the screw entry point O along the screw direction was measured, to give the upper boundary of the screw fixation range. The point R that was 16 mm from the screw exit point P along the screw direction was measured, to give the lower boundary of the screw fixation range; the distance QR from point Q to point R along the screw direction was measured, to give the length of the range of the acetabular posterior column to which the screw can fix (Figure 6).
Measurement of Related Parameters of the Magic Screw Bone Channel

Using the "re-cutting" function of the software, an osteotomy was performed perpendicular to the longitudinal axis of the screw, with a section thickness of 1 mm and a spacing of 2 mm. The osteotomy range was from point O to point P. The measurement results of the maximum diameter of the screws were arranged in descending order. With the diameter of the screw at 95% of both males and females as the reference, the changing law of the width of the screw channel was observed on each osteotomy, and the narrowest distance H1 between the screw edge and the acetabulum and the distance from the stenosis of the acetabulum to the entry point were measured (Figure 7).

Data Processing

Statistical analysis was performed using IBM Statistical Package for the Social Sciences (SPSS) 23.0 statistical software (IBM SPSS Statistics for Windows, Armonk, NY, USA). First, the measurement data were analyzed using the Shapiro-Wilk test to determine whether the data were normally distributed. The measurement data were all normally distributed and the homogeneity of variance was expressed as ±s. The measurement data were then compared between two groups using the two independent samples t test, and $P < 0.05$ indicated that the difference was statistically significant.

Results

Maximum Diameter and Length of Magic Screw

The largest diameter of the screw was 6.97 ± 0.98 mm for males and 6.39 ± 0.85 mm for females, and the difference between the two groups was statistically significant ($t = 2.914, P < 0.05$). When the maximum screw diameter measurement results were listed in descending order, the screw diameters at 95% were 5.5 mm (5.5–9.2 mm) for males and 5.2 mm (5.2–8.0 mm) for females. The length of the screw was 76.73 ± 9.20 mm for males and 63.64 ± 8.37 mm for females, and the difference between the two groups was statistically significant ($t = 8.293, P < 0.05$).

Body Surface Entry Point and Bone Entry Point of the Magic Screw Guide Pin, and the Length of the Soft Tissue That the Guide Pin Passes Through

For the body surface entry point of the screw guide pin, the body surface projection point of the vertex of the anterior superior iliac spine was taken as the reference. There was no significant difference in the location of the body surface entry point between males and females ($P > 0.05$, Table 1). For the bone entry point of the screw guide pin, the vertex of the anterior inferior iliac spine and the vertex of the upper margin of the acetabulum were used as reference points, and there was no significant difference in the distance to the posterior side of the anterior inferior iliac spine between males and females ($P > 0.05$, Table 1). The distance from the top of the acetabulum to the cephalad side in males was significantly larger than that in females, and the difference was statistically significant ($P < 0.05$, Table 1). The length
of soft tissue through which the guide pin passed in females was significantly longer than that in males, and the difference was statistically significant ($P < 0.05$, Table 1).

**Magic Screw Placement Direction and Safety Range**
There was no significant difference in the back rake angle, leaning inside angle and safety ranges of screw placement between males and females ($P > 0.05$, Table 1). However, the angle between the Magic screw and the lateral wall of the iliac wing was significantly larger in men than that in women, and the difference was statistically significant ($P < 0.05$, Table 1).

**Magic Screw Fixation Range**
For males, screws with a diameter of 5.5 mm were used as the reference. Specimens with the upper boundary of the screw fixation range higher than the acetabular top accounted for 60% (30/50), and those lower than the acetabular top accounted for 40% (20/50). For females, screws with a diameter of 5.2 mm were used as the reference. The specimens with the upper boundary of the screw fixation range higher than the acetabular top accounted for 24% (12/50), and those lower than the acetabular top accounted for 76% (38/50). The difference in screw fixation range between males and females was statistically significant ($P < 0.05$, Table 1).

**Position Change of the Screw in the Channel**
From the screw entry point, the Magic screw gradually approached the acetabulum until it reached the narrowest distance from the acetabulum. Thereafter, the screw was moved away from the acetabulum and towards the sciatic spine, and its distance from the posterior wall of the acetabulum and the area of the quadrilateral gradually narrowed. The screw was tangential to the posterior wall or the bone cortex of the area of the quadrilateral at the most distal end of the screw (Figure 8). The distance from the acetabular stenosis to the entry point was significantly greater in men than in women, and the difference was statistically significant ($P < 0.05$, Table 1). Here, screws with diameters of 5.5 mm and 5.2 mm were used for men and women, respectively. There was no significant difference in the distance from the screw edge to the acetabulum between men and women ($P > 0.05$, Table 1).
|                                | Males            | Females          | t value | P value |
|--------------------------------|------------------|------------------|---------|---------|
| Distance from anterior superior iliac spine to posterior side (mm) | 29.37 ± 12.93    | 28.52 ± 13.13    | 0.26    | 0.40    |
| Distance from anterior superior iliac spine to cephalic side (mm) | 8.29 ± 6.56 (29/50) | 6.84 ± 6.42 (31/50) | 0.52    | 0.29    |
| Distance from anterior superior iliac spine to caudal side | 6.47 ± 3.64 (21/50) | 7.73 ± 4.46 (19/50) | 0.78    | 0.23    |
| Distance from anterior inferior iliac spine to posterior side | 33.32 ± 5.52     | 33.94 ± 5.43     | -0.36   | 0.37    |
| Distance from acetabular top to cephalic side (mm) | 13.42 ± 3.68     | 9.11 ± 3.82      | 4.06    | <0.01   |
| Length of soft tissue that the guide pin passes through (mm) | 62.88 ± 9.24     | 71.39 ± 12.35    | -2.71   | <0.01   |
| Back rake angle (°) | 57.37 ± 6.53     | 55.61 ± 7.94     | 0.83    | 0.24    |
| Leaning inside angle (°) | 52.12 ± 5.61     | 51.53 ± 5.59     | 0.30    | 0.73    |
| Angle between screw and lateral wall of iliac wing (°) | 15.16 ± 3.45     | 9.76 ± 3.69      | 5.26    | <0.01   |
| Safety range of back rake angle (°) | 7.18 ± 3.32      | 8.39 ± 2.83      | -1.31   | 0.10    |
| Safety range of Leaning inside angle (°) | 9.42 ± 3.96      | 10.37 ± 3.92     | -0.82   | 0.21    |
| Fixation range that Q is above L₂ (mm) | 60.45 ± 5.92 (30/50) | 52.19 ± 7.76 (12/50) | 2.17    | 0.03    |
| Fixation range that Q is below L₂ (mm) | 50.68 ± 6.49 (20/50) | 38.40 ± 4.35 (38/50) | 4.88    | <0.01   |
| Distance from acetabular stenosis to entry point (mm) | 34.23 ± 7.67     | 25.18 ± 7.56     | 4.15    | <0.01   |
| Narrowest distance from the screw edge to acetabulum (mm) | 0.71 ± 0.45      | 0.58 ± 0.42      | 1.54    | 0.08    |

Point Q was the upper boundary of the Magic fixation range, and L₂ was a parallel line passing through the vertex of the upper margin of the acetabulum and the vertex of the lower margin of the acetabulum to the sciatic spine.

**Discussion**

Among the 100 pelvic specimens in this study, the maximum diameter of Magic screws was $6.97 ± 0.98$ mm for men and $6.39 ± 0.85$ mm for women. Due to the trend in anatomical morphology of the
acetabular posterior column thinning from the acetabular top to the bottom [9], when screws with a diameter greater than 5.5 mm or 5.2 mm were used to fix the acetabular posterior column for men and women respectively, with the increase in screw diameter and length, the distal end of the screw would be tangential to the posterior wall of the acetabulum or the bony cortex of the area of the quadrilateral, or even pierce them. The important anatomical structure on the surface of the posterior wall of the acetabulum was the sciatic nerve, which traveled outward and downward at the upper-middle third of the line connecting the posterior superior iliac spine and the ischial tuberosity, and passed through the inferior foramen of the piriformis, descending across the posterior wall of the acetabulum, and traveled between the greater trochanter of the femur and the ischial tuberosity [10]. Its median distance from the sciatic spine was 24 mm (range 13–36 mm) [11], and its medial side was accompanied by inferior gluteal vessels, with a median distance of 19 mm (range 4–33 mm) from the sciatic spine [11]. The proximal ends of the screws for males have safety ranges of about 7° and 9° back rake angle and leaning inside angle, while for females, they have safety ranges of about 8° and 10° back rake angle and leaning inside angle. If the back rake angle or the diameter of the screw is rather large, it is easy for the screw to pierce the posterior wall and damage the sciatic nerve and inferior gluteal vessels. The internal pudendal artery accompanied by the pudendal nerve passes out of the pelvis from the inferior foramen of the piriformis, travels around the sacrospinous ligament to the posteromedial side of the sciatic spines, and enters the pelvis from the sciatic foramen [12]. The median distances between the internal pudendal artery and the sciatic spines, between the pudendal nerve and the sciatic spines were 4 mm (range 0–8 mm) and 0 mm (range 0–9 mm) [11], respectively. If the leaning inside angle of the screw was too large and the screw was too long, the neurovascular bundle would be easily damaged. Controlling the placement direction of the screw and selecting the screw with appropriate diameter and length are the keys to avoid damaging the adjacent vascular nerves. Chang et al. [13] performed biomechanical analysis on two fixation methods for acetabular double-column fractures, i.e., anterior-posterior column lag screw, anterior column screw + posterior column plate, and they found that the fixation strength of the 6.5 mm lag screw was stable enough. However, in clinical application, Ruan et al. [7] successfully fixed five cases (three males and two females) with quadrilateral plate fractures using Magic screws with a diameter of 4.5 mm, while Li et al. [8] used Magic screws with a diameter of 7.3 mm in a case of slightly-displaced quadrilateral plate fracture in a male. The screws did not enter the hip joint nor cause vascular nerve damage, and satisfactory prognosis was achieved. Thus, there are large individual differences in the choice of screw diameter.

The positions of the body surface entry point and bone entry point for males were higher than those of females. Among them, the body surface entry point was located at 8.29 ± 6.56 mm cephalad side of the anterior superior iliac spine in 58% of men, and 6.47 ± 3.64 mm caudal side of the anterior superior iliac spine in 42%; for women, the body surface entry point was located at 6.84 ± 6.42 mm of the cephalad side of the anterior superior iliac spine in 62% of cases; and at 7.73 ± 4.46 mm on the caudal side of the anterior superior iliac spine in 38%. The bone entry point for males was 13.42 ± 3.68 mm on the cephalad side of the acetabular top, while that for females was 9.11 ± 3.82 mm. This is related to the fact that females have a relatively wide pelvis and relatively large valgus angle of the ilium. The body surface entry
point and the bone entry point of the Magic screw guide pin were easily covered by the iliac crest. The screw length was 76.73 ± 9.20 mm in men and 63.64 ± 8.37 mm in women, with a larger fixation range in men than in women, all of which were related to the narrow male pelvis.

Compared with the traditional open reduction and internal fixation, percutaneous lag screw fixation of the acetabular posterior column does not allow the operator to directly observe the fixation effect, so intraoperative fluoroscopy is essential. Supine fluoroscopy is often used for acetabular fractures involving the posterior column. If fluoroscopy is used during the operation with the pelvis in the normal position, the ilium in the 45° oblique position, and the obturator foramen in the 45° oblique position [14], the "blind area" for fluoroscopy will be generated in the posterior side of the posterior column due to the occlusion of the acetabular rim. Autopsy and MRI measurements have shown that 85% of the sciatic nerve is wholly or partially located in the "blind area" [15]. Therefore, the angle of fluoroscopy during the operation is crucial to determine whether the screw passes through the posterior wall. Some scholars have proposed the adaption of an obturator inclination of 55–60° [16], that is, rotation of the "C" arm 10–15° more to the affected side on the basis of the obturator inclination, so that the posterior wall overlaps with the posterior edge of the posterior column. The relationship between the screw and the posterior edge of the posterior column can then be used to determine whether the screw passes through the posterior wall [15]. According to the placement direction of the screws, we recommend that during Magic screw placement, the patient should adopt the supine position, and the C-arm should be rotated outward by 50–55° and toward the head by 55–60° to eliminate the back rake angle and incline the inside angle of the Magic screw. In this way, the screw becomes a dot in the perspective view. We can verify whether the screw penetrate the acetabulum through this view. During the placement of the Magic screw guide pin, the position of the guide pin should be repeatedly determined by observation at the above angles.

A posterior column fixed with a Magic screw has the following characteristics: (1) The distance from the body surface entry point of the guide pin to the bone surface is about 7 cm, and it is difficult to accurately reach the bone entry point. (2) The screw placement area on the bone surface is steep, and it is easy to slide when the guide pin is placed. (3) The screw channel is irregular, and the safety range is very small. During the placement, the screw may have the risk of successively entering the acetabulum, and exiting the posterior wall and the area of the quadrilateral. Therefore, it is very difficult to place Magic screws. In order to reduce the risk of screw placement, Mimics software can be used to carry out 3-D reconstruction of the CT data of the pelvis of the patient and simulate the screw placement before operation, thus, obtaining parameters such as the entry point, direction, screw length and diameter.

When placing the guide pin, the bone entry point was fixed using a sleeve with a toothed inclined surface, and the guide pin was slowly inserted. After piercing the cortex, the correct position and direction of the guide pin were determined through fluoroscopy, and then the guide pin was struck with a bone hammer. When greater resistance was felt, the position and direction of the guide pin were determined through fluoroscopy again.
Some limitations of our study must be noted. First of all, the measurement of the placement parameters of Magic screws in this study was based on 3-D reconstruction of the pelvic model, and its effectiveness needs further clinical verification. Secondly, the participants in our study may not be representative of the whole population, and the results may be different in different ethnic groups.

Conclusion

The percutaneous Magic screw is a minimally-invasive fixation method for posterior column fractures, with high surgery difficulty. It can fix fractures located in the middle and upper segment of the posterior column. In this study, through digital analysis of CT images, we determined the ideal position and fixation range of Magic screws, which provides the anatomical basis for intraoperative placement.

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.

Declarations

Ethics approval and consent to participate

All experimental protocols were approved by the Ethics Committee of the Second People's Hospital of Bengbu. All procedures were conducted in accordance with the Declaration of Helsinki and relevant policies in China. All patients involved in this study gave their consent for the participation and the informed consent was obtained from all participants.

Consent for publication

All patients involved in this study gave their consent for the anonymized data to be used for scientific purposes and published in a scientific journal.

Availability of data and materials

All data used in this article were collected from raw CT data of 100 subjects. The datasets generated and analyzed during the current study are not publicly available due to individual privacy of participants but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Authors’ contributions

All authors have read and approved the manuscript. All authors contributed to the article. Study design has been suggested by Quanyi Lu. Data were collected and analyzed by Quanyi Lu, Xiaobao Gong, Chen Xuan, and Hao Lu. The manuscript was drafted by Hao Lu, Quanyi Lu revised the manuscript.

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**Figures**
Figure 1

Digital analysis of the Magic screw fixation channel: a. 3-D reconstruction of the hemipelvis and axial segmentation of the Magic screw channel; b. Cross section after segmentation shows the boundary of the Magic screw channel and the maximum screw placement area in the safety zone; c. Virtual display of Magic screw channel position.
**Figure 2**

Measurement of the position of the bone central entry point and the length of the Magic screw. a. The horizontal distance OG from the central entry point O to the vertex of the anterior inferior iliac spine and the vertical distance OH from central entry point O to the vertex of the upper margin of the acetabulum. b. Screw length OP.

**Figure 3**
Position of the entry point of the body surface guide pin. a. The entry point of the body surface guide pin was higher than the anterior superior iliac spine: BC was the distance that the anterior superior iliac spine moved to the cephalad side. b. The entry point of the guide pin on the body surface was lower than the anterior superior iliac spine: BC was the distance that the anterior superior iliac spine moved to the caudal side. Point A was the projection point on the body surface of the anterior superior iliac spine. Point B was the entry point of the guide pin. AC was the distance that the anterior superior iliac spine moved to the posterior side. OB was the length of the guide pin passing through the soft tissue.

Figure 4

Measurement of screw placement angle and safety range. a. Coronal plane image of the hemipelvis, with a solid white line indicating the sagittal plane. b. Sagittal plane image of the hemipelvis, with a white solid line indicating the coronal plane. Point O shows the screw entry point, while point P shows the screw exit point. The red arrow was the optimal direction of the screw, while the yellow arrows at both sides were the critical directions.
Figure 5

Measurement of the angle between the screw and the lateral wall of the iliac wing. a. The plane S of the lateral wall of the iliac wing was constructed in the lateral position of the hip joint. Point Y was the lowest point of the outer surface of the iliac nodule, point N was the lateral point of the vertex of the anterior superior iliac spine, and point M was the midpoint of the line connecting the vertex of the anterior inferior iliac spine and the vertex of the greater sciatic notch. b. The model was rotated from the lateral position of the hip joint to the positive position of the pelvis until plane S became a line. Then, point X was the intersection point of plane S and the screw.
Figure 6

Measurement of the Magic screw fixation range. a. Point Q is above L₂. b. Point Q is below L₂. Point O and point P are the entry and exit points, respectively, while point Q and point R are the upper boundary and the lower boundary of the fixation range, respectively. L₁ is the line from the vertex of the lower margin of the acetabulum to the ischial spine, and L₂ is the parallel line to L₁ that passes through the vertex of the upper margin of the acetabulum.

Figure 7

Modeling of acetabular posterior column osteotomy. a. Osteotomy of the acetabular posterior column was performed with the entry point O and the exit point P as the starting point and the terminating point, respectively. b. Cross section of the screw closest to the acetabulum, where H₁ is the distance from the screw edge to the acetabulum.
Figure 8

Cross-section of the intraosseous channel of the screw. a-b. The screw gradually approached the acetabulum. c-d. The screw gradually moved away from the acetabulum. e-f. The screw gradually approached the posterior wall of the acetabulum and the area of the quadrilateral.