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Designation and Validation of a Posterior Anatomical Plate for the Anterior Column of the Acetabulum

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Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
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Background: Surgical treatment of acetabular fractures is one of the greatest challenges for orthopedic surgeons. Fixation of most displaced fractures requires extensive exposure, which may lead to complications, including blood loss, neural or vascular injury, postoperative infection, wound healing problems, and heterotopic bone formation.

Material/Methods: This study was conducted to certify an anatomic plate with an anterior column lag screw guiding device to repair the posterior acetabulum. Complete pelvic spiral computed tomography (CT) scan data were collected from 56 patients. The posterior column of the acetabulum was simulated with a lag screw. The guiding device for the plate was designed by measuring the position of the screw point and the direction and maximum diameter of the screw.

Results: The distance from the screw point to the apex of the greater sciatic notch was farther in women than in men. The distance from the screw point to the ischial spine was also farther in women than in men. The θ angle (front inclination angle) of the screw was lower in women than in men. The φ angle (camber screw angle) was greater in women than in men. The success rate when using the guided device was significantly higher than when using traditional pedicle screws.

Conclusions: The guided device was very useful for improving placement success and accuracy rates of the acetabular posterior anatomical anterior column plate using antegrade lag screws, and for reducing surgical risk and injury.

MeSH Keywords: **Acetylgalactosamine • Fiducial Markers • Medroxyprogesterone Acetate**

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Backround

Surgical treatment of acetabular fractures is one of the most challenging techniques for orthopedic surgeons [1,2]. Open reduction and internal fixation are the gold standard for displaced fractures involving the weight-bearing dome and fractures with intra-articular fragments [3].Traditional treatment methods involve inter-fixation and restoration of articular anatomy with stable internal fixation to allow early mobilization of the patient. Fixation of most displaced fractures requires extensive exposure, which may lead to complications, including blood loss, neural or vascular injury, postoperative infection, wound healing problems, and heterotopic bone formation [4–7]. In this study, the anatomic parameters of the nail entry point and nail entry orientation were obtained by computer-aided design and computer-aided manufacturing (CAD/CAM) methodology and computed tomography (CT) scans. We designed an anatomic plate with a lag screw guiding device to repair the posterior and anterior columns of the acetabulum.

Material and Methods

Between 2012 and 2014, we treated 56 patients (27 men and 29 women) who had acetabular fractures. All patients underwent an emergency multi-directional radiographic examination, CT and three-dimensional (3D)-CT scans (GE CTT 8800, General Electric, Milwaukee, WI, USA). A 3-D model of the reconstructed pelvis was obtained using Mimics 15.0 software (Materilise NV, Leuven, Belgium) (Figure 1).

Simulated insertion of the acetabular posterior column lag screw

We designed the plate from the sciatic notch by moving along the surface of the column of the acetabulum and stopping at sciatic nodules. The following four points are based on the steel plate design requirements and the operative field of view that should be satisfied to repair the anterior column of the acetabulum: 1) the screw point cannot exceed the height of the sciatic notch vertex, so that the operative field can be exposed during the operation; 2) the screw point must be located in front of the pubic bone; 3) the lag screw cannot enter into the joint cavity or pierce cortical bone; 4) the diameter of the lag screw must be as large as possible (≥4 mm) to provide sufficient fixation strength. The reconstructed 3D model was rotated 90° ipsilaterally (equivalent to the pelvic side of the X-ray) using translucent processing software. The cylinder was built by Med CAD (Dallas, TX, USA). The 3D cylinder (i.e., lag screw) was placed virtually in the anterior acetabular column, according to the position requirements, and was observed in the horizontal, coronal, and sagittal planes of the 3D model to ensure that it was not in the joint cavity or piercing the bone cortex. The maximum diameter of the lag screw was determined by gradually increasing the diameter of the 3D cylinder at a rate of 0.1 mm until immediately before it pierced the cortical bone (Figure 2).

Determining and measuring the screw point and angles

Point (O) on the cylinder going through the rear of the acetabular posterior column is the entering point for the antegrade lag screw, with the greater sciatic notch vertex (A) and the ischial spine (B) as reference points. "Measure 3D Distance": in "Tools" was selected to measure distance OA between the entering point of the screw and the greater sciatic notch vertex, as well as distance OB between the entering point of the screw and the ischial spine. Finally, the entering point of the screw was imported into the posterior acetabular anatomical plate data, and the most proximal screw entering hole was used as the guide for the anterior column antegrade lag screw to prepare the locking hole and calibrate the entering angle of the screw (Figure 3A).

The entering angle of the antegrade lag screw was measured; that is, the angle formed between the cylinder and the posterior surface of the acetabular posterior column, where parallel line OT and perpendicular line OP of the medial margin of the acetabular posterior column were used as reference lines. "Measure 3D Angle" in "Tools" was selected to measure the angle formed between the cylinder and line OP (extraversion angle, $\angle \varphi$) representing the tilt angle of the screw in the medial-lateral direction, and the angle formed between the cylinder and line OT (anteversion angle, $\angle \theta$) representing the tilt angle of the screw in the anterio-posterior direction (Figure 3B).

Fabrication and preliminary validation of the guide

The measured parameters were saved as.stl files. The solid pull screw guide device was created using a digital milling machine. The success rate for placing the guide was verified on 19 dried pelvic specimens (11 males and eight females) using the auxiliary pulling screw guide on the left side. The specimens received the traditional screw setting in the right pelvis.

The criterion to determine the performance of screw fixation via the posterior approach was if the guiding needle point was on the superior ramus of the pubis and in front of the iliopectineal tuberosity (Figure 4); otherwise, screw fixation was unsuccessful if the needle entered the acetabulum or broke through the medial or lateral bone cortex of the pubic ramus.

Statistical analysis

Continuous variables are expressed as means ± standard deviations. Differences between groups were detected by one-way

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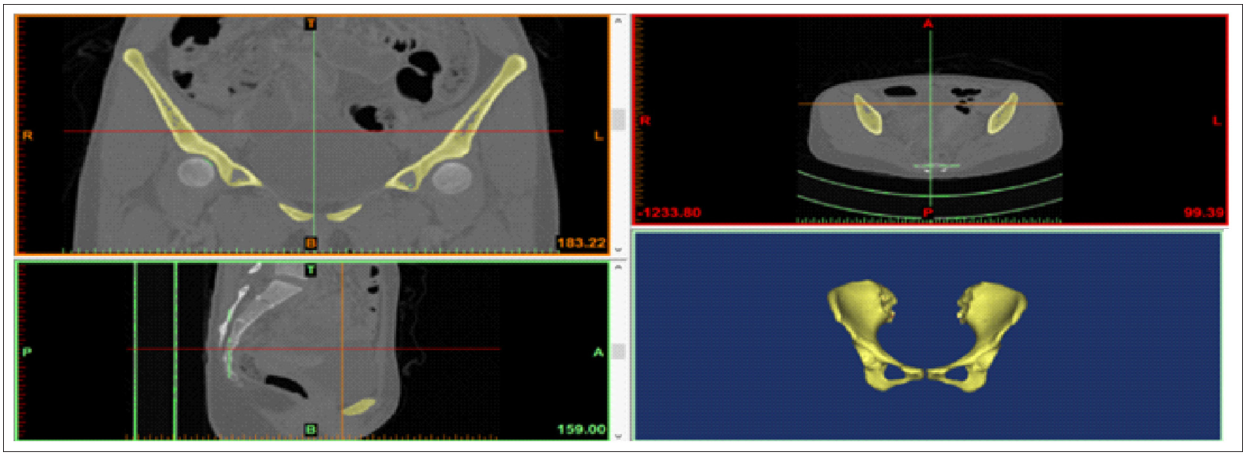

Figure 1. Three-dimensional model of the reconstructed pelvis.

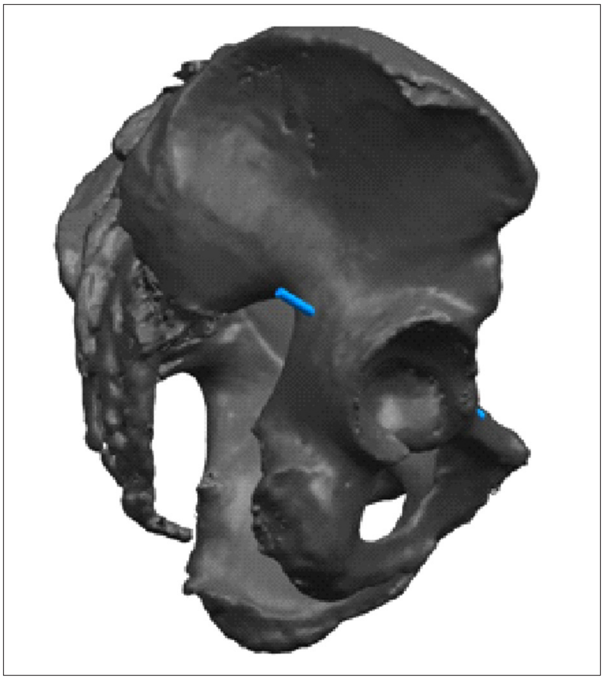

Figure 2. The anterior column of the acetabulum simulated with a lag screw. The blue cylinder represents the lag screw.

analysis of variance. All analyses were performed using SPSS 20.0 software (SPSS Inc., Chicago, IL, USA). A *p* value <0.05 was considered statistically significant.

Results

Screw point and angles

The mean OA distance was 21.11±4.19 mm, the mean OB distance was 56.18±2.01 mm, the mean camber angle phi was 68.51±4.52°, and the mean dip angle theta was 73.67±3.17°. The mean maximum diameter of the screws placed was 6.51±2.14 mm. Significant differences were detected in the OA and OB distances, as well as the inclination φ angle and anteversion θ angle between males and females (Table 1).

Success rate of the guide-assisted screw set

The success rate of screw guide-assisted placement was 84.21%, and that of conventional pedicle screws was 31.58% (*p*<0.05). These results suggest that the lag screw guide significantly improved the success and accuracy rates of screw placement.

Discussion

Acetabular fractures are one of the most common but severe and complex injuries seen in the clinic. An epidemiological survey showed that the mean annual incidence rate of acetabular fractures is 3/100,000 [8,9]. Acetabular fractures caused by traffic injuries are increasing due to population aging and increased use of automobiles for transportation [10–15]. High quality anatomical reduction and reliable internal fixation are key to improve treatment of intra-articular acetabular fractures [10,16,17]. Reconstruction with plate and screw fixation is the most widely used method to treat an acetabular fracture [15].

In this study, the pelvic anatomy differences between males and females were considered when selecting the entry point. If the female pelvis is small, and the pubic bone is natural, the safe placementof the screw in the anterior column channel may be limited. The screw should be placed in a more upward and outward positon in women than men, to make better use of the medullary cavity of the pubic ramus, and the screw angle is important for choosing the ideal entry point. A hook was designed to touch the greater sciatic notch based on the distance between the screw entry point and the greater sciatic notch vertex. The location of plate and position of the screw point were fixed.

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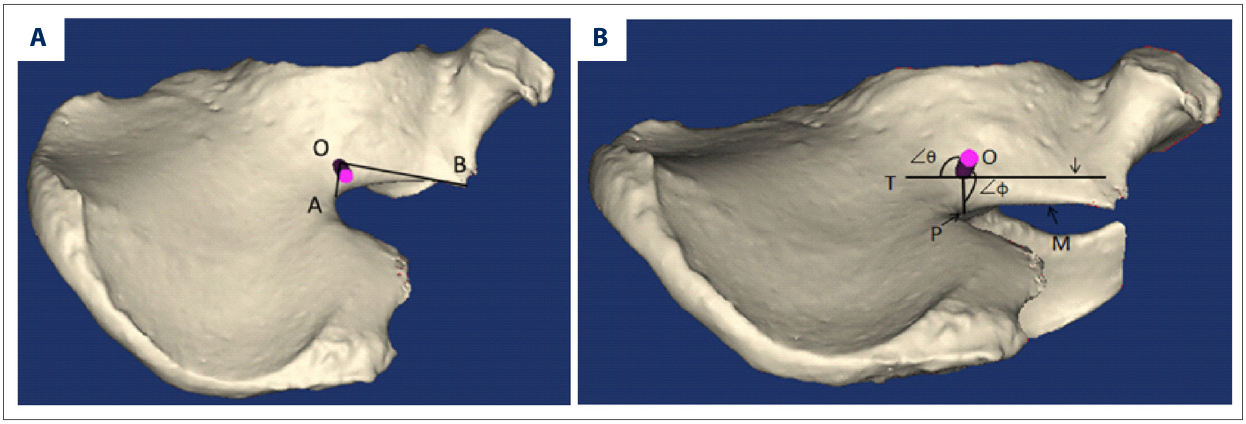

Figure 3. Screw point and angle. (**A**) Location map of the entry point. O – screw point; OA – distance from screw point to the sciatic notch vertex; OB – distance from screw point to the ischial spine. (**B**) Screw angle. θ – front inclination angle; φ – camber screw angle.

Figure 4. Application of the screw guiding device to the anterior column of the acetabulum. (**A**) Acetabular square anatomical plate and direct tension screw guiding device. (**B**) Guide screw and guide pin insertion. (**C**) Outside the lateral surface of the iliac bone. (**D**) Medial surface of the iliac bone. (**E**) Piercing point pin.

Table 1. OA distance, OB distance, ∠θ, ∠φ and the maximum diameter of screw insertion.

	Female (n=27)	Male (n=29)
OA (mm)	25.11±5.91	17.51±2.94*
OB (mm)	60.11±5.37	52.64±6.30*
∠θ (°)	69.72±5.66	78.14±3.50*
∠φ (°)	75.55±13.66	62.18±8.60*
The maximum diameter of screw insertion (mm)	6.18±1.73	6.43±2.16

* Compared to the female, there was significant difference (P<0.05).

The angle of the screw was key in the plate design. The angle between the plane of the tension screw and the screw point was measured, and the screw point was lower in males than that in females. Therefore, the front angle of the tension screw was larger. The screw did not enter or exit the medial acetabular cortical bone. The lag screw path was as far away as possible and in line with the second half of the pubic branch in the horizontal section.

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The data were saved as.stl files to verify the screw position and accuracy of the screw angle. The solid tension screw guide device for transmission was digitally inputted, and the validation was performed on 19 semi-pelvic specimens. This approach was useful to validate the point position of the nail in our design and the accuracy of the method for measuring the screw angle.

Conclusions

Measuring the antegrade lag screw point and angle provided the anatomic parameters for the anterior column of the acetabulum. The method was very useful in improving placement success and accuracy rates for antegrade lag screws into an anterior or posterior acetabular column plate and reducing surgical risk and injury.

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