

Correlation Between Postoperative Morphologic Changes of Ankle Mortise and Ankle Joint Function After Pilon Fracture

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Objectives: We aimed to explore the correlation between the postoperative morphologic changes of ankle mortise and ankle joint function after Ruedi-Allgower type III pilon fracture.

Methods: A retrospective analysis was performed for 60 patients with Ruedi-Allgower type III pilon fractures receiving surgical treatment. The height, width, depth, coronal angle, and sagittal angle of ankle mortise were measured based on X-ray films during the last follow-up. The ankle joint function on the injured side was scored according to the Mazur ankle grading scale, and the patients were divided into an excellent group ($n = 41$), a good group ($n = 12$), and a mediocre + poor group ($n = 7$).

Results: The correlation between the morphologic changes of ankle mortise and function was analyzed by comparing the five indices of ankle mortise on injured and healthy sides. The injured and healthy sides had significantly different widths, depths, and coronal and sagittal angles of ankle mortise. The differences between the indices of ankle mortise on injured and healthy sides, except for that between heights, were negatively correlated with scores. The differences increased with decreasing score. Effective treatment of the width and depth, together with coronal and sagittal angles of ankle mortise, was significantly correlated with postoperative ankle joint function.

Conclusions: Anatomical reduction for the width, depth, and coronal and sagittal angles of ankle mortise of patients with Ruedi-Allgower type III pilon fractures exerts significant positive effects on ankle joint function. Thus, the anatomical form of ankle mortise should be restored as much as possible during surgery.

Key words: Ankle joint – Ankle mortise – Fracture – Function

The ankle joint is the largest hinge joint of the human body, which consists of the lower end of the tibiofibula and the trochlea of talus. The inner and outer ankle joint surfaces form ankle mortise. The morphologic changes of ankle mortise can reduce the contact area of the tibiotalar joint, withstand pressure imbalance, and result in load conduction disorder and eventually traumatic arthritis.^{1,2} The main purpose of surgery for a pilon fracture is to obtain a stable, painless, and active joint. The surgery should restore the smoothness of the tibiotalar joint surface as much as possible.³ During treatment, attention should be paid to prevent skin necrosis, a blood supply disorder of the limb end, and traumatic arthritis.⁴ Whether the ankle mortise contour reconstructed after pilon fracture is complete and whether the articular surface is smooth not only affect the ankle joint activity but also work as important indices for predicting the occurrence of traumatic arthritis.⁵

The aim of this study was to explore the relationship between the morphologic changes and functional scores of ankle joint on the injured side after a Ruedi-Allgower type III pilon fracture and to analyze whether the morphologic changes of ankle mortise affected ankle joint function and the underlying cause.

Materials and Methods

Baseline clinical data

This study was approved by the ethics committee of our hospital, and written consent was obtained from all patients. A retrospective analysis was conducted for 60 patients with Ruedi-Allgower type III pilon fractures who underwent surgical treatment from January 2016 to March 2017, including 32 men and 28 women that were 20–55 years old (average, 38 years). Causes of injury were as follows: 17 cases of traffic accidents and 34 cases of falling injury. The time from injury to surgery was 12 hours to 7 days, with an average of 3 days. All cases had fresh fractures, including 8 open fractures (5 cases of Gustilo type I and 3 cases of type II) and 52 cases of closed fractures. They were followed up for 18–24 months (average, 20 months).

During the last follow-up, the ankle joint function on the injured side was scored according to the Mazur ankle grading scale, and the patients were divided into an excellent group (90–100 points, $n = 41$), a good group (80–90 points, $n = 12$), and a mediocre + poor group (<80 points, $n = 7$).

Treatment methods

Of the 60 patients, 14 underwent emergency surgery within 12 hours, including 8 cases of open fractures. Also, 37 and 9 cases received surgical treatment within 3 and 7 days, respectively.

According to the degrees of fracture displacement and damage of surrounding soft tissue, 3 surgical methods were used.

Open reduction of fracture and internal fixation

This method included 35 cases, with 5 cases of open fracture (Gustilo type I). All surgeries were performed according to AO principles and procedures. Active and passive non-weight-bearing ankle joint flexion and extension exercises were started 4–6 weeks after surgery.

Limited internal fixation combined with external fixation

This study included 19 cases, with 2 cases of open fracture (Gustilo type II). The universal joint at the distal stent was loosened 4–6 weeks after surgery to exercise the ankle joint. External fixation was no longer used when X-ray films collected 3–6 months after surgery revealed fracture healing.

Step-by-step delayed open reduction and internal fixation

This method included 6 cases, with 1 case of open fracture (Gustilo type II). Through 7–14 days of stent fixation or calcaneal traction and detumescence, open reduction and internal fixation were carried out at the distal tibia after soft tissue swelling subsided. Active and passive non-weight-bearing ankle joint flexion and extension exercises were performed 4–6 weeks after surgery.⁶

Observation indices during follow-up

The X-ray films of ankle mortise and the lateral ankle joint were taken 3, 6, and 12 months after surgery and during the last follow-up to detect the following indices.

Height of ankle mortise

The distance from the intersection of perpendicular line of the central axis of tibia and the prominence of the medial malleolus to the intersection of the central axis of tibia and the tibial articular surface was disclosed by the X-ray film of ankle mortise.

Table 1 Indices of ankle mortise on injured and healthy sides

Item	Height (mm)	Width (mm)	Depth (mm)	Coronal angle (°)	Sagittal angle (°)
Injured side	31.28 ± 3.29	40.51 ± 3.86	42.62 ± 3.74	9.12 ± 1.68	16.24 ± 3.12
Healthy side	30.66 ± 3.07	36.25 ± 3.57	37.15 ± 2.96	6.04 ± 1.17	11.28 ± 2.81
<i>P</i> value	0.816	0.031	0.028	0.012	0.009

Width of ankle mortise

The distance from the 2 vaults of the talus to the intersection of anterior and posterior ankles was disclosed by the X-ray film of ankle mortise.

Depth of ankle mortise

The distance between anterior and posterior ankle margin lines was disclosed by the lateral X-ray film of ankle joint.

Coronal angle of ankle mortise (α)

The angle formed by the central axis of tibia and the vertical line connecting two vaults of ankle mortise was disclosed by the X-ray film of ankle mortise.

Sagittal angle of ankle mortise (β)

The angle formed by the central axis of tibia and the vertical line connecting anterior and posterior ankle margins was disclosed by the lateral X-ray film of ankle joint.

Statistical analysis

All data were statistically analyzed by SPSS 16.0 software. $P < 0.05$ was considered statistically significant.

The indices on the healthy and injured sides were compared by measuring the height, width, depth, and coronal and sagittal angles of ankle mortise on the X-ray films during the last follow-up using the independent-sample *t* test.

The differences between the indices on the injured and healthy sides of ankle mortise among excellent, good, and mediocre + poor groups were compared by measuring the height, width, depth, and coronal and sagittal angles of ankle mortise on the X-ray films during the last follow-up through analysis of variance.

Results*Adverse reactions*

One patient with an open fracture appeared to have skin necrosis at the edge of the cut. After a local skin flap transfer, the other cuts had primary healing.

The fixation time of fracture reduction was 2–3 hours, with an average of 2.16 hours. There were 3 patients with general Mazur scores, and 2 patients had poor scores because of joint stiffness 1–3 months after surgery. Although the patients strengthened with positive and passive joint exercise treatment, the improvement was not obvious. A patient with poor Mazur scores had symptoms of traumatic arthritis 3–6 months after surgery. Although treatment was medication, strengthening muscle strength exercises, and using a walking aid, long-term follow-up showed increased traumatic arthritis.

Indices of ankle mortise on the injured and healthy sides

The difference was not statistically significant in the ankle mortise height between the affected side and the uninjured side ($P > 0.05$), indicating that the ankle mortise height of the affected side recovered better after surgery, and the difference was not obvious compared with normal ankle mortise. The differences in the ankle mortise width, depth, and coronal and sagittal angles were statistically significant between the affected side and the uninjured side ($P < 0.05$), indicating that the postoperative ankle mortise width, depth, and coronal and sagittal angles have changed. There was a certain correlation between the change and the function of ankle joint on the affected side (Table 1).

Differences between indices of ankle mortise on the injured and healthy sides of excellent, good, and mediocre + poor groups

There was no significant difference in the height difference among the 3 groups ($P > 0.05$; Table 2), suggesting that the recovery of ankle joint function was not highly correlated with the height of ankle mortise. The difference in the width of ankle mortise was statistically significant among the 3 groups ($P < 0.05$; Table 2). The *q* test used for pairwise comparison showed that the differences between width were statistically significant ($P < 0.05$; Table 3), where the difference in the width of the mediocre + poor group was >2 mm on average and that of the

Table 2 Differences between indices of ankle mortise on injured and healthy sides of excellent, good, and mediocre + poor groups

Item	Case number (n)	Height difference (mm)	Width difference (mm)	Depth difference (mm)	Coronal angle difference (°)	Sagittal angle difference (°)
Excellent group	41	0.32 ± 0.08	0.72 ± 0.11	1.63 ± 0.28	2.06 ± 0.47	1.01 ± 0.23
Good group	12	0.37 ± 0.09	1.12 ± 0.14	2.01 ± 0.32	2.72 ± 0.56	1.95 ± 0.31
Mediocre + poor group	7	0.39 ± 0.09	2.91 ± 0.36	3.82 ± 0.44	4.98 ± 0.71	3.43 ± 0.39
P value		0.715	0.007	0.016	0.012	0.008

excellent and good groups was <1 mm. Therefore, the width of ankle mortise during surgery had a significant effects on postoperative outcomes. In addition, the differences in the ankle mortise depth and coronal and sagittal angles were statistically significant among the 3 groups ($P < 0.05$; Table 2). The pairwise q test revealed that there were statistically significant differences among the 3 groups in intraoperative ankle mortise depth and coronal and sagittal angles ($P < 0.05$; Table 3), suggesting all these factors had significant impact on postoperative outcomes.

Discussion

The maintenance of the height of ankle mortise depends on the integrity of fibula and the recovery of the top of tibia fornix. The reasons for the change include fibula or lateral malleolus comminuted fracture displacement causing fibula shortening and external rotation; distal tibia comminuted compression fracture not retracted during reduction; and insufficient or no bone grafting at metaphysis.^{7,8} In this study, the height change of ankle mortise was small, with a range of <0.5 mm compared with the uninjured side. No statistically significant differences were found in the height change and the ankle joint function score. Probably, the nonobvious loss of ankle mortise height was related to the anatomical reduction of the intraoperative fibula and the emphasis on bone graft filling of metaphysis.

An increase in the width of ankle mortise causes the astragalus to move outward in ankle mortise,

resulting in instability of the lateral side of ankle joint, loss of anastomosis on the articular surface, reduction of the weight-bearing area, and uneven pressure, which aggravates ischemia and cartilage degeneration.⁹ Moreover, after the widening of ankle mortise, its restrictive effect on the astragalus is weakened, which results in anterior and posterior instability, eventually leading to ankle joint traumatic arthritis.¹⁰ The reasons for the change in width of ankle mortise include reduction of malleolus medialis fracture, less than ideal displacement of the fibula or lateral malleolus fracture; no reduction or fixation performed on the tibiofibular syndesmosis separation; and a compressed burst fracture at the lower end of tibia end that was not retracted during transverse separation and reduction.^{11,12} Herein, the 2-year follow-up results showed that 7 patients in the mediocre + poor group had Mazur scores of the ankle joint of <80, poor function of the ankle joint, and an increase in the width of ankle mortise by >2 mm on the uninjured side, which indicates that the width changes of ankle mortise has a greater impact on the function of the ankle joint in the future.

The depth of ankle mortise increases, causing the astragalus to sink deep inside, and the front is prone to collide and affect joint activity.¹³ Hak *et al* confirmed by biomechanical experiments that the posterior malleolar fracture can cause the stress center of the ankle joint contact to move forward and inward, so that it withstands huge contact stress during exercises, causing traumatic arthritis of the ankle joint.¹⁴ Zhang *et al* found that when the distal tibia fracture block was greater than or equal to 10% of the articular surface of the tibial fracture, surgical

Table 3 Pairwise q test results and P values

Item	Width difference		Depth difference		Coronal angle difference		Sagittal angle difference	
	q	P	q	P	q	P	q	P
Excellent: good group	2.662	0.013	6.151	0.005	6.383	0.004	3.158	0.010
Good: mediocre + poor group	4.256	0.008	6.843	0.003	8.651	0.002	4.565	0.007
Excellent: mediocre + poor group	8.846	0.000	6.455	0.004	8.697	0.001	8.554	0.002

reduction and fixation of the posterior fracture block were required.¹⁵ The reasons for the depth change of ankle mortise include rupture fracture at the lower end of tibia causing the fracture block to be separated at the sagittal plane and not dissected and fixed during treatment; and displacement of the posterior bone block of distal tibia being difficult to expose during surgery, causing dissatisfactory fixation.¹⁶ For the patients with mediocre + poor scores of ankle joint function, the depth difference of ankle mortise between affected and uninjured sides was 2–5 mm. The 1/2 osteotomy at the lower end of tibia is equivalent to 65% of the normal contact area of ankle joint.

The causes for the angle change of ankle mortise include poor restoration of anterior lateral bone mass (Cha-put nodule) at the lower end of tibia; uneven tibia bone graft filling; improper selection of a steel plate and uneven support; and premature load of the ankle joint.¹⁷ Anatomically, the ankle mortise angle change reflects the change in the load force line of the ankle joint.¹⁸ In this study, the coronal angle of the ankle mortise on the uninjured side was $6.04^\circ \pm 1.17^\circ$, and the sagittal angle was $11.28^\circ \pm 2.81^\circ$, which is the load force line of the normal ankle joint. When the distal tibia is damaged by high-energy injury, the accompanying fibula often has a fracture shift, and the perpendicular line of the connection line of the two fornix tops of ankle mortise no longer maintains an approximately right angle with the connection line between the anterior and posterior ankle margins, thus exhibiting the changes of coronal and sagittal angles of ankle mortise. After the deviation of the load force line of ankle joint, the stress distribution of the ankle joint may be changed, resulting in a disorder of the bone joint load and causing arthritis in ankle joint. This study showed statistically significant differences in the ankle mortise coronal and sagittal angles among the 3 groups. In our clinical follow-up, 2 patients with ankle joint Mazur scores of <87 points after external fixation treatment had traumatic arthritis, and the difference in the ankle mortise coronal angle was $>5^\circ$ between the affected and the uninjured sides and that of the sagittal angle was $>3^\circ$, indicating that the change in ankle mortise angle affects its function.

When reconstructing the ankle mortise anatomy, the length of fibula or lateral malleolus should be restored first, and the fracture end should be initially stabilized; then, with the 3 major fracture blocks (*i.e.*, the malleolus medialis fracture block, the

anterior lateral fracture block [Tillaux-Cha-put], and the labium posterius fracture block [Volkmanns triangle]) as the reference points, the tibiocalar articular surface received anatomical reduction.¹⁹ The main points of surgical reconstruction of ankle mortise include restoring the load force line and length of tibia and fibula (especially tibia), that is, restoring the height of ankle mortise, and making the ankle mortise coronal and sagittal angles normal; restoring the anatomical structure of the tibia articular surface and ensuring the surface to be smooth and flat; restoring the anatomical relationship of tibiofibular syndesmosis; preventing the expansion of ankle mortise; and trying to achieve strong and stable fixation, which is good for early activities and prevents morphologic deformation of posterior ankle mortise.^{20,21} According to the fracture situation, we should choose suitable inner and outer side panels or judge whether the front and rear are additionally fixed. Attention should be paid to the bone grafting of the metaphyseal bone defect to ensure that the ankle mortise is stable on the top, the reconstructed articular surface is smooth and intact, and the ankle mortise angle is normal.

In summary, anatomical reduction for the width, depth, and coronal and sagittal angles of ankle mortise of patients with Ruedi-Allgower type III pilon fractures exerts significant positive effects on ankle joint function. Thus, the anatomical form of ankle mortise should be restored as much as possible during surgery.

Acknowledgments

YL and CW conceived and designed the study. YL, LZ, HZ, and TZ performed the study. LZ, HZ, and TZ analyzed the data. LZ, HZ, and TZ interpreted the data. YL, CW, LZ, HZ, and TZ wrote the article. The authors declared no conflict of interest.

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