CLINICAL ARTICLE

The Measurement of the Inclination Angle of the Hamate and Analysis of the Inclination Angle for the Rotation Deformity of the Little Finger in the Fixation of the Carpometacarpal Joint

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Objective: Complex base fractures of the fifth metacarpal bone and dislocation of the fifth carpometacarpal joint are more prone to internal rotation deformity of the little finger sequence after fixation with a transarticular plate. In the past, we have neglected that there is actually a certain angle of external rotation in the hamate surface of transarticular fixation. This study measured the inclination angle of the hamate surface relative to the fifth metacarpal surface for clinical reference.

Methods: In a prospective single-center study, we investigated the tilt angle of 60 normal hamates. The study included thin-layer computed tomography (CT) data from 60 patients from the orthopaedic clinic and inpatient unit from January 2017 to March 2020, including 34 men and 26 women who were 15~59 years old, average 35 years old. The CT data of 60 cases in Dicom format of the hand was input into Mimics and 3-Matics software for three-dimensional (3D) reconstruction and measuring the angle α between hamate surface and the fifth metacarpal surface. According to the possible placement of the transarticular plate on the fifth metacarpal surface, we measured the angle β between the hamate surface 1 and the fifth metacarpal surface and the angle γ between the hamate surface 2 and the fifth metacarpal surface.

Results: The average angle between the hamate surface and the fifth metacarpal surface was 11.66°. The hamate surfaces 1 and 2 have an external rotation angle of 7.30° and 7.51° on average with respect to the fifth metacarpal surface, respectively. There is no statistically significant difference in the angles between the two groups ($P > 0.05$).

Conclusions: The horizontal angle of the dorsal side of the hamate is different from the back of the fifth metacarpal surface, and the hamate has a certain external rotation angle with respect to the fifth metacarpal surface. No matter how the transarticular plate is placed, the plate always has a certain external rotation angle relative to the fifth metacarpal surface. When the fixation is across the fifth carpometacarpal joint, if the plate does not twist and shape, it will inevitably cause internal rotation of the fifth metacarpal, resulting in internal rotation deformity of the little finger sequence.

Key words: Carpometacarpal joint; 3D reconstruction; Deformity; Hamate; Inclination; Transarticular plate

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Introduction

The fifth metacarpal bone is the most common among hand injuries[1]. Rotational deformity of the finger sequence is a serious complication of hand fractures[2]. Up to 10% of patients with fractures of the phalanges and metacarpals had rotational deformities[3]. Another study reported that 25% of patients with metacarpal fractures had malrotation of the finger sequence after surgery[4], especially in the fifth metacarpal fracture patients. Most people believed that the poor reduction of the metacarpal fracture was the main cause of rotational deformity[5]. Because the comminuted fracture of the base of the fifth metacarpal bone is extremely unstable, it is usually accompanied by dislocation of the wrist and metacarpal joint. At the same time, the fifth metacarpal bone and the second metacarpal bone together constitute the skeleton structure of the palm, which is an integral part of the transverse arch and longitudinal arch of the hand, so it strives for anatomical reduction[6]. In the past, K-wire fixation was clinically used, but K-wire fixation had obvious limitations, which showed that the fixation strength was insufficient, the fracture pieces of comminuted fractures were many and small, and it was difficult to maintain the reduction and fixation of the K-wires. Also, plaster or braces are needed for adjuvant therapy after the operation. It is difficult to obtain satisfactory reduction and fixation results. It is easy to break or withdraw the needle, and there is a risk of nail tract infection[7]. Therefore, the fifth metacarpal plate is usually selected for transarticular fixation at present. However, despite the anatomical reduction of the fracture using the trans-articular plate fixation, some rotation deformities of the little finger sequence were still found after surgery[8]. The proximal fixed end of the transarticular fixation is the hamate. It is found in clinical evaluation that the hamate surface is not parallel to the horizontal plane. When the metacarpophalangeal joint and interphalangeal joint are fully extended, the hamate has a certain inclination angle with the horizontal plane. The existence of this special anatomy makes the transarticular plate have a certain external tilt angle with the fifth metacarpal plane. At present, there are no scholars to measure this tilt angle. We hypothesize that the rotation deformity of the little finger sequence caused by the comminuted fracture of the fifth metacarpal base and the dislocation of the carpometacarpal joint after transarticular fixation with plate was caused by the existence of a certain inclination angle between the hamate surface and the fifth metacarpal surface. Therefore, our department used digital medical technology to measure the inclination angle formed by the hamate surface and the fifth metacarpal surface in 60 cases. The study results are as follows.

Methods

Clinical Data

The criteria for inclusion of patients in this study were as follows: (i) thin-layer CT of patients with normal hands and no fracture at all; (ii) thin-layer CT of patients with metacarpal and phalangeal fractures that do not involve the hamate and palm joint; (iii) thin-layer CT of patients with distal radius fractures with normal wrist and finger bones.

The criteria for exclusion of patients were as follows: (i) thin-layer CT of patients with fractures of the fourth and fifth metacarpal and hamates; (ii) thin-layer CT data of patients with rheumatoid joints, wrist gout stones, and osteoporosis; (iii) thin-layer CT data of patients with osteoarthritis who are over 60 years old; (iv) previous medical history of metacarpal and hamates fractures of the fourth and fifth metacarpal and hamates.

This study was defined as a single-centre prospective study. This study was approved by the Ethics Committee of Nanjing First Hospital, and all data were obtained from patients with informed consent. The study included thin-layer CT data from 60 patients from the orthopaedics clinic and inpatients of Nanjing First Hospital from January 2017 to March 2020, including 34 men and 26 women who were 15-59 years old, average 35 years old; 22 cases with left hand and 38 cases with right hand (Table 1).

Technique

Axial volume scan of the patient's hand was performed using a dual-source 64-slice spiral CT (Siemens Sensation, Germany) at the Medical Imaging Center of Nanjing First Hospital, Nanjing Medical University. Scanning layer thickness is 0.75 mm, scanning matrix is 512 * 512, bone window is reconstructed by 1.0 mm after scanning, and the data result after scanning is stored in Dicom format data file. Enter the Dicom format data of CT into Mimics 19.0 software (Materialize, Belgium), select the bone window to extract the full picture of the hand using the area growth and mask editing functions, and perform 3D reconstruction. According to the principle of determining a surface at three points, determine the fifth metacarpal surface and the hamate surface (transarticular plate plane). In the Mimics software, first select the angle measurement button, then select the flat button. The fifth metacarpal surface is a plane defined by three points composed of the central point A of the metacarpal head and the two points B and C on the radial side and ulnar side of the base of the metacarpal bone. The hamate surface is composed of the proximal apex D of the hamate and the two points B' and C' on the radial and ulnar side of the distal hamate. The hamate surface 1 is composed of the center point A of the fifth metacarpal head and two points B' and C' on the radial side and ulnar side of the distal end of the hamate. The hamate surface 2 is composed of the center point A' of the longitudinal axis of the fifth metacarpal bone and two points B' and C' on the radial side and ulnar side of the distal end of the hamate (Figs 1 and 3C). According to the actual situation, choose the size and color of the four plane parameters for easy identification. At the same time, open 3-Matic 13.0 software (Materialize, Belgium), import four plane masks and 3D models in Mimics into 3-Matic software, select the measurement angle button, and select the angle measurement between the two surfaces.

TABLE 1 General data of 60 patients

Case	Gender (M,F)	Hand (L,R)	Age (y)	BMD (T score)	Γ (°)	Case	Gender (M,F)	Hand (L,R)	Age (y)	BMD (T score)	γ (°)
1	M	L	22	1.34	10.49	31	M	L	28	1.32	11.36
2	M	L	18	1.28	11.76	32	F	R	32	1.22	11.58
3	F	R	23	1.32	12.13	33	F	L	38	1.24	10.36
4	M	R	32	1.28	11.83	34	M	R	35	1.36	11.26
5	F	L	28	1.22	10.47	35	M	L	45	−0.18	13.20
6	M	R	20	1.39	11.35	36	M	R	47	0.45	11.28
7	M	L	45	−0.11	11.72	37	F	L	37	1.23	10.45
8	F	R	23	1.26	12.34	38	M	R	38	1.15	12.52
9	M	L	25	1.22	11.50	39	M	R	59	−0.22	12.70
10	F	R	38	1.23	10.86	40	M	R	50	−0.12	13.64
11	F	R	24	1.19	9.98	41	M	L	45	−0.12	10.45
12	M	R	25	1.28	15.01	42	M	R	38	1.23	14.50
13	F	L	24	1.26	11.23	43	F	R	43	1.45	10.46
14	M	R	25	1.22	11.35	44	M	R	37	1.34	11.46
15	F	R	23	1.16	11.35	45	F	R	40	1.22	12.78
16	M	L	23	1.27	11.26	46	M	L	38	1.33	14.61
17	M	R	34	1.31	10.29	47	F	R	56	−0.12	11.36
18	M	R	54	−0.25	11.35	48	M	L	38	1.22	12.47
19	M	L	35	1.16	12.50	49	F	L	48	−0.11	11.54
20	F	R	36	1.29	11.25	50	F	R	32	1.22	11.26
21	F	R	37	1.23	10.78	51	M	R	34	1.25	10.36
22	F	R	38	1.21	10.63	52	F	R	38	1.24	11.65
23	F	L	30	1.26	12.16	53	M	L	39	1.32	11.67
24	M	R	34	1.35	12.78	54	M	L	39	1.14	10.75
25	F	R	35	1.25	11.45	55	F	R	41	1.18	11.89
26	M	L	36	1.22	11.42	56	M	R	36	1.31	11.34
27	F	R	38	1.25	11.35	57	M	R	35	1.22	16.02
28	M	R	35	1.22	10.68	58	F	L	37	1.39	10.24
29	F	R	30	1.36	11.75	59	M	L	38	1.11	10.26
30	F	R	30	1.35	11.54	60	M	R	35	1.17	11.35

BMD, bone mineral density; F, female; L, left; M, male; R, right; y, year.

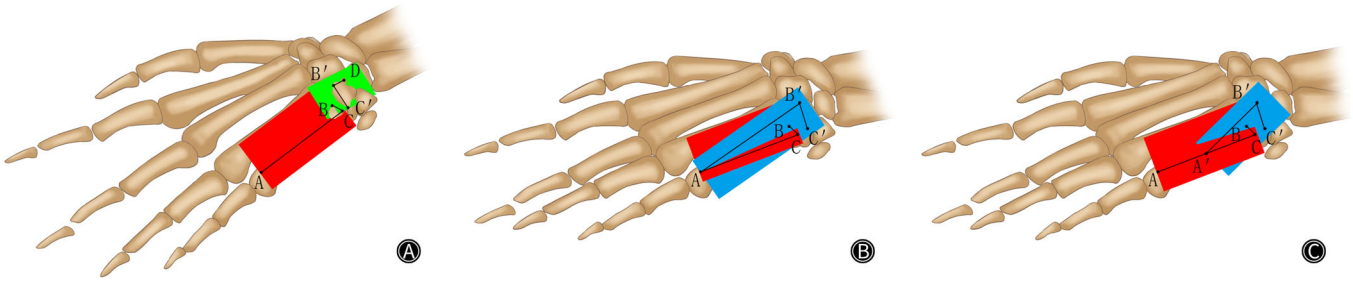

Fig. 1 A, B, and C show the principle of determining a surface based on three points on the 3D model to determine the fifth metacarpal surface, the hamate surface, the hamate surface 1, and the hamate surface 2.

The reason for choosing two hamate surfaces (transarticular plate plane) is to consider that some of the base fractures involve metacarpal shaft fractures, and the plate needs to be placed more distally, so the most distal position is selected, the fifth metacarpal head center point A. The selection of the center point A of the longitudinal axis of the fifth metacarpal bone takes into account that the plate cannot be too close to the fracture line of the base and requires a certain working length of the plate. The real anatomical angle between the metacarpal surface and the hamate surface is α (Fig. 2A). The angle between the metacarpal surface and the hamate surface 1 is β (Fig. 2B), and the angle between the metacarpal surface and the hamate surface 2 is γ (Fig. 2C). After measuring the angle, export and save in .bmp format.

Clinical Evaluation

Bone mineral density (BMD) is an important indicator of bone strength, expressed in grams per cubic centimeter

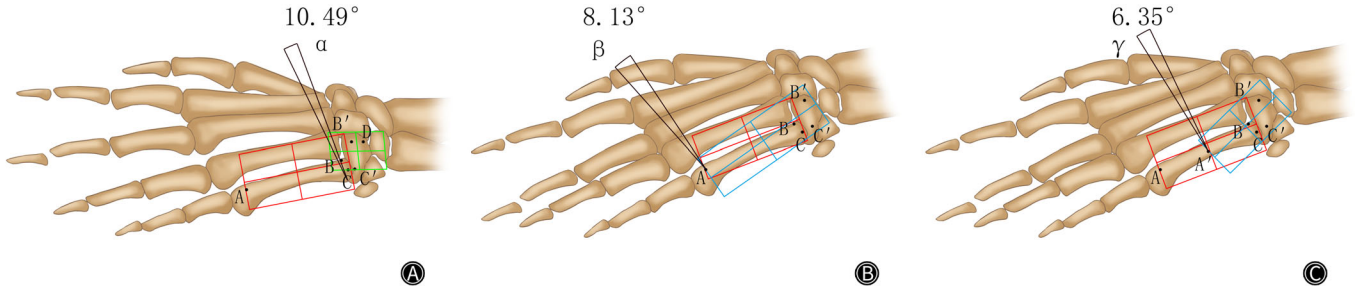

Fig. 2 A, B, and C show that the hamate surface and the fifth metacarpal surface is 10.49°, and the angle between the hamate surface 1 and the fifth metacarpal surface is 8.13°, and the angle between the hamate surface 2 and the fifth metacarpal bone is 6.35°.

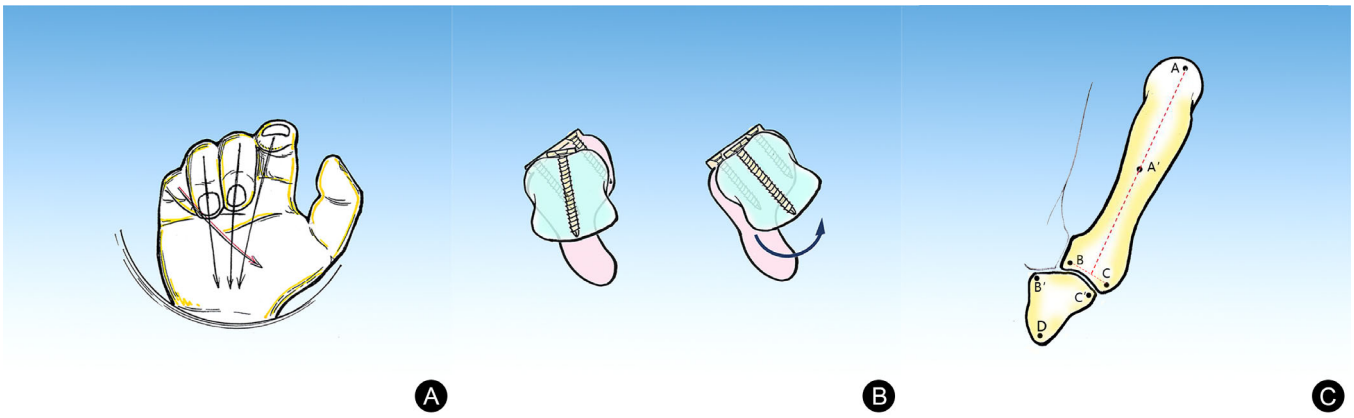

Fig. 3 A shows the deformity of the internal rotation of the little finger; the left of B shows that if the plate is pre-bent, the normal position of the metacarpal bone can be guaranteed. The right of B shows that if it is not pre-bent, the internal rotation of the metacarpal bone will appear according to the original plane of the plate; C shows how to determine the plane.

and as an absolute value. In the clinical use of bone density values, because the absolute values of different bone density testers are different, the T value is usually used to determine whether the bone density is normal. T value is a relative value, and the normal reference value is between −1 and +1. It is abnormal when the T value is lower than −2.5. Bone density is an important indicator of bone quality, reflecting the degree of osteoporosis and an important basis for predicting the risk of fracture[9].

DICOM format image files refer to files stored in accordance with the DICOM standard, generally composed of DICOM file headers and DICOM data sets. The file header stores detailed relevant information, and records rich clinical and image-related information such as patient name, image size, layer thickness, layer distance, and pixel resolution. The data set stores 16-bit grayscale images.

Mask editing is similar to the "pencil" and "eraser" tools in Photoshop and is the most familiar image-editing method. After being divided into an object in Mimics software, it is the mask. The mask is a two-dimensional image independent of the original tomographic image.

The area growth in Mimics software is a process of image segmentation by further subdividing the unconnected segmented regions on the initial threshold segmentation mask to generate new masks.

Statistical Analysis

For statistical analysis, SPSS 21.0 statistical software was used. The continuous variables were expressed as mean and SD. The angle between the two groups was compared using two independent sample t tests. $P < 0.05$ was considered statistically significant.

Results

The average bone mineral density was (1.06 ± 0.49), and the results showed that all patients had normal bone mass and there was no osteoporosis (Table 1). The horizontal angle of the dorsal side of the hamate is different from the back of the fifth metacarpal surface, and the hamate does have a certain external rotation angle with respect to the fifth metacarpal surface. The external rotation angle is 11.66° ± 1.20° (Table 1). The hamate surface 1 has an external rotation angle of 7.30° ± 0.37° relative to the fifth metacarpal surface, and the hamate surface 2 has an external

TABLE 2 Comparison of the external rotation angle between the two groups

	α (°)	β (°)	*t*	*P*
Statistics	7.30 ± 0.37	7.51 ± 0.73	−1.955	0.054

rotation angle of 7.51° ± 0.73° relative to the fifth metacarpal surface 2. There is no statistically significant difference in the angles between the two groups ($P > 0.05$). It can be concluded that no matter how the transarticular plate is placed, the plate always has a certain external rotation angle relative to the fifth metacarpal surface (Table 2).

Discussion

The comminuted fracture of the base of the fifth metacarpal bone is extremely unstable, often accompanied by different types and degrees of dislocation of the wrist and palm joint and may be accompanied by hamate fractures and ulnar nerve injury[10]. At present, for the treatment of this fracture or dislocation of the metacarpal joint with hamate, the effect is more accurate through the fifth metacarpal plate transarticular fixation[11]. Inappropriate treatment will deform the proximal transverse arch, the distal transverse arch, and the longitudinal arch of the palm, affect the balance of the internal and external muscles of the hand, and have a great influence on the function of the hand and wrist. Complications such as shortening of the fifth metacarpal bone, pain, joint extension and flexion and abduction dysfunction, and weakened fist strength will remain[12]. However, the most common and more serious complication in the clinic is malrotation of the little finger after the fifth metacarpal fracture[2,13,14]. Manktelow and Mahoney found that a 10° malrotation in the fifth metacarpal fracture can lead to a 2 cm overlap deformity at the fourth and fifth fingertips[15]. Using a simple triangular Pythagorean theorem, for a finger with a length of 3 to 6 cm from the proximal interphalangeal joint to the fingertip, the proximal end of the phalanx rotates 5°, and the fingertip of the finger translates 0.3 to 0.5 cm. If malrotation occurs in the metacarpal bone, the translation distance of the fingertip can be doubled[2,4]. Clinically, in addition to the rotation deformity of the little finger sequence caused by poor reduction, another problem that is easily overlooked is that the external rotation angle of the plate plane after the placement of the plate causes the internal rotation deformity of the little finger sequence (Fig. 3A). We have found clinically that in some cases, although the fracture reduction was satisfactory during the operation, the plate was not shaped in the opposite direction before the plate was placed, resulting in loss of the reduction, so there is still rotation that causes internal rotation of the little finger sequence after surgery deformity (Fig. 3B).

However, it is particularly important for accurate judgment of rotational malformation. It is useless to show whether there is malrotation by plain film. The most reliable way to check is to observe if there is cross overlap or separation between the fingers while flexing the fingers, and the plane of the nail plate in the extended state of the fingers[16]. Some scholars have found that even after anatomical reduction of the fifth metacarpal shaft fracture, the occurrence of the internal rotation deformity of the little finger is observed. Some researchers constructed a soft tissue swelling model by injecting 4–8 ml of normal saline into the fourth metacarpal space. The results show that in the absence of a fracture, the swelling of the joint space of the fifth metacarpophalangeal joint will cause the internal rotation deformity of the little finger in the fully flexed state, but the nail plane of the little finger has not changed, so it is called "pseudorotation deformity." If it is a true rotation deformity of the metacarpal bone, it will cause the change of the nail plane[13]. Therefore, when evaluating the rotation of the little finger, it is necessary to recheck the finger after the soft tissue swelling disappears 1 week after the fracture. At the same time, it is necessary to pay attention to check whether there is any rotation deformity of the little finger when the metacarpophalangeal joint is fully flexed. And it is also necessary to observe whether there is any change in the nail plane of the little finger when extended.

The hamate is located on the ulnar side of the distal row of carpal bones, and is divided into a dorsal hamate body and a palm hamate hook. The distal end of the hamate body is related to the base of the fourth and fifth metacarpal bones, respectively, forming the fourth and fifth wrist metacarpal joints. The fifth carpometacarpal joint and the fourth carpometacarpal joint have flexion and extension activities of 30° and 15°, respectively[17]. The dorsal part of the distal end of the hamate body has a palm inclination angle of about 28°, so there is a partial step with the fifth metacarpal bone[14]. Moreover, it is found in clinical practice that the hamate has an oblique angle with respect to the metacarpal surface, but the specific angle is not yet known, and there is no relevant literature report at present. Therefore, in the fifth metacarpal plate transarticular fixation, there must be a certain external rotation angle. However, this angle has not been paid attention to in previous clinical studies, and no prebending shaping of the plate was performed during the operation. Therefore, even if the metacarpal fracture was satisfactorily reduced, the internal rotation deformity of the little finger sequence appeared after the operation. In this study, using digital medical technology, the external rotation angle α of the hamate surface relative to the fifth metacarpal surface was measured in 60 cases, which was 11.66°on average. According to the principle that a plane can be determined at three points, we measured the angle β between the fifth metacarpal surface (composed of the central point A of the metacarpal head and the two points B and C on the radial side and ulnar side of the base of the metacarpal bone) and the hamate surface 1 (composed of the center point A of the fifth metacarpal head and two points B and C on the radial side and ulnar side of the distal end of the hamate). But considering that some cases

only involve base fractures or dislocation of the metacarpal joint, transarticular fixation does not require a particularly long plate fixation, that is, the plate does not need to be fixed to metacarpal head. According to the clinical application, we measured the angle γ between hamate surface 2 (composed of the center point A of the longitudinal axis of the fifth metacarpal bone and two points B and C on the radial side and ulnar side of the distal end of the hamate) and fifth metacarpal surface (Fig. 3C). The hamate surface 1 has an external rotation angle 7.30° ± 0.37° with respect to the fifth metacarpal surface, and the hamate surface 2 has an external rotation angle7.51° ± 0.73° with respect to the fifth metacarpal surface 2. However, the difference between the external rotation angles of the two groups was not statistically significant ($P > 0.05$). It can be concluded that no matter how the transarticular plate is placed, the hamate surface always has a certain external rotation angle relative to the fifth metacarpal bone. We measured the average angle of 7.30° to 7.51°. According to the aforementioned simple triangular Pythagorean theorem, it can be calculated that if the proximal phalanx rotates 5°, the fingertip of the finger translates 0.3 to 0.5 cm. If malrotation occurs in the metacarpal bone, the translation distance of the fingertip can reach 1 cm. Therefore, when we do the fifth metacarpal joint fixation, we must pre-bend the plate in the opposite direction to resist the external rotation of the anatomy itself.

Conclusions

The horizontal angle of the dorsal side of the hamate is different from the back of the fifth metacarpal surface, and the hamate has a certain external rotation angle with respect to the fifth metacarpal surface. When the fracture or dislocation is fixed across the fifth carpometacarpal joint, if the plate does not twist and shape, it will inevitably cause internal rotation of the fifth metacarpal bone, resulting in rotation deformity of the little finger sequence. This study is a single-center study, and the number of cases measured is relatively small. The measurement data of large samples in multiple centers will further improve the level of evidence of the study.

An Authorship Declaration

All authors listed meet the authorship criteria according to the latest guidelines of the International Committee of Medical Journal Editors, and all authors are in agreement with the manuscript.

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