A New Alternative to Quantify Finger Rotation: Angles between the Axis of Flexed Fingers and the Axis of Third Metacarpal Bone

Chatchanin Mayurasakorn MD*,
Suriya Luenam MD*, Arkaphat Kosiyatrakul MD*,
Kanista Luenam MEd*, Sanya Prachaporn MD*

** Division of Hand and Microsurgery, Department of Orthopaedics, Phramongkutklao Hospital, Bangkok, Thailand*

Objective: *To determine whether the proposed angle, formed between the axis of middle and distal phalanges of each of flexed fingers and the axis of the third metacarpal bone was symmetrical between both hands in adult population.*
Material and Method: *Thirty-one volunteers (12 males and 19 females) having normal and uninjured hands with an average age of 38 years underwent a fluoroscopic examination of their hands. All volunteers put their hands in a special positioning device that passively held the metacarpophalangeal and proximal interphalangeal joints in full flexion with distal interphalangeal joint in full extension. Fluoroscopic images were then taken and angles were digitally measured.*
Results: *Mean angles of the flexed index, middle, ring and small fingers compared to the third metacarpal bone were -4.07 (SEM = 1.041), 5.22 (SEM = 0.889), 12.91 (SEM = 1.009) and 23.11 (SEM = 1.370) degrees, respectively. The angles were statistically symmetrical between both hands ($p = 0.838$, 0.546, 0.620 and 0.641, respectively). The genders had no effect on the symmetry ($p > 0.3$). The differences between angle of each finger and the angle of the middle finger were also found to be statistically symmetrical.*
Conclusion: *Side-to-side comparison of the angle formed between the axis of flexed fingers and the third metacarpal bone measured from radiographic images can be used as an additional alternative to determine the finger rotation. The angular relationship between each finger with respect to the middle finger can also be used to purposefully reduce x-ray beam projection variation.*

Keywords: *Digital alignment, Digital rotation, Rotational alignment, Finger fracture*

J Med Assoc Thai 2011; 94 (12): 1476-81
Full text. e-Journal: *http://www.jmat.mat.or.th*

Fractures of the metacarpals and phalanges are common. In the US, these fractures represent 41% of all fractures of hand and forearm[1]. Although most of these injuries can be successfully treated non-operatively, certain fractures are better managed with surgery. Improper management can lead to deformity and functional limitation[2-4]. Malrotation is one of the debilitating complications, which was found in 10% of metacarpal and phalangeal fractures[5], resulting in finger overlapping or scissoring. Therefore, an assessment of fracture rotation during treatment is essential for preventing the rotational malunion.

The well-accepted clinical test for finger rotation is to simultaneously flex the fingers and observe the fingertips for any evidence of overlapping or divergence[6] and by comparison with the contralateral hand, which is a qualitative method[3]. However, Tan et al found a digital overlap in a healthy individuals and suggested that 50% or less overlap of the nail plate was within normal limit[7]. During the past 30 years, a considerable amount of literature has been published on finger malrotation assessment such as scaphoid convergence[2,3,7,8], determination of the parallelism relate to the middle finger[7] or an end-on examination of fingernails[7,9-13]. Nevertheless, the fingernail examination have been opposed that it is an inadequate method of evaluating rotation[14]. As of the authors' review of prior literatures, debate continues about the best strategies for the assessment of malrotation; moreover, some methods are difficult for clinical application.

Regarding the fact that finger malrotation becomes obvious and troublesome when simultaneously

Correspondence to:
Mayurasakorn C, Department of Orthopaedics, Phramongkutklao Hospital, Bangkok 10400, Thailand.
Phone: 0-2354-7600 ext. 93456
E-mail: chatchanin@hotmail.com

flexing all fingers and the third metacarpal bone is an immobile structure, the authors proposed a new quantitative method to determine the finger scissoring, which can represent malrotation. The authors use the angle formed between the axis of middle and distal phalanges of each of flexed fingers and the axis of the third metacarpal bone. The purpose of the present study was to determine whether the aforementioned angle was symmetrical in a cohort of healthy individuals with use of C-arm fluoroscopic examination.

Material and Method

The present study was approved by the Institutional Review Board, Royal Thai Army Medical Department and all volunteers provided informed consent after explanation of the present study. Volunteers were recruited by randomization from the employees of the institution where the research was carried out. The hospital where the recruitment was done employed over 4,000 individuals with a varied work force such as maintenance, housekeeping and skilled trades, as well as the allied health professions. All volunteers met the following inclusion criteria, (1) age between 20-50 years and (2) no history of hand injury, arthritis of the hands, previous hand surgery, or with a suspicion of pregnancy. Participation in the present study was voluntary and no compensation was offered.

The authors recruited 31 volunteers providing 248 fingers (index, middle, ring, and small). There were 12 men and 19 women with an average age of 37.7 (range 22-50). On the basis of the previous work of Tan et al[7], each volunteer placed their hands in a special positioning device that passively held the meta-carpophalangeal (MCP) and proximal interphalangeal (PIP) joints in full flexion with distal interphalangeal (DIP) joint in full extension (Fig. 1, 2). The wrist was in neutral alignment. Antero-posterior fluoroscopic image of each hand was then taken. The printed fluoroscopic image was scanned into a digital file.

Rotation was quantified by measuring the angle formed between the axis of middle and distal phalanges of each of flexed fingers and the axis of the third metacarpal bone (Fig. 3). The measurement was performed by a single observer using angular measurement software (MB-Ruler 4.0; MB-Software solutions, Germany).

In order to reduce the effect of the x-ray beam projection variation, which may cause the variation of the measured angle, the authors also analyzed the difference between the angles of each finger and the angle of ipsilateral middle finger. For example, if the measured angles of left index, middle, ring and small fingers were -7, 2, 10 and 21 degrees respectively, the calculated difference values of index, ring and small fingers from the value of middle finger would be -9, 8 and 19 degrees respectively.

The mean and the 95% confidence intervals were calculated for angles of each digit. The data was recorded and analyzed on Microsoft Excel 2010 (Microsoft, Chicago, Illinois). Statistical analysis was done using IBM SPSS Statistics version 19.0 (SPSS

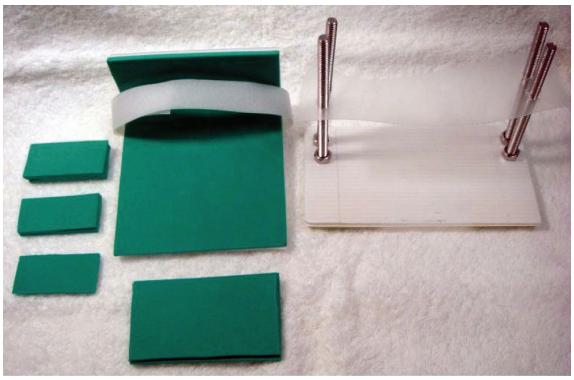

Fig. 1 Special hand positioning device, modified from the previous work of Tan et al[7], that passively held the MCP and PIP joints in full flexion with DIP joint in full extension

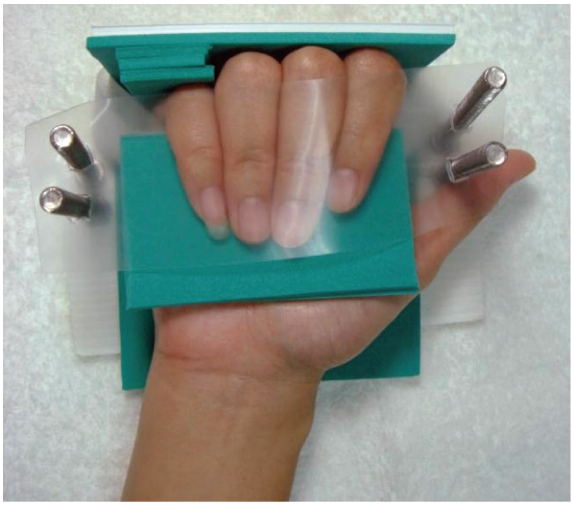

Fig. 2 Photograph of hand positioned in the device. Transparent plastic belt holds the PIP joint in full flexion and allows the examiner to confirm the DIP joint extension. Placement of additional pad in the palm helps passive extension of DIP joint

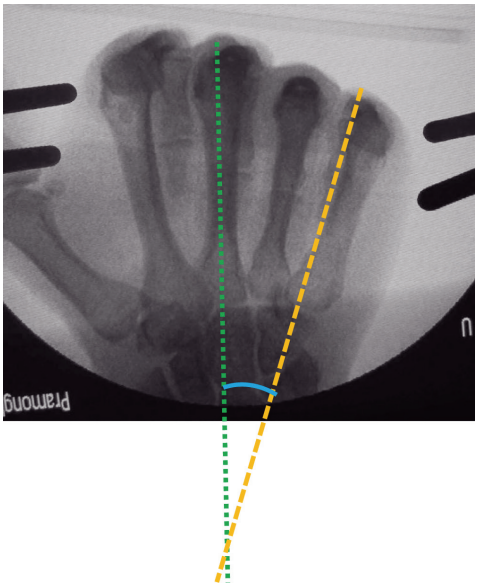

Fig. 3 Angular measurement. A round dotted line represents the axis of the third metacarpal bone. A dash line represents the axis of the middle and distal phalanges of the small finger

Inc., Chicago, Illinois) and MedCalc version 11.4 (MedCalc Software, Mariakerke, Belgium). Pair t-test was performed to determine the symmetry of the angles between both hands. Agreement analysis by Bland-Altman plot was used to determine the difference of the angle between both hands whether they were within mean difference of ± 1.96 SD. A p-value of less than 0.05 was set for significant difference.

To evaluate the reproducibility of this measuring technique, the angle measurement of each finger was repeated by the same observer 6 months later and by the other orthopedic surgeon to determine the intra- and interobserver reliability, respectively. The data were interpreted with intraclass correlation coefficient (ICC).

Results

The result for the measured angles of each finger is provided in Table 1. Each finger was matched and analyzed individually to its pair. There were no significant differences between both hands. Rotation of the index finger averaged -4.18° on the right versus -3.96° on the left (p = 0.838); the middle finger, 5.49° versus 4.94° (p = 0.546); the ring finger, 13.16° versus 12.66° (p = 0.620); and the small finger, 23.44° versus 22.79° (p = 0.641), left versus right respectively.

As illustrated in Fig. 4, Bland-Altman plot analysis revealed that, most subjects had angle differences between each pair of fingers within the range of ± 1.96 SD (94% for index, 100% for middle, ring and small fingers).The genders had no effect on the symmetry (p > 0.3).

The results, as demonstrated in Table 2, are the difference between the angles of each finger and

Table 1. Normal ranges of digital rotation (n = 31)

Finger	Right hand*(°)		Left hand*(°)		Mean difference	Standard error	95% confidence interval	p-value
	Mean	SD	Mean	SD				
Index	-4.18	5.72	-3.96	6.50	-0.2148	1.0410	-2.3409 to 1.9112	0.838
Middle	5.49	6.08	4.94	4.36	0.5429	0.8898	-1.2742 to 2.3600	0.546
Ring	13.16	5.85	12.66	4.37	0.5055	1.0094	-1.5560 to 2.5670	0.620
Small	23.44	7.62	22.79	5.28	0.6458	1.3703	-2.1528 to 3.4444	0.641

* Positive value = finger trajectory points radial relative to third metacarpal, negative value = ulnar

Table 2. Angular relationship of each finger with respect to the angle of middle finger (n = 31)

Finger	Right hand(°)		Left hand(°)		Mean difference	Standard error	95% Confidence interval	p-value
	Mean	SD	Mean	SD				
Index	9.66	3.88	8.90	4.16	0.7577	0.8713	-1.0216 to 2.5371	0.391
Ring	7.68	3.97	7.72	3.46	0.0374	0.6304	-1.2500 to 1.3249	0.953
Small	17.95	5.96	17.85	5.93	-0.1029	0.9986	-2.1423 to 1.9365	0.919

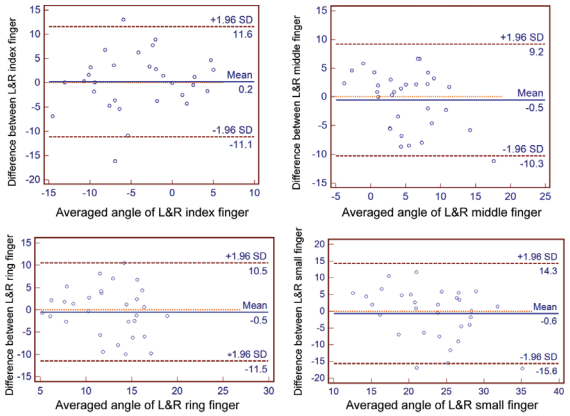

Fig. 4 Bland-Altman plot analysis revealed that most of angle differences fell into the range of ± 1.96 SD

the angle of the middle finger. It is apparent from the table that the differences of angle of index, ring and small fingers relative to the angle of ipsilateral middle finger are statistically symmetrical ($p > 0.05$).

The reproducibility of measuring technique was good as shown by the intraobserver ICC ($r = 0.802$-0.985) and interobserver ICC ($r = 0.742$-0.889) ($p < 0.05$) in Table 3 and Table 4, respectively.

Discussion

Malrotation of the finger is a common complication of finger fractures. Significant malrotation will result in functional impairment, pain from joint malalignment and diminished grip strength[4,14].

Table 3. Intraobserver ICC

Finger	Right	Left
Index	0.955	0.802
Long	0.972	0.923
Ring	0.985	0.952
Small	0.961	0.954

Table 4. Interobserver ICC

Finger	Right	Left
Index	0.832	0.742
Long	0.889	0.874
Ring	0.841	0.809
Small	0.784	0.850

Thereupon, early recognition of malrotation is necessary. Opgrande and Westphal[15] demonstrated that 1-degree rotation of metacarpal fracture could produce five degrees of fingertip rotation. Ten degrees of malrotation, which risks as much as 2 cm of overlap at the fingertips[16,17]. Bansal and Craigen[13] described that, by using simple trigonometry, a five-degrees malrotation in the proximal phalanx results in a translation of 0.3 to 0.5 cm at the tip of the finger for a finger measuring 3 to 6 cm from the PIP joint to the fingertip.

Despite the fact that the easiest and most used method to determine malrotation is the clinical test by flexing all fingers and observe any finger overlapping[6], there is variation of 50% or less digital overlap in a normal population[7]. In addition, the contralateral hand should not be used for comparison of digit overlap because of side-to-side asymmetry and variability[7]. The authors measured digital alignment with the angular measurement using a quantification method, instead of the distance, since the angle is theoretically constant regardless of the finger length. The intra- and interobserver ICC demonstrated the good reproducibility of this measuring technique. When matched to its pair on the contralateral hand, the angles measured by the authors' proposed technique were statistically symmetrical. Another important finding was that the angular relationship of each finger to the angle of middle finger was also statistically symmetrical. Therefore, this angular relationship can also be used to purposefully reduce x-ray beam projection variation in addition to the side-to-side comparison of the angle alone. Given this information, the clinician could manage the debilitating rotational problems of finger fractures with more objectivity and could quantitatively document digital malrotation.

This angular measurement, the difference of angles and comparison to the contralateral hand can probably be used as an additional alternative to determine the finger rotation, particularly in whom physical examination reveals equivocal digital overlap or who sustains multiple digit injuries, which the adjacent finger can't be used as a reference finger. Moreover, it may be beneficial for the intraoperative assessment during corrective osteotomy procedure and fixation of the fracture with severe comminution or with bone loss.

The other measuring techniques with the scaphoid convergence[2,3,7,8], the end-on examination of fingernails[7,9-14] and the parallelism related to the middle finger[7] were proposed. It has been reported

that all digits should converge to a point overlying the scaphoid tubercle when in flexion[2,3]. However, this concept has been challenged by Tan et al who studied in 30 volunteers and found that in no hand did all 4 fingers converge onto scaphoid tuberosity but the finger trajectories were apart from the scaphoid tuberosity at some distance[7]. Assessment of finger rotation with the end-on fingernail examination was described[7,9-14] but it was also considered inadequate to evaluate the rotation[14]. The measurement technique with parallelism determined by physical examination of angular relationship between the index, ring and small with respect to the middle finger was recently proposed[7]. A symmetrical parallelism between both hands of each individual was presented. However, the clinical data regarding its reproducibility is still limited.

Although the present study was able to determine symmetry of the angles and establish the normal values for a baseline assessment, the limitations of the present study is lacking of the comparison group with fractures. Further comparative studies with the other techniques along with the fracture group are required.

To conclude, the angle formed between the axis of flexed fingers and the third metacarpal bone measured from fluoroscopic images was proposed for an additional alternative to determine the finger rotation. From the present study, the angles were statistically symmetrical between both hands. The angular relationship between each finger with respect to the middle finger can also be used to purposefully reduce x-ray beam projection variation.

Acknowledgement

The authors are grateful to Miss Supak Saengow for her invaluable help with statistical analysis. The authors also owe our deepest gratitude to Dr. Korapat Mayurasakorn for his encouragement in the completion of the present study.

Potential conflicts of interest

None.

References

1. Chung KC, Spilson SV. The frequency and epidemiology of hand and forearm fractures in the United States. J Hand Surg Am 2001; 26: 908-15.
2. Ashkenaze DM, Ruby LK. Metacarpal fractures and dislocations. Orthop Clin North Am 1992; 23: 19-33.
3. Jupiter JB, Axelrod TS, Belsky MR. Fractures and dislocations of the hand. In: Browner BB, Jupiter JB, Levine A, Trafton P, editors. Skeletal trauma: fractures, dislocations, ligamentous injuries. 3rd ed. Philadelphia: Saunders; 2003: 1153.
4. Stern PJ. Fractures of the metacarpals and phalanges. In: Green D, Hotchkiss R, Pederson WC, Wolfe S, editors. Green's operative hand surgery. 5th ed. Philadelphia: Elsevier; 2005: 277-341.
5. Ip WY, Ng KH, Chow SP. A prospective study of 924 digital fractures of the hand. Injury 1996; 27: 279-85.
6. Rosenwasser MP, Quitkin HM. Malunion and other posttraumatic complications in the hand. In: Berger RA, Weiss APC, editors. Hand surgery. Philadelphia: Lippincott Williams & Wilkins; 2004: 207-31.
7. Tan V, Kinchelow T, Beredjiklian PK. Variation in digital rotation and alignment in normal subjects. J Hand Surg Am 2008; 33: 873-8.
8. Chang J. Plastic surgery: contributions to hand surgery. In: Mathes SJ, Hentz VR, editors. Plastic surgery. Vol. VII: The hand and upper limb, Part 1. 2nd ed. Philadelphia: Saunders/Elsevier; 2005: 20.
9. Barton NJ. Fractures and joint injuries of the hand. In: Wilson JN, editor. Watson-Jones fractures and joint injuries. 6th ed. Edinburgh: Churchill Livingstone; 1982: 739-88.
10. Royle SG. Rotational deformity following metacarpal fracture. J Hand Surg Br 1990; 15: 124-5.
11. Davis TRC, Oni JA. Metacarpal and phalangeal fractures. In: Bulstrode C, Buckwalter J, Carr A, Marsh L, Fairbank J, Wilson-MacDonald J, et al., editors. Oxford textbook of orthopaedics and trauma. New York: Oxford University Press; 2002: 1873-89.
12. Calandruccio JH, Jobe MT. Fractures, dislocations and ligamentous injuries. In: Canale ST, Beaty JH, editors. Campbell's operative orthopaedics. 11th ed. Philadelphia: Mosby; 2008: 3921-78.
13. Bansal R, Craigen MA. Rotational alignment of the finger nails in a normal population. J Hand Surg Eur Vol 2007; 32: 80-4.
14. Henry MH. Hand fractures and dislocations. In: Bucholz RW, Court-Brown CM, Heckman JD, Tornetta P, editors. Rockwood and Green's fractures in adults. 7th ed. Philadelphia: Lippincott Williams and Wilkins; 2010: 709-80.
15. Opgrande JD, Westphal SA. Fractures of the hand. Orthop Clin North Am 1983; 14: 779-92.
16. Manktelow RT, Mahoney JL. Step osteotomy: a

precise rotation osteotomy to correct scissoring deformities of the fingers. Plast Reconstr Surg 1981; 68: 571-6.

17. Seitz WH Jr, Froimson AI. Management of malunited fractures of the metacarpal and phalangeal shafts. Hand Clin 1988; 4: 529-36.

การวัดการหมุนของนิ้วมือด้วยมุมระหว่างแกนนิ้วมือขณะงอเทียบกับกระดูกเมตาคาพัลของนิ้วกลาง

ชัชชนินทร์ มยุระสาคร, สุริยา ลือนาม, อรรคพัฐ โกสิยตระกูล, ขนิษฐา ลือนาม, สัญญา ประชาพร

วัตถุประสงค์: *เพื่อวัดมุมของนิ้วมือขณะงอ เทียบกับแกนของกระดูกเมตาคาพัลของนิ้วกลาง และเปรียบเทียบระหว่างมือทั้งสองข้างในประชากรปกติ ว่าสมมาตรกันหรือไม่*

วัสดุและวิธีการ: *อาสาสมัครจำนวน 31 ราย (ชาย 12 ราย และหญิง 19 ราย) อายุเฉลี่ย 38 ปี และไม่เคยได้รับบาดเจ็บที่มือ ตรวจโดยวางมือในอุปกรณ์ควบคุมให้ข้อนิ้วมือทุกนิ้วงอเต็มที่ และเหยียดข้อปลายนิ้วมือ ถ่ายภาพรังสีของมือด้วยฟลูออโรสโคป และวัดมุมด้วยคอมพิวเตอร์*

ผลการศึกษา: *ค่าเฉลี่ยของมุมของนิ้วชี้ นิ้วกลาง นิ้วนาง และนิ้วก้อย เท่ากับ -4.07 (SEM = 1.041), 5.22 (SEM = 0.889), 12.91 (SEM = 1.009) และ 23.11 (SEM = 1.370) องศา ตามลำดับ มุมของแต่ละนิ้วของมือทั้งสองข้างมีความสมมาตรกัน (p = 0.838, 0.546, 0.620 และ 0.641 ตามลำดับ) นอกจากนั้น ผลต่างของมุมแต่ละนิ้วเมื่อเทียบกับมุมของนิ้วกลางมีความสมมาตรกันระหว่างมือทั้งสองข้างเช่นเดียวกัน*

สรุป: *การเปรียบเทียบมุมที่เสนอ ระหว่างมือทั้งสองข้าง สามารถใช้ประเมินการหมุนของนิ้วมือได้ นอกจากนั้น การเปรียบเทียบผลต่างระหว่างมุมแต่ละนิ้วเทียบกับมุมของนิ้วกลาง สามารถใช้ได้เช่นกันในกรณีที่ต้องการลดความแปรปรวนของค่ามุมจากการถ่ายรังสี*