Locked Intramedullary Nail: Metacarpal Geometry Study in Adults

Chinnakart Boonyasirikool MD*,
Sunyarn Niempoog MD*

** Department of Orthopedics Surgery, Faculty of Medicine, Thammasat University, Pathumthani, Thailand*

Background: *Ideal fixation for metacarpal fracture should provide immediate stability to allow early rehabilitation. Locked intramedullary nail may fulfill the need. Metecarpal geometry has to be studied in order to design the locked intramedullary nail.*
Objective: *To study metacarpal geometry in adult cadaver for locked intramedullary nail design.*
Material and Method: *Radiographs of metacarpals taken from 50 embalmed adult cadavers were measured for essential parameters for locked intramedullary nail design. Total length, proximal metaphyseal width, distal metaphyseal width, isthmus width and medullary canal width were measured. The parameters were analyzed by descriptive statistic.*
Results: *The average total lengths were ranged from 44.53 to 65.42 mm. The average metaphyseal widths of metacarpal bone were between 11.42 to 16.42 mm. The average medullary canal widths were between 3.05 to 6.74 mm. The extreme small (less than 3 mm) medullary canals were found in index, middle, ring and small metacarpals.*
Conclusion: *The results of our study provide crucial preliminary data for locked metacarpal nail design for adult patient.*

Keywords: *Metacarpal, Metacarpal fracture, Intramedullary nail, Bone geometry*

J Med Assoc Thai 2014; 97 (Suppl. 8): S194-S198
Full text. e-Journal: *http://www.jmatonline.com*

Fracture of metacarpal bone is a common fracture in the hand. The overall incidence is 18% of all fractures in forearm and hand[1]. Poorly treated metacarpal fractures may cause stiffness, shortening and scissoring fingers[2]. Various types of treatment have been proposed[3]. Unstable and malaligned metacarpal shaft fractures need a stable fixation to provide adequate strength to resist possible deforming forces. The ideal method of fixation should provide stable fixation to allow early rehabilitation while minimizing soft tissue damage. It should also be simple and easy to perform.

Intramedullary fixations have been an interesting technique due to benefit by lack of soft tissue stripping around fracture site. Flexible nail function an internal splint, prevents displacement by filling up the canal together with three-point fixation mechanism. Multiple techniques have been published in literatures. Single intramedullary pin is limited to simple transverse fracture where rotation is controlled by the intermetacarpal ligament[4]. Multiple small pre-bent intramedullary pins or "Bouquet osteosynthesis" add more stability to rotational control by three-point fixation mechanism of Ender's concept[5-7]. Although both techniques are more stable, they are still contraindicated in long oblique and bicortical comminution and need period of postoperative immobilization[6]. Recently, Orbay et al[4] have reported success in using intramedullary nail with locking option. By its locking mechanism, indication of intramedullary nail is expanded to spiral and comminuted fractures. However, they still recommended a metacarpophalangeal, flexion block splint in these unstable patterns. Some drawbacks are that the proximal end of a nail may irritate extensor tendons, the patient needs splinting to prevent extensor tendon irritation and the nail needs to be removed routinely.

Locked intramedullary nail has a potential to be the standard fixation for metacarpal shaft fractures in order to provide an immediate stability for all fracture configurations with less soft tissue disturbance. The authors anticipate a benefit of developing a new locked intramedullary nail for adults. In the present study, the authors aimed to provide geometry of adult cadaveric metacarpal bone for further development of a locked intramedullary metacarpal nail.

Correspondence to:
Boonyasirikool C, Department of Orthopedics Surgery, Faculty of Medicine, Thammasat University, 99 Moo 18, Khlong Nueng, Khlongluang, Pathumthani 12120, Thailand.
Phone: 08-1866-2825, Fax: 0-2926-9793
E-mail: chinnakartb@gmail.com

Material and Method

The authors harvested 50 hands from embalmed adult cadavers (age ranged from 56 to 85 years at the time of death). Not all cadavers had a history of fracture in hand. Surrounding soft tissue was stripped off metacarpal bones. All specimens were evaluated by inspection for any sign of previous fracture, malunion and surgery involving the bone. None of the specimen was rejected. The authors placed each bone on radiolucent board and fixed them with cardboard mount. The authors then obtained radiograph for each metacarpal both in posteroanterior and lateral views. The interested parameters were measured in plain radiograph using non-digital vernier caliper including total length (TL), proximal metaphyseal width (PW), distal metaphyseal width (DW), isthmus width (IW) and medullary canal diameter (CW) at the narrowest part (Fig. 1). TL was the greatest length of metacarpal, metaphyseal width was the widest diameter of metaphysis, isthmus width was the narrowest shaft of metacarpal and medullary canal diameter was the narrowest part of medullary canal measured between inner cortexes at the same level. All measurements were analyzed using SPSS version 15.0 software.

Results

The average isthmus width (IW) of ring metacarpal was 5.89 mm (95% confidence interval [CI], 5.01-6.77 mm) which was the smallest one. The IW of metacarpal are larger in order from ring, small, middle, index and to the thumb metacarpal. The average medullary canal width (CW) of ring is also smallest which is equal to 3.05 mm (95% confidence interval [CI], 2.27-3.83 mm) measured in lateral radiograph. The average CW was wider in the same order with cortical average IW. Narrow CW (less than 3 mm) can be found in index, middle ring and small metacarpals.

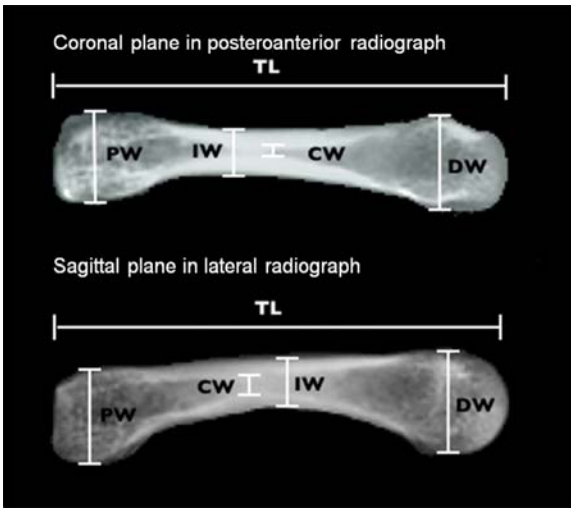
The average total length (TL) is ranged from 44.53 mm (95% confidence interval [CI], 42.49-46.57 mm) of thumb metacarpal to 65.42 mm (95% confidence interval [CI], 61.67- 69.17 mm) of index metacarpal. The shortest metacarpal in the present study belonged to small metacarpal (40.4 mm), while the longest were from index metacarpal (73.1 mm).

The average distal metaphyseal width (DW) of ring and small are apparently smaller than other metacarpals. The narrowest average DW measured from small metacarpal in frontal plane was 11.89 mm (95% confidence interval [CI], 10.84-12.94 mm). The widest average DW is 15.26 mm (95% confidence interval [CI], 13.6-16.92 mm) from index metacarpal in sagittal plane. In proximal part, the average proximal metaphyseal width (PW) is ranged from 11.42 mm (95% confidence interval [CI], 10.20-12.64 mm) in ring metacarpal to 16.42 mm (95% confidence interval [CI], 14.71-18.13 mm) in index metacarpal (Table 1, 2).

Discussion

Ideal metacarpal nail fixation should be simple but strong enough to resist all plane of deforming forces regardless of fracture patterns to allow immediate rehabilitation with less soft tissue violation. Moreover, secondary removal should not be necessary. Single intramedullary pin, wiring and multiple pre-bent pins do not provide sufficient stability in unstable fracture configurations (long oblique, spiral and, bicortical comminution). Plating is stable method of fixation but own major disadvantages of soft tissue adhesion and stiffness. Locked intramedullary nail may achieve ideal metacarpal fixation characteristics.

To our knowledge, this is the first study to provide complete morphologic information important for designing locked metacarpal nail. A previous cadaveric study by Khanpetch P et al[8] reported mean lengths of metacarpal were between 40.6 to 64.9 mm, mean base width, comparable to our proximal width (PW), were between 7.6 to 15.6 mm and mean head widths, comparable to our distal width (DW), were between 8.2 to 13.9 mm. However, the investigators did not measure the canal diameter that is crucial for



TL = total length; PW = proximal metaphyseal width; DW = distal metaphyseal width; IW = isthmus width; CW = medullary canal width

Fig. 1 Parameters measured in the study.

Table 1. Coronal plane metacarpal geometry parameters from posteroanterior radiographs

Measurements (mm)	Small		Ring		Middle		Index		Thumb	
	Min-max	Mean ± SD	Min-max	Mean ± SD	Min-max	Mean ± SD	Min-max	Mean ± SD	Min-max	Mean ± SD
TL	40.4-58.2	50.26±3.25	48.7-60.2	54.89±13.83	54.8-70.3	63.79±3.90	57.3-72.8	65.42±3.75	40.5-51.2	44.95±2.01
PW	9.4-14.0	11.63±1.86	9.7-14.0	11.74±1.41	13.2-18.3	15.21±1.69	13.5-18.7	16.32±1.42	13.6-18.5	15.32±1.70
DW	9.4-13.7	11.89±1.05	10.8-15.4	12.79±1.75	13.0-18.0	14.68±1.60	13.2-18.1	14.79±1.51	12.8-18.4	15.00±1.60
IW	5.2-7.2	6.32±0.82	5.0-7.3	6.00±0.94	5.9-9.3	7.79±1.13	6.4-9.2	7.74±0.99	7.1-10.2	8.53±1.26
CW	2.4-4.5	3.36±0.60	2.2-4.3	3.21±0.85	2.5-5.2	3.84±1.12	2.3-5.0	3.63±1.12	4.2-7.8	5.58±1.17

TL = total length; PW = proximal metaphyseal width; DW = distal metaphyseal width; IW = isthmus width; CW = medullary canal width

Table 2. Sagittal plane metacarpal geometry parameters from lateral radiographs

Measurements (mm)	Small		Ring		Middle		Index		Thumb	
	Min-max	Mean ± SD	Min-max	Mean ± SD	Min-max	Mean ± SD	Min-max	Mean ± SD	Min-max	Mean ± SD
TL	40.3-58.2	50.21±3.22	47.7-61.2	54.11±3.77	53.3-68.3	63.00±3.50	57.3-73.1	64.95±3.66	40.4-52.4	44.53±2.04
PW	10.2-14.1	12.11±1.79	9.8-13.5	11.42±1.22	12.4-17.2	14.21±1.44	14.5-18.8	16.42±1.71	13.3-17.2	15.11±1.56
DW	10.1-14.3	12.00±1.33	10.2-15.1	12.47±1.87	13.2-16.3	14.58±1.17	13.4-18.7	15.26±1.66	12.9-17.4	14.68±1.63
IW	5.1-7.7	6.47±1.07	4.8-7.2	5.89±0.88	5.5-10.1	7.95±2.17	6.1-10.0	8.05±1.78	7.1-11.7	9.32±2.11
CW	2.4-4.9	3.89±0.88	2.2-4.0	3.05±0.78	1.7-7.3	4.26±2.81	3.1-5.5	4.32±1.11	4.3-9.3	6.74±2.21

TL = total length; PW = proximal metaphyseal width; DW = distal metaphyseal width; IW = isthmus width; CW = medullary canal width

nail design. Extreme short metacarpals and small metaphyseal portions in this study belonged to female cadavers. Our measurement expected to be higher due to being uncategorized by sex.

The smallest medullary canal was 3.05 mm (95% confidence interval [CI], 2.27-3.83 mm) from ring metacarpal. The intramedullary nail diameter should be largest, yet small enough to insert into most metacarpals. Therefore, we considered 3 mm-diameter nail would be appropriate for metacarpal. If the diameter is smaller than 3 mm, it will decrease stiffness of a nail as well as affect a size of screws and locking screw holes. Because metacarpal is not a weight-bearing bone, metacarpal nail act as stable internal splinting to allow early rehabilitation, larger size of nail may not be necessary. A careful pre-operative template is needed in extremely small medullary canal especially in index, middle, ring and small metacarpal.

The total length of metacarpal indicates an appropriate length of the nail. The present study found average metacarpal length ranged from 44.53 to 65.42 mm. The thumb metacarpal is relatively short and has the shortest length in the present study, 40.4 mm, similar findings also found in previous study[8]. The nail must be shorter than the actual length of the metacarpal to allow proximal tip of nail to sink into the bone to prevent impingement between nail tip and extensor apparatus. From this study, appropriate length should be between 30 to 55 mm to fit all possible lengths of metacarpal, especially extremely short metacarpal in female thumb[11].

The proximal and distal metacarpal widths in the present study provide data for proper locking screw length for metacarpal nail. The average metacarpal widths are between 11.42 to 16.42 mm. According to the measurement of the metacarpal width, the locking screw length should range from 10 to 18 mm. Shorter screw lengths have to be provided for very small metaphysis in females[8].

The population in the present study was typical Southeast Asian adult that may differ from other ethnics[9-11]. Measuring bone geometry from radiograph may not represent an actual size of medullary canal because of poorly defined inner cortex in some samples. Nevertheless, the locked metacarpal nail does not have to be perfectly fit to a canal. The locking screw at both ends add stability to bone-nail construct, so nail diameter can be small to fit to most of canals.

Conclusion

The results of the present study provide preliminary data for locked metacarpal nail design. The average medullary canal widths of metacarpal are between 3.05 to 6.74 mm. The average lengths of metacarpal range were from 44.53 to 65.42 mm. In addition, the average metaphyseal widths were between 11.42 to 16.42 mm. These measurements are crucial data for designing locked metacarpal nail for adults.

Acknowledgement

Special thanks should be given to technicians of the cadaveric laboratory of the anatomydepartment and radiology department for their help in this project.

What is already known on this topic?

Khanpetch P et al[8] have studied metacarpal geometry in Thai cadavers. But the study did not provide any important data for developing an intramedullary device, which is of medullary canal width. The authors are interested in this parameter so to conduct further research.

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. Henry M. Fractures and dislocations of the hand. In: Bucholz RW, Heckman JD, Court-Brown CM, editors. Rockwood and Green's fractures in adults. 6th ed. Philadelphia: Lippincott Williams & Wilkins; 2006: 772-857.
3. Weistein LP, Hanel DP. Metacarpal fracture. J Am Soc Surg Hand 2002; 2: 168-80.
4. Orbay JL, Indriago I, Gonzalez E, Badia A, Khouri R. Percutaneous fixation of metacarpal fractures. Operat Tech Plast Reconstr Surg 2002; 9: 138-42.
5. Foucher G. "Bouquet" osteosynthesis in metacarpal neck fractures: a series of 66 patients. J Hand Surg Am 1995; 20 (3 Pt 2): S86-90.
6. Gonzalez MH, Igram CM, Hall RF Jr. Flexible intramedullary nailing for metacarpal fractures. J Hand Surg Am 1995; 20: 382-7.
7. Gonzalez MH, Hall RF Jr. Intramedullary fixation of metacarpal and proximal phalangeal fractures of the hand. Clin Orthop Relat Res 1996; (327): 47-54.
8. Khanpetch P, Prasitwattanseree S, Case DT, Mahakkanukrauh P. Determination of sex from the metacarpals in a Thai population. Forensic Sci Int 2012; 217: 229-8.

9. Aroonjarattham P, Jiamwatthanachai P, Mahaisavariya B, Kiatiwat T, Aroonjaratthammd K, Sitthiseripratip K. Three-dimensional morphometric study of the Thai proximal humerus: cadaveric study. J Med Assoc Thai 2009; 92: 1191-7.
10. Tan SH, Teo EC, Chua HC. Quantitative three dimensional anatomy of cervical, thoracic and lumbar vertebrae in Chinese Singaporean. Eur Spine J. 2004: 13: 137-146.
11. Zindrick MR, Wiltse LL, Doornik A, Widell EH, Knight GW, Patwardhan AG, et al. Analysis of the morphometric characteristics of the thoracic and lumbar pedicles. Spine (Phila Pa 1976) 1987; 12: 160-6.

การศึกษาลักษณะกระดูก metacarpal ในผู้ใหญ่เพื่อพัฒนาแกนโลหะดามกระดูก

ชินกาจ บุญญสิริกูล, สัญญาณ เนียมปุก

ภูมิหลัง: *การยึดตรึงกระดูก metacarpal หักที่ดีต้องแข็งแรงพอที่สามารถให้ผู้ป่วยเริ่มฟื้นฟูสภาพได้เร็วที่สุด การดามกระดูกโดยแกนโลหะชนิดมีสกรูยึดน่าจะเป็นวิธีที่สามารถตอบสนองจุดมุ่งหมายดังกล่าวได้ การศึกษาลักษณะกระดูก metacarpal จึงจำเป็นอย่างยิ่งสำหรับการออกแบบแกนโลหะยึดกระดูก metacarpal*

วัตถุประสงค์: *ศึกษาลักษณะกระดูก metcarpal เพื่อพัฒนาแกนโลหะดามกระดูกที่เหมาะสมสำหรับผู้ป่วย*

วัสดุและวิธีการ: *การวัดภาพถ่ายรังสีของกระดูก metacarpal ที่ได้จากการเลาะออกจากศพจำนวน 50 ร่าง โดยวัดความยาวของกระดูกส่วนที่กว้างที่สุดของหัวกระดูกส่วนที่กว้างที่สุดของฐานกระดูกส่วนที่แคบที่สุดของกระดูกและช่วงที่แคบที่สุด ของโพรงกระดูกวิเคราะห์ข้อมูลที่ได้ด้วยสถิติเชิงพรรณนา*

ผลการศึกษา: *ค่าเฉลี่ยของความยาวกระดูก metacarpal อยู่ระหว่าง 44.53 ถึง 65.42 มิลลิเมตร ค่าเฉลี่ยความกว้าง ของส่วนที่กว้างที่สุดของหัวกระดูกและส่วนที่กว้างที่สุดของฐานกระดูกอยู่ระหว่าง 11.42 ถึง 16.42 มิลลิเมตร ความกว้างเฉลี่ยของส่วนที่แคบที่สุดโพรงกระดูกอยู่ระหว่าง 3.05 ถึง 6.74 มิลลิเมตร พบส่วนที่แคบที่สุดโพรงกระดูกน้อยกว่า 3 มิลลิเมตรในกระดูก metacarpal ของนิ้วชี้ นิ้วกลาง นิ้วนางและนิ้วก้อย*

สรุป: *การศึกษาให้ข้อมูลเกี่ยวกับลักษณะกระดูก metacarpal ที่จำเป็นและสามารถนำไปใช้พัฒนาแกนโลหะ ดามกระดูก metacarpal สำหรับผู้ป่วยผู้ใหญ่*