Int. J. Morphol.,
40(4):1075-1080, 2022.

Morphometric Evaluation of Second to Fifth Metacarpals for Retrograde Intramedullary Headless Screw Fixation

Evaluación Morfométrica del Segundo al Quinto Metacarpianos para la Fijación Retrógrada con Tornillos Intramedulares sin Cabeza

Abdullah Örs[1]; Tuncay Çolak[1]; Belgin Bamaç[1]; Medine Isık[1]; Aydın Özbek[2]; Gür Akansel[3]; Kaya Memisoglu[4] & Behçet Ayyıldız[2,5]

ÖRS, A.; ÇOLAK, T.; BAMAÇ, B.; ISIK, M.; ÖZBEK, A.; AKANSEL, G.; MEMISOGLU, K. & AYYILDIZ, B. Morphometric evaluation of second to fifth metacarpals for retrograde intramedullary headless screw fixation. *Int. J. Morphol., 40(4)*:1075-1080, 2022.

SUMMARY: Intramedullary headless screw fixation has come to the fore in the treatment of metacarpal fractures in recent years with its advantages. Our aim was to evaluate the metacarpal morphometry for retrograde intramedullary entrance and to determine the optimal entry point. Computed tomography images of 105 patients including 64 men and 41 women, were examined. Distal and proximal metacarpal widths, medullary cavity width, cortex thickness and the measurements of the optimal entry site in volar-dorsal and radio-ulnar directions were measured in both coronal and sagittal planes. In the sagittal plane, the second metacarpal had the widest proximal width (16.29 mm), distal width was greatest in the third metacarpal (14.34 mm) which was significantly different between the sexes ($p<0.001$). Third metacarpal had the widest medullary cavity width in the sagittal plane (4.12 mm). In the coronal plane, it was the second metarcarpal with the widest proximal (16.14 mm) and distal width (13.92 mm) and was also the longest (66.32 mm). Unlike the sagittal plane, the medullary cavity width in the coronal plane was at the widest (4.06 mm) in fifth metacarpal. The points determined for optimal entry were respectively (4.60 mm; 4.97 mm; 4.55 mm; 4.36 mm) in the dorsal-volar plane, close to the dorsal side. There was no significant difference between the sexes for optimal insertion point in the sagittal planes in all the measured metacarpals. Considering its three dimensional structure, metacarpal bones have irregular morphometric properties and these features differ in sagittal and coronal planes. The optimal entry site is located in the midline in the coronal plane, while it is located in the sagittal plane close to the dorsal part. Knowing these properties can reduce the complication rate by reducing entry attempts and help select the correct material.

KEY WORDS: Metacarpal; Morphometry; Retrograde; Intermedullary fixation.

INTRODUCTION

Metacarpal fractures are common in the community. The incidence was reported to be 13.6 per 100.000 people per year in the USA (Nakashian *et al*., 2012). The incidence in hand fractures varies between 12.2 % and 44 % in various studies (Pun *et al*., 1989; Kollitz *et al*., 2014). Treatment is mostly conservative. However, there is no consensus among the methods of k-wire, plate or intramedullary headless screw fixation for treatment when surgical intervention is required (Mirza *et al*., 2018; Dreyfuss *et al*., 2019). However, in recent years, the intramedullary screw fixation method has come to the fore due to providing an earlier range of motion (Ruchelsman *et al*., 2014; Doarn *et al*., 2015), minimal invasion requirement (Kaiser *et al*., 2009), short operation time (Corkum *et al*., 2013; Kibar *et al*., 2021) and low cost (Labèr *et al*., 2020).

Intramedullary fixation can be performed either retrograde or anterograde, according to the fracture site. It is important to know the anatomical features for the correct entry site selection. There are very few morphometric studies for the intramedullary headless screw fixation method. One of them investigated the use of materials in appropriate sizes for retrograde intramedullary fixation (Dunleavy *et al*., 2022). Another investigated the optimal point for antegrade entry (Hoang *et al*., 2021).

[1] Department of Anatomy, Faculty of Medicine, Kocaeli University, Kocaeli, Turkey.
[2] Department of Anatomy, Faculty of Medicine, Istinye University, Istanbul, Turkey.
[3] Department of Radiology, Faculty of Medicine, Kocaeli University, Kocaeli, Turkey.
[4] Department of Orthopedics and Traumatology, Faculty of Medicine, Kocaeli University, Kocaeli, Turkey.
[5] Anatomy PhD Program, Graduate School of Health Sciences, Kocaeli University, Kocaeli, Turkey.

Received: 2022-04-05 Accepted:2022-05-09

The aim of surgical operations is to give the most appropriate shape to the anatomical structure (Rivlin *et al.*, 2015). In addition, anatomical features are important for defining the fracture pattern and determining the optimal treatment option (Blazar & Leven, 2010). Metacarpal morphometry should be well understood in order for intramedullary headless screw fixation to be successful and to minimize complications. Knowing the optimal point for retrograde insertion can reduce the complication rate and increase the success of the operation by avoiding minimal invasion and repetitive attempts. In addition, the thickness of the medullary cavity and the morphometry of the metacarpals will be useful in choosing the screw diameter and length. The aim of our study was to determine the optimal insertion site and important parameters for screw selection in women and men in retrograde intramedullary headless screw fixation procedures.

MATERIAL AND METHOD

In this retrospective study hand computed tomography (CT) imaging taken at our institution for any reason between 2010-2020 were used. Images of patients under the age of 18 and those with fractures in their metacarpal bones, tumors, inflammatory diseases and those that do not allow measurement for technical reasons were excluded from the study.

CT images were acquired with Toshiba Aquilion 64 or Toshiba Activion 16 Multislice CT (Toshiba Medical Systems, Otawara, Japan). Images were evaluated using the institutional Picture Archiving and Communication System (PACS) and Sectra Workstation IDS7 (Sectra AB, Linköping, Sweden) software was used for measurements.

Corrected CT images were used in our measurements. Morphometric parameters in the sagittal and coronal planes were measured for each of the second to fifth metarcarpals. A mean of two measurements made by two independent researchers was used. For each metacarpal in both the sagittal and coronal planes, the following measurements were made: distal width, proximal width, medullary cavity width, cortical thickness at the point of the narrowest medullary cavity width and optimal entry point measurements. In addition, length measurements were made in the coronal plane. See Figures 1A and 1B for descriptions of sagittal measurements and Figures 1C and1D for coronal measurements.

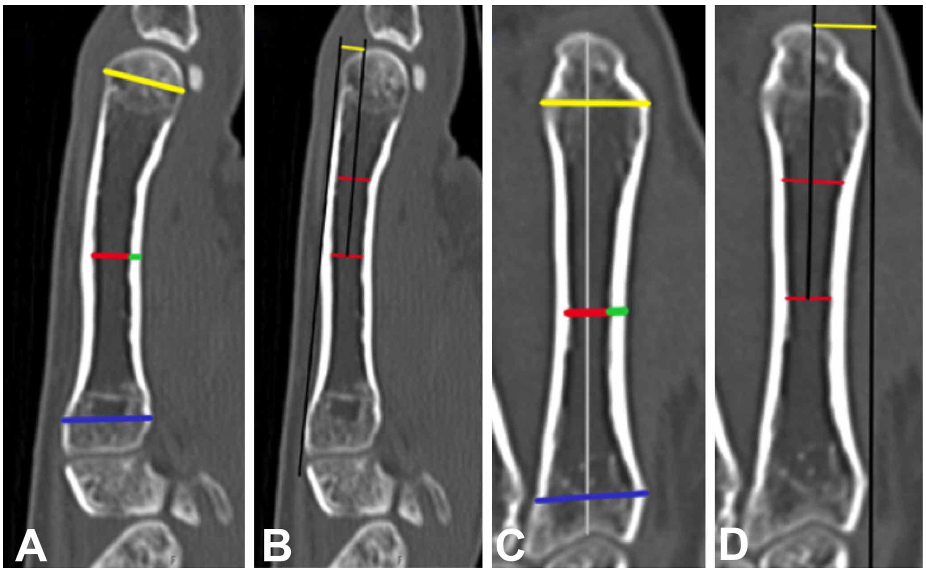

Fig. 1. Measurements. A: In the sagittal plane, distal width (yellow line), proximal width (blue line), medullary cavity width (red line), cortical thickness at the narrowest point of the medullary cavity (green line) are shown. B: In order to determine the optimal entry point in the sagittal plane, a line was drawn (red line) from the area where the narrowest medullary cavity width was and from the distal shaft part where the metacarpal angulation began, and the distance between the line passing through the midpoint of these two lines and the line passing through the dorsal side of the metacarpal (black lines) was measured (yellow line). C: In the coronal plane, distal width (yellow line), proximal width (blue line), medullary cavity width (red line), cortex thickness at the narrowest point of the medullary cavity (green line) are shown. D: In order to determine the optimal entry point in the coronal plane, a line was drawn from the area with narrowest medullary cavity width and the point between this line and the distal of the metacarpal (red lines) and the line passing through the midpoint of these two lines and the radial for the 2nd and 3rd metacarpals, for the 4th and 5th metacarpals, the distance between the lines (black lines) passing through the ulnar side was measured (yellow line).

Normal distribution of data sets was evaluated by Kolmogorov-Smirnov and Shapiro-Wilk tests. Intra-class correlation coefficient (ICC) was used to determine the degree of agreement between observers. Values between 0.75 and 0.90 are accepted as good fit and values between 0.90 and 1.00 as a excellent fit (Koo & Li, 2016). The t-test was used to compare two independent groups with parametric distribution and the Mann-Whitney U test was used to compare two independent groups with non-parametric properties. For statistical significance p<0.05 was considered significant at 95 % confidence. The Statistical Package for the Social Sciences (SPSS), version 22.0 program was used for statistical analysis (IBM Inc., Chicago, IL, USA).

The study was approved by the Kocaeli University Non-Interventional Ethics Committee with the decision number 80418770-730.99/85527 and project number 2020/348. The study was conducted in accordance with the principles of the Declaration of Helsinki.

RESULTS

CT images from 105 individuals (60.9 % men) were assessed mean male age was 31.97 ± 12.97 (min-max: 18-80) years and mean female age was similar at 36.00 ± 15.22 (min-max: 18-73) years (p=0.229). Most (64,8 %) of the images were on the right side and there was no significant difference between men and women in terms of side (p=0.285).

ICC ranged from 0.856 to 0.962 for a total of 11 parameters measured. Accordingly, it was accepted that the agreement between the two observers was between good and excellent.

Sagittal plane measurements are shown in Table I. The second metacarpal had the greatest proximal width in the sagittal plane. The third metacarpal had the greatest distal width. The medullary cavity width was located in the third metacarpal as the widest and there was no significant difference between men and women (p=0.223). The cortical thickness at the point of the narrowest medullary cavity thickness was the narrowest on the fifth metacarpal. There was no significant difference between males and females for the most suitable entry point in the sagittal plane (all p>0.05).

In the measurements made in the coronal plane (Table II), the second metacarpal had the widest distal and proximal width, followed by the third metacarpal. While the fifth metacarpal had the widest narrowest medullary cavity width, there was a significant difference between men and women (p=0.017). Although the second metacarpal is the longest finger, there significant difference between the sexes for the point determined as the most appropriate entry point in the coronal plane for the second (p<0.001), third (p=0.008) and fourth (p=0.040) metacarpals. See Figure 2 for optimal points for retrograde intramedullary entrances.

Table I. Measurements and statistical analysis in the sagittal plane

		2ND MC		3RD MC		4TH MC		5TH MC	
	Sex	Mean ± SD	p	Mean ± SD	p	Mean ± SD	p	Mean ± SD	p
Proximal width	M	16.80±1.12	0.000	15.46 ± 1.26	0.000	12.78 ± 1.18	0.000	11.60±1.47	0.000
	F	15.50±1.05		13.83 ± 0.97		11.47 ± 0.90		10.46±1.24	
	O	16.29±1.28		14.82 ± 1.40		12.27 ± 1.25		11.15±1.49	
Distal width	M	14.55±1.06	0.000	14.98 ± 1.17	0.000	14.01 ± 0.91	0.000	13.10±1.18	0.000
	F	13.21±1.09		13.34 ± 1.00		12.38 ± 0.80		11.52±0.78	
	O	14.02±1.25		14.34 ± 1.37		13.37 ± 1.18		12.48±1.30	
Medullary cavity width	M	3.67 ± 0.85	0.460	4.22 ± 0.86	0.223*	3.40 ± 0.77	0.228	3.77±0.80	0.200
	F	3.59 ± 0.83		3.96 ± 0.92		3.26 ± 0.73		3.60±0.79	
	O	3.64 ± 0.84		4.12 ± 0.89		3.34 ± 0.75		3.70±0.79	
Cortical thickness**	M	2.82 ± 0.43	0.003*	2.72 ± 0.53	0.007	2.22 ± 0.41	0.097*	2.07±0.57	0.049
	F	2.54 ± 0.44		2.48 ± 0.42		2.16 ± 0.50		1.86±0.43	
	O	2.70 ± 0.45		2.62 ± 0.51		2.20 ± 0.44		1.98±0.53	
Optimal Point ***	M	16.80±1.12	0.342*	4.98 ± 0.91	0.881	4.51 ± 0.74	0.462	4.38±1.02	0.720
	F	15.50±1.05		4.95 ± 0.79		4.62 ± 0.60		4.31±0.88	
	O	16.29±1.28		4.97± 0.86		4.55 ± 0.69		4.36±0.97	

M: male; F: female; O: Overall - the whole cohort; SD: Standard deviation; p: p value; t test used. * Mann Whitney-U test; ** measured at the narrowest medullary cavity width. ** * The optimal point was measured as the distance to the dorsal in sagittal sections.

Table II. Measurements and statistical analysis in the coronal plane.

	sex	2^{ND} MC Mean ± SD	p	3^{RD} MC Mean ± SD	p	4^{TH} MC Mean ± SD	p	5^{TH} MC Mean ± SD	p
Proximal width	M	16.69±1.72	0.000	13.57±1.22	0.000	12.25± 1.23	0.000	14.46±1.47	0.000
	F	15.27±1.33		12.15± 0.98		11.17± 0.97		12.87±1.18	
	O	16.14±1.72		13.01± 1.32		11.83± 1.25		13.84±1.59	
Distal width	M	14.42±1.35	0.000	14.32±1.14	0.000	12.32±1.26	0.000	12.04±1.55	0.001
	F	13.14±1.12		13.11±1.17		11.44±1.26		11.16±0.88	
	O	13.92±1.41		13.85±1.30		11.97±1.29		11.70±1.39	
Medullary cavity width	M	3.32±0.82	0.169*	3.30±0.77	0.763*	2.99±0.69	0. 035*	4.20±0.95	0.017
	F	3.17±0.96		3.29±0.79		2.73±0.55		3.80±0.78	
	O	3.24±0.88		3.30±0.77		2.89±0.65		4.06±0.91	
Cortical thickness**	M	2.69±0.54	0.026*	2.49±0.39	0.152*	2.08±0.59	0.362*	2.09±0.46	0.601*
	F	2.44±0.41		2.43±0.46		2.00±0.31		2.05±0.38	
	O	2.59±0.50		2.47±0.41		2.04±0.50		2.07±0.42	
Length	M	68.40±3.48	0.000	65.43±3.79	0.000	56.47±3.08	0.000	51.97±5.90	0.000*
	F	63.06±3.81		60.54±4.36		51.79±3.34		48.43±3.53	
	O	66.32±4.45		63.52±4.51		54.64±3.91		50.59±5.38	
Optimal Point ***	M	7.31±0.89	0.000	7.31±1.07	0.008	5.69±0.85	0.040	50.1±0.97	0.371
	F	6.50±0.89		6.83±0.91		5.34±0.74		4.81±0.89	
	O	7.04±0.95		7.13±1.03		5.51±0.82		4.94±0.94	

M: male; F: female; O: Overall - the whole cohort; SD: Standard deviation; p: p value; t test used. * Mann Whitney-U test was used; ** measured at the narrowest medullary cavity width. *** The optimal point was calculated as the distance to the radial side for the 2nd and 3rd metacarpals and as the distance to the ulnar side for the 4th and 5th metacarpals in coronal sections.

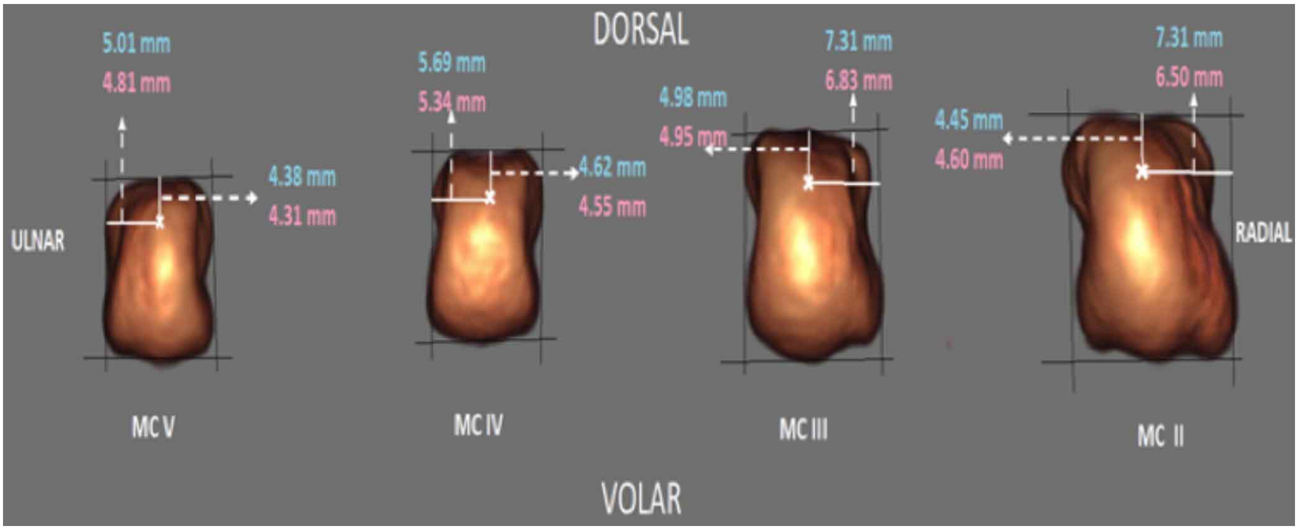

Fig. 2. Retrograde optimal points. Blue = male; pink = female; MC: metacarpal.

DISCUSSION

Understanding metacarpal anatomy is difficult due to considerable natural variation. Two-dimensional images can make this irregular bone structure difficult to understand. Although there are many studies concerning the morphometry of human metacarpals, these measurements were generally made using postero-anterior images of dry bone or x-ray radiographs. The literature has shown that the lengths of all metacarpals range between 44.53 and 65.42 mm (Boonyasirikool *et al*., 2015; Sephien *et al*., 2020). Wong *et al*. (2018) reported the second to fifth metacarpal bone lengths as 62, 59, 53, and 48 mm, respectively. Singla *et al*. (2017) reported these same measurements to be 65, 64, 54, 51 mm., respectively in a different population. In our study, length measurement was performed in the coronal section and measurements were similar to these previous studies, suggesting compatibility.

Complications have been associated with the intramedullary fixation method, as well as in its abutment aspects. These include infection, tendon damage, breakage of the material or damage caused by the material coming out of the bone tissue and the surrounding tissue. (Gonzalez *et al*., 1995; Ozer *et al*., 2008; Blazar & Leven, 2010). We suggest that complications may be reduced by a better understanding of the three-dimensional anatomy of the metacarpals, together with correct material usage.

The metacarpal medullary cavity is relatively narrow at the mid shaft and gradually expands towards the two metaphyses (Lazar & Schulter-Ellis, 1980). However, Zhai *et al*. (2004) showed that the narrowest medullary cavity width may not be located exactly in the middle of the shaft, so the correct measurement should be found by determining the narrowest part of the medullary cavity. Besides, medullary cavity width is important for intramedullary interventions in both volar dorsal and radial-ulnar directions. Therefore, in our study, measurements in both coronal and sagittal sections were made in order to identify the medullary cavity width. Dunleavy *et al*. (2022) evaluated this measurement on axial section CT images and stated that the metacarpal with the widest midshaft intramedullary cavity was the fifth metacarpal. Our results were consistent with those of Dunleavy *et al*. (2022) who performed midshaft measurements. Thus, the fifth metacarpal had the widest medullary cavity width at the narrowest point on coronal sections, while the third metacarpal had the widest medullary cavity width at the narrowest point on sagittal sections. The medullary cavity width did not show a significant difference between sexes in either section. Both volar dorsal and radial-ulnar widths are important in choosing the material to be used as the use of wide material can prevent the it from moving or damaging the bone cortex.

The curved and angled structure of the metacarpals can make it difficult to plan the optimal surgical approach and to make intramedullary interventions. Therefore, it is important to determine the optimal entrance location. Hoang *et al*. (2021) used CT scans and aimed to determine the optimal point for anterograde entry using the same method. These authors stated that the screw could be placed anterograde with minimal articular surface infringement. ten Berg *et al*. (2013) using three dimensional CT, reported that retrograde access can be achieved with a loss of four percent articular surface by systemizing the joint surface. According to our results, the optimal entry point in the coronal plane corresponds to the midpoint of the distal head of the metacarpal. The reason for this is that the intramedullary line is located in the midline in the coronal plane without an angle. However, the metacarpal angle in the sagittal plane shifts the optimal entry level up from the midpoint. Besides, there is no significant difference between the sexes for the optimal entry point in the sagittal plane. Using the optimal entry point, an accurate entry can be achieved into the intramedullary line. This both minimizes the loss of joint surface by reducing repetitive attempts and prevents the tip of the screw from damaging the surrounding tissues or the cortex.

Our study has some limitations. Although our measurements are compatible with the literature, bone morphometry may show ethnic and social differences. Besides, age groups were not evaluated in our study. A further weakness of the study was the use of CT images of healthy bone structures and, as it was carried out retrospectively, soft tissue diseases that patients may have could not be excluded. Prospective, large CT studies, taking into account ethnicity, age and sex would provide better information about bone morphometry.

The intramedullary fixation method has emerged as a prominent method in recent years compared to plate and k-wire applications. When the three dimensional structure is considered, medullary cavity width differs in the sagittal and coronal planes. However, the optimal entry site is located approximately in the midpoint of the metacarpal head in the radial-ulnar direction in the coronal plane. This optimal entry point is located close to the dorsal part in the dorsal-volar direction in the sagittal plane. Knowledge of this information may help to reduce the postoperative complication rate of the intramedullary fixation technique by aiding in identification of the optimal entry site, as well as selection of the best material to use for each patient.

ÖRS, A.; ÇOLAK, T.; BAMAÇ, B.; ISIK, M.; ÖZBEK, A.; AKANSEL, G.; MEMISOGLU, K. & AYYILDIZ, B. Evaluación morfométrica del segundo al quinto metacarpianos para la fijación retrógrada con tornillos intramedulares sin cabeza. *Int. J. Morphol., 40(4)*:1075-1080, 2022.

RESUMEN: En los últimos años, debido a sus ventajas la fijación intramedular con tornillos sin cabeza ha pasado a primer plano en el tratamiento de las fracturas de los huesos metacarpianos. Nuestro objetivo fue evaluar la morfometría del hueso metacarpiano para la entrada intramedular retrógrada y determinar el punto de entrada óptimo. Se examinaron imágenes de tomografía computarizada de 105 pacientes, incluidos 64 hombres y 41 mujeres. Los anchos de los huesos metacarpianos distal y proximal, el ancho de la cavidad medular, el grosor de la cortical y las medidas del sitio de entrada óptimo en las direcciones palmar-dorsal y radioulnar se midieron en los planos coronal y sagital. En el plano sagital, el segundo hueso metacarpiano presentó el mayor ancho proximal (16,29 mm), el ancho distal fue mayor en el tercer hueso metacarpiano (14,34 mm), lo que fue significativamente diferente entre individuos de ambos sexos (p<0,001). El tercer metacarpiano tenía la cavidad medular más ancha en el plano sagital (4,12 mm). En el plano coronal, era el segundo hueso metarcarpiano con mayor ancho proximal (16,14 mm) y distal (13,92 mm) y también era el más largo (66,32 mm). A diferencia del plano sagital, el ancho de la cavidad medular en el plano coronal era más ancho (4,06 mm) en el quinto hueso metacarpiano. Los puntos determinados para la entrada óptima fueron respectivamente (4,60 mm; 4,97 mm; 4,55 mm; 4,36 mm) en el plano dorsal-volar, próximo del lado dorsal. No hubo diferencia significativa entre ambos sexos para el punto de inserción óptimo en los planos sagitales en todos los huesos metacarpianos medidos. Teniendo en consideración su estructura tridimensional, los huesos metacarpianos tienen propiedades morfométricas irregulares, y estas características difieren en los planos sagital y coronal. El sitio de entrada óptimo se encuentra en la línea mediana en el plano coronal, mientras que se ubica en el plano sagital cerca de la parte dorsal. Conocer estas propiedades puede reducir la tasa de complicaciones al disminuir los intentos de entrada y ayudar a seleccionar el material correcto.

PALABRAS CLAVE: Huseo metacarpiano; Morfometría; Retrógrado; Fijación intermedular.

REFERENCES

Blazar, P. E. & Leven, D. Intramedullary nail fixation for metacarpal fractures. *Hand Clin. 26(3)*:321-5, 2010.

Boonyasirikool, C.; Tanakeatsakul, S. & Niempoog, S. The metacarpal locked ıntramedullary nail: comparative biomechanical evaluation of new ımplant design for metacarpal fractures. *J. Med. Assoc. Thai., 98 Suppl. 3*:S91-5, 2015.

Corkum, J. P.; Davison P. G. & Lalonde, D. H. Systematic review of the best evidence in intramedullary fixation for metacarpal fractures. *Hand (N. Y.), 8(3)*:253-60, 2013.

Doarn, M. C.; Nydick J. A.; Williams, B. D. & Garcia, M. J. Retrograde headless intramedullary screw fixation for displaced fifth metacarpal neck and shaft fractures: short term results. *Hand (N. Y.), 10(2)*:314-8, 2015.

Dreyfuss, D.; Allon, R.; Izacson, N. & Hutt, D. A comparison of locking plates and ıntramedullary pinning for fixation of metacarpal shaft fractures. *Hand (N. Y.), 14(1)*:27-33, 2019.

Dunleavy, M. L.; Candela, X. & Darowish, M. Morphological analysis of metacarpal shafts with respect to retrograde ıntramedullary headless screw fixation. *Hand (N. Y.), 17(4)*:602-8, 2022.

Gonzalez, M. H.; Igram, C. M. & Hall Jr., R. F. Flexible intramedullary nailing for metacarpal fractures. *J. Hand Surg. Am., 20(3)*:382-7, 1995.

Hoang, D.; Vu, C. L.; Jackson, M. & Huang, J. I. An anatomical study of metacarpal morphology utilizing CT scans: evaluating parameters for antegrade ıntramedullary compression screw fixation of metacarpal fractures. *J. Hand Surg. Am., 46(2)*:149.e1-149e8, 2021.

Kaiser, M. M.; Tafazzoli, K.; Theilena, T. M.; Schulz, A. P.; Paech, A. & Wessel, L. M. Intramedullary nailing for metacarpal 2-5 fractures. *J. Pediatr. Orthop. B, 18(6)*:296-301, 2009.

Kibar, B.; Cavit, A. & Örs, A. A comparison of intramedullary cannulated screws versus miniplates for fixation of unstable metacarpal diaphyseal fractures. *J. Hand Surg. Eur. Vol., 47(2)*:179-85, 2021.

Kollitz, K. M.; Hammert, W. C.; Vedder, N. B. & Huang, J. I. Metacarpal fractures: treatment and complications. *Hand (N. Y.), 9(1)*:16-23, 2014.

Koo, T. K. & Li, M. Y. A guideline of selecting and reporting ıntraclass correlation coefficients for reliability research. *J. Chiropr. Med., 15(2)*:155-63, 2016.

Labèr, R.; Jann, D.; Behm, P.; Ferguson S. J.; Frueh F. S. & Calcagni, M. Intramedullary screw fixation for metacarpal shaft fractures: a biomechanical human cadaver study. *J. Hand Surg. Eur. Vol., 45(6)*:595-600, 2020.

Lazar, G. & Schulter-Ellis, F. P. Intramedullary structure of human metacarpals. *J. Hand Surg. Am., 5(5)*:477-81, 1980.

Mirza, A.; Mirza, J.; Healy, C.; Mathew, V. & Lee, B. Radiographic and clinical assessment of ıntramedullary nail fixation for the treatment of unstable metacarpal fractures. *Hand (N. Y.), 13(2)*:184-9, 2018.

Nakashian, M. N.; Pointer, L.; Owens, B. D. & Wolf, J. M. Incidence of metacarpal fractures in the US population. *Hand (N. Y.), 7(4)*:426-30, 2012.

Ozer, K.; Gillani, S.; Williams, A.; Peterson, S. L. & Morgan, S. Comparison of intramedullary nailing versus plate-screw fixation of extra-articular metacarpal fractures. *J. Hand Surg. Am., 33(10)*:1724-31, 2008.

Pun, W. K.; Chow, S. P.; So, Y. C.; Luk, K. D. K.; Ip, F. K.; Chan K. C.; Ngai, W. K.; Crosby, C. & Ng, C. A Prospective Study on 284 Digital Fractures of the Hand. *J. Hand Surg. Am., 14(3)*:474-81, 1989.

Rivlin, M.; Kim, N.; Lutsky, K. F. & Beredjiklian, P. K. Measurement of the radiographic anatomy of the small and ring metacarpals using computerized tomographic scans. *Hand (N. Y.), 10(4)*:756-61, 2015.

Ruchelsman, D. E.; Puri, S.; Feinberg-Zadek, N.; Leibman, M. I. & Belsky, M. R. "Clinical Outcomes of Limited-Open Retrograde Intramedullary Headless Screw Fixation of Metacarpal Fractures. *J. Hand Surg. Am., 39(12)*:2390-5, 2014.

Sephien, A.; Bethel, C. F.; Doyle, C. M.; Gulick, D.; Smith, C. J. & Schwartz-Fernandes, F. A. Morphometric analysis of the second through fifth metacarpal through posteroanterior X-rays. *Clin. Anat., 33(7)*:1014-8, 2020.

Singla, A.; Kalsi, G.; Masih, N.; Gupta, T. & Sharma, M. Morphological and topographical anatomy of nutrient foramens in human metacarpals and their surgical importance. *Surg. Radiol. Anat., 39(11)*:1227-33, 2017.

ten Berg, P. W. L.; Mudgal, C. S.; Leibman, M. I.; Belsky, M. R. & Ruchelsman, D. E. Quantitative 3-dimensional CT analyses of intramedullary headless screw fixation for metacarpal neck fractures. *J. Hand Surg. Am., 38(2)*:322-330.e2, 2013.

Wong, A. L.; Meals C. G. & Ruff, C. B. Computed tomographic analysis of the internal structure of the metacarpals and its implications for hand use, pathology, and surgical intervention. *Anat. Sci. Int., 93(2)*:231-7, 2018.

Zhai, L. Y.; Lim, B. H.; Chong, A.; Chou, S. M. & Tsou, I. Tsou. *Measurement of human metacarpals on radiographs - An engineering perspective*. Proceedings of the Second IASTED International Conference on Biomechanics, 2004. pp.51-4.

Corresponding author:
Behçet Ayyıldız
Department of Anatomy
Istinye University
Maltepe
Istinye Üniversitesi Topkapı Kampüsü
Teyyareci Sami Sk. No.3
34010 Zeytinburnu/Istanbul
TURKEY

E-mail: behcet.ayyildiz@istinye.edu.tr